

OIL AND THE MACROECONOMY: A CASE OF KOREA

JOON H. SONG* JUNHEE LEE †

May. 2009

Abstract

Concerns over the oil price has been long subdued since oil prices were maintained on a stable level for many years. The recent run-up in oil price renewed interests from both academics and policymakers not only because it exhibited a record-breaking price level, but also the macroeconomic impacts of oil shocks were so different from the experiences in the 1970s. Historically, most of the previous oil price shocks are due to supply contractions from wars and geopolitical uncertainty tied in oil-exporting countries. The latest rise in oil prices is understood to have sprouted from increased world demands.

The first goal of the paper is to verify whether this assertion still holds true in the Korean case. We investigate the nature of recent oil price run-up and its impact on the Korean macroeconomy with a 4-variable structural VAR. We find that there have been a dramatic change in the macroeconomic responses to oil price in recent years. We also study whether monetary policy responds optimally to stabilize the macroeconomy in recent years. Based on an estimated DSGE model, we find that monetary policy has been aggressive with non-oil prices but accommodative with oil prices and this is not different from the implications of the optimal policy rule, although the evidence is rather weak.

JEL Classification: E32, E52, E58

Key word: Oil Price, Structural VAR, DSGE, Monetary Policy

*Corresponding author. Korea Development Institute, Division of Macroeconomic and Financial Policies, P.O. Box 113, Cheongnyang, Seoul 130-012, Korea, Tel: +82-2-958-4101, Fax: +82-2-958-4088, E-mail: jhsong@kdi.re.kr

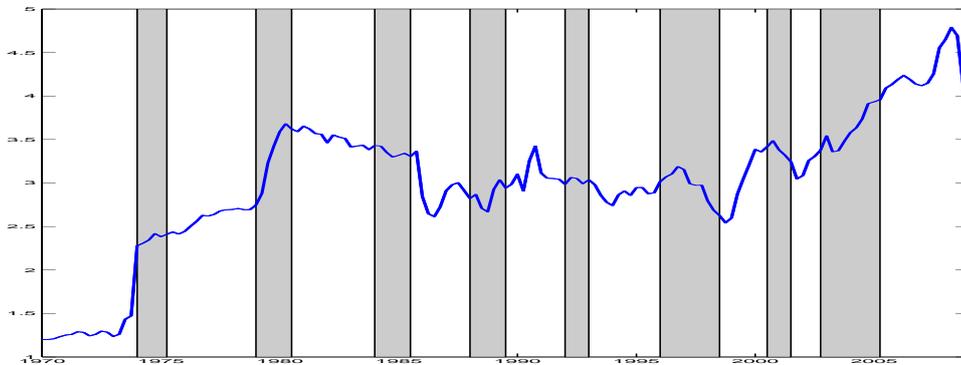
†Yeungnam University, School of International Trade and Commerce, 214-1 Dae-Dong, Kyeongsan-Si, Kyeongsangbuk-Do, Tel: (053) 810-2769, E-mail: lee1838@ynu.ac.kr

1 Introduction

Since the second oil crisis in 1979-1980, oil price has shown a stable trend. After the short period of price drop in 2001, oil price turned its course and increased steadily and substantially since 2002 and reached the record high in the summer of 2008. Figure 1 displays the evolution of the WTI(Western Texas Intermediate) oil price in U.S. dollars since 1970 and the Korean recession periods. This figure illustrates several episodes of oil price hikes including 1973-1974, 1979-1980, 1990, and recent price run-ups. Glancing over the figure, one can find many recession periods overlap with the oil price hikes.

Unlike the 1980s and 90s when there were many literature with ideas associating oil prices with economic recessions, the recent episode of the price run-up has been rather subdued as the oil price has not brought a sharp economic downturn unlike previous episodes until lately. Even though the price of oil has started to stabilize since the autumn of 2008 and we are no longer faced with sky-high oil prices, another round of fluctuations in oil price sparked debates from both academics and policymakers not only because it exhibited a record-breaking price level, but also macroeconomic impacts of oil shocks were different from the experiences in the 1970s as well as the origin of the recent shock.

Figure 1: RECESSION AND OIL PRICE



Note: Shaded areas indicate recession periods of Korea.

The increase in oil price will affect the GDP growth adversely both in consumption and production channels.¹ In consumption channel, oil price hikes will reduce disposable income as consumers pay more money to operate their vehicles and to heat their homes. The effects of the rise in oil price will be larger when the demand for oil consumption is less elastic.

¹Further discussion can be found in Kilian(2008).

Consumer might postpone their consumption as their disposable income is reduced, hence, the economic activities will be sluggish. Also, increase in oil prices may add uncertainty in the future economic outlook, and consumer may save more as a precautionary measure, hence it will adversely affect the economy. In addition to this, Hamilton(2005) stressed the indirect effect arising when patterns of consumption expenditure change. The shifts in expenditure patterns will disturb sectoral allocation of resources and result in cutbacks in consumption as well as increase in unemployment in the presence of friction in both labor and capital markets.

Production may decline as the GDP growth rate becomes lower when production costs are raised and secondly, large oil price changes may increase uncertainty in business investment, hence, inducing lower aggregate output. The extent to which oil price increases translated into overall rise in inflation depends on their persistence and the share of energy prices in inflation measures.(Rotemberg and Woodford 1996)

Historically, most of the previous oil price shocks arose due to supply contractions from wars and geopolitical uncertainty tied in with oil-exporting countries. Hamilton(1996) showed that most of the U.S. recessions were preceded by increases in oil prices and expounded the increase in oil prices is the main cause of recessions. Guo and Kliesen(2005) found that oil price volatility has had a significant adverse effect on fixed investment, consumption, employment and the unemployment rate using NYMEX crude oil futures data.² However, the latest rise in oil prices is understood to be have stemmed from strong market demands and should be treated as endogenous.³ As economic powerhouses, China and India have become huge consumers of crude oil and the demands from other Asian countries have also increased as their economy recovered from the financial crisis of the late 1990s. Also, developed countries have decreased their interest rates in this period, which accounts for asset price bubbles and increase in commodity prices throughout this period. Some argue that the advancement of financial derivatives turned into speculative boom, contributing to the sky-high rise in energy prices. However, there appears no consensus on how much of the price increases are contributed by speculative forces and fundamental movements. Other conspicuous feature is that recent oil price hikes resulted in divergence between headline and core inflation rates which exclude volatile energy and food prices. The recent oil price

²Barsky and Kilian(2004) and Kilian(2008) refused the idea of exogeneity of oil shocks to the U.S. economy. They argue that precautionary demand shocks driven by expectation shifts may have a major impact on the U.S. economy. They added this type of shocks were associated with the geopolitical events in the Middle East, hence, caused misinterpretation of the source of the shocks.

³Kilian(2007) provide evidence that unanticipated crude oil supply shocks are far less important than shocks from the demand for crude oil.

increases seem to slowly pass the impact to the price of non-energy goods and services and led to dissociation between the headline and core inflation. This widening gap between two measures of inflation re-ignites debates over which inflation measure the central bank should focus has been resurfaced.⁴

The goal of this paper is to analyze the nature of recent oil price hikes and the effect on the Korean macroeconomic activities. The Korean economy has experienced quite different responses of output and prices to oil price inflation compared to the two previous oil shocks. Early part of this paper will be devoted to investigate the changing patterns of the responses. Also, we will discuss whether monetary policy to oil price change has been operated optimally to stabilize the macroeconomy. For this purpose, we build a DSGE model with a Taylor type monetary policy where monetary policy responds differentially to oil and non-oil prices. This can be interpreted that monetary policy reacts to overall CPI inflation *per se*. However, the magnitude of intervention is different based on the types of price, i.e. core or non-core price.

Earlier literature on which measures of inflation the central bank should focus on to oil shocks tends to side with core inflation rather than headline inflation. The oft-quoted reasoning for this is that headline inflations are inherently noisy as they include volatile items like food and energy, and they do not reflect changes in the underlying rate of inflation. Also, monetary policy targeting headline inflation could lead to aggravate economic activity when oil shocks are transitory. Suppose that a central bank tightens its policy stance in reaction to the rise of energy prices. Monetary policy action is typically believed to have at least 6-month lag before coming into effect. However, around that time, the energy prices will eventually go back to its original path as the shock is temporary and the outcome of such monetary policy will result in decline in both unemployment and inflation which is undesirable in view of the stabilizing role of monetary policy.

Goodfriend and King(1997) suggest that the monetary policy should focus on the sticky component of prices rather than overall components, suggesting core inflation is the major price index that the central bank should be concerned with. Aoki(2001) formalize a model with two price sectors, one sticky and the other flexible, and support the view of Goodfriend and King. Blinder and Reis(2005) provide evidence that core inflation predicts future headline inflation better than headline inflation itself.⁵ Erceg and Bodenstein(2008) argue that core inflation targeting in response to adverse energy supply shocks has better stabilization

⁴Countries differ in their choice of inflation measures. For example, Bank of England as well as Bank of Korea sets headline inflation as its policy target, while the U.S. Federal Reserve put more emphasis on core inflation in its policy operation.

⁵Cogley(2002) and Rich and Steindel(2007) also found significant reversion of headline inflation to core inflation.

property for both the operational conduct of central banks compared to headline inflation targeting under sticky wage and price settings.

On the other hand, Harris et al.(2009) criticize the policy recommendation from standard new Keynesian models in that those models assumed the complete anchoring of inflation expectations. They showed the longer-term consumer expectations on inflation respond to oil shocks and allude that the Fed should have put more weight on the increase in headline inflation.⁶ Describing three statistical characteristics of oil shocks from historical data: (1) permanent, (2) difficult to predict, and (3) governed by very different regimes at different points in time, Hamilton(2008) contends that the oil price shocks cannot be treated as merely transitory and the central bank should pay more attention to the development of headline inflation which includes energy and food prices.⁷

We are not going to favor one from the other in this paper. The main findings in this paper is that the recent oil shocks are triggered by demand sides in contrast to the previous oil shocks and the optimal monetary policy is to accommodate oil price inflation when the stickiness of oil prices is mild. In an estimated DSGE model, oil prices are relatively flexible compared to wages and non-oil prices and the monetary policy should be operated to accommodate oil price inflation, which is implemented by the central bank of Korea. Combining those findings, we argue that both the nature of the oil price inflation and the appropriate monetary policy are conducive to stabilizing the Korean macroeconomy.

The structure of this paper is as follows. Section 2 describes basic findings from data. A 4-variable VAR model is constructed and analyzed in Section 3. Section 4 presents a DSGE model with oil sector and estimation results. Section 5 investigates the shape of optimal monetary policy depending on the stickiness of oil prices. Concluding remarks are provided in Section 6.

⁶Janet Yellen(2009) criticized Harris et al.(2009)'s view of unanchored inflation expectations that the expected inflation in 2008 was only about 10 basis points higher than what it would have been in the absence of the increase in oil price over this period.

⁷Although agreeing to the idea that the Fed should focus on core inflation, Mishkin(2007) discussed two reasons that a central bank should also watch over the headline inflation when the price of an excluded item receives a permanent shock and the headline inflation deviated from the core measure for an extended period of time. First, a longer period of high headline inflation increases the risk of inflation expectations unanchored. Second, prolonged divergence between core and headline measures of inflation could hamper communications between a central bank and the public. He described that the recent rise in oil prices seemed to be more persistent compared to past experiences and the headline inflation has deviated from the core inflation by a considerable margin during 2004-2006 periods.

Table 1: SUMMARY STATISTICS

	Pre-Crisis		Post-Crisis	
	Mean	Std. Dev.	Mean	Std. Dev.
$\Delta \log$ WTI	1.45	12.08	3.08	15.64
$\Delta \log$ CPI	2.39	1.96	0.76	0.44
$\Delta \log$ CORE	2.06	1.75	0.70	0.31
$\Delta \log$ RGDP	1.87	1.29	1.09	1.43
$\Delta \log$ Real Wage	0.96	2.15	0.80	1.53

Note: Log difference from the previous quarter times 100.

2 Data

Quarterly data on the real GDP, CPI, CORE, real wage and oil prices (represented by the WTI) are examined in this section. Oil prices are translated into local currency to control for the exchange rate effects. In order to evaluate how the oil prices and macroeconomic activities differ before and after the crisis, we divide the data set before and after the currency crisis of 1997. The dividing year is between in 1998-1999 when the Korean economy experienced a structural break. A variety of evidence supports that the Korean economy has experienced important and long-term changes during this periods, Oh(2007), and Kim and Kang(2004) among others. Korea has introduced a free floating exchange rate system and the central bank has applied inflation targeting, departing from the previous monetary aggregate targeting in 1998. Also, a wide range of restructuring in the corporate and financial sectors have changed the landscape of those industries in these years.

For these reasons, empirical tests are based on two subperiods which are 1970:I-1997:IV (pre-crisis sample) and 2000:I-2009:I (post-crisis sample), omitting 1998 and 1999. Table 2 shows selected summary statistics for log-differenced data in those two subperiods and the existence of unit roots is investigated in Table 2. Despite the increase in the standard deviation of oil prices in the post-1998 sample, those of CPI, Core, and real wage inflation have substantially reduced in the same period compared to the pre-1998 sample. One interesting finding from the unit root test is that CPI rejects unit root in the post-crisis sample in all test statistics. This is consistent with low inflation of recent years in Figure 2 where the cumulative inflation processes show a pronounced difference from the earlier years.

To observe how the dynamic impact of oil shocks on the macroeconomy has changed, we provide the cumulative growth of real GDP and CPI inflation. Each series has duration of 4 years and the oil shock datings coincide with those selected in Blanchard and Gali(2007) in

Figure 2: CUMULATIVE GROWTH OF GDP AND CPI INFLATION

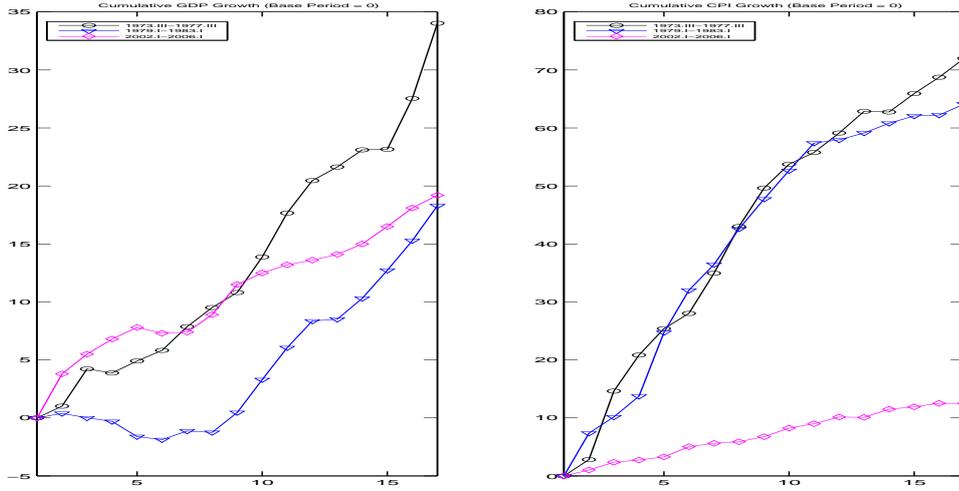


Table 2: UNIT ROOT TESTS

	Pre-Crisis					Post-Crisis				
	PP test		ADF test		KPSS test	PP test		ADF test		KPSS test
	ρ	t-val	ρ	t-val	LM-stat	ρ	t-val	ρ	t-val	LM-stat
WTI	-0.03	-1.63	-0.04	-1.56	0.24	-0.20	-1.85	-0.47	-3.15	0.13
CPI	-0.02	-1.92	-0.01	-1.89	0.24	-0.20	-2.31	-0.29	-2.06	0.08
CORE	-0.01	-1.78	-0.03	-2.46	0.11	-0.01	-1.53	-0.24	-3.07	0.08
RGDP	0.00	-0.15	-0.00	-0.41	0.31	-0.15	-1.73	-0.65	-2.87	0.09
Real Wage	-0.52	-1.07	0.14	0.15	0.12	0.05	-0.43	-0.13	-0.58	0.13
CALL	-0.31	-1.61	-0.29	-1.32	0.15	-0.14	-2.00	-1.90	-2.25	0.13
CD	-0.26	-0.97	-0.38	-1.78	0.12	-0.13	-1.82	-0.20	-2.26	0.15
$\Delta \log$ WTI	-0.86	-9.75	-0.82	-5.76	0.08	-0.54	-3.52	-0.68	-2.30	0.09
$\Delta \log$ CPI	-0.45	-6.03	-0.37	-4.14	0.11	-0.96	-5.71	-0.87	-2.84	0.06
$\Delta \log$ CORE	-0.33	-4.79	-0.18	-2.24	0.12	-0.47	-3.54	-0.47	-2.66	0.10
$\Delta \log$ RGDP	-0.83	-8.67	-0.75	-5.15	0.07	-0.93	-5.65	-1.03	-2.96	0.09
$\Delta \log$ Real Wage	-1.66	-4.95	-0.21	-0.21	0.15	-0.86	-4.86	-0.70	-1.89	0.10

Note: Asymptotic critical values for LM statistics are 0.216, 0.146, and 0.199 at 1%, 5%, 10% respectively

Figure 2.⁸

The right hand side of the figure indicates the cumulative real GDP growths in each oil shock periods. We observe that adverse effects of oil prices on the real GDP growth are most conspicuous in the second oil shock period which is during 1979:I-1983:I. In the same period, the economic activities have been shrunk almost two years before bouncing back to its growth trend. Compared to the earlier oil shocks, the recent episode brought a different picture and the real GDP growth seems to be little affected for at least one year when oil price started to climb up. Later on, the real GDP growth has declined a bit but the contraction effects are not pronounced.

⁸Blanchard and Gali(2007) identify 4 episodes of oil shocks when the cumulative changes in (log) oil prices are above 50 per cent. We discard the 3rd episode(1999:I-2000.IV) as the periods are close to the 4th one(2002.I-2005.III), and those two episodes are back to back under our 4-year window convention.

The left hand side of the figure illustrates the cumulative CPI inflation of the same periods. The cumulative price increases in the first and second oil shock periods are similar. In both periods, the CPI inflation have increased around 70% in 4 years. However, the recent oil price hike haven't passed through its impact to the CPI price. The CPI inflation has reached only 12% in 4 years, i.e. 3% increase of the CPI per annum, indicating the macroeconomic effects of oil price shocks have changed in recent years.

In order to contrast the pre- and post-crisis macroeconomic responses to oil price shocks, nonparametric estimation results of real GDP and CPI inflation to oil prices are presented in Figure 3.⁹ The two graphs in the left column is the response of real GDP and CPI inflation in the pre-crisis sample and the two graphs in the right column is those in the post-crisis sample. In the pre-crisis period, real GDP growth and oil price are negatively related. CPI inflation, however, is less clear on its functional form to the oil price changes. In the post-crisis period, real GDP growth are almost flat to oil price changes and one cannot find any clear functional relations between real GDP and oil prices unlike the previous sample. Turning to the overall price, increases in oil prices do not bring forth the rise in CPI inflation, indicating oil prices are not conducive to the rise in CPI inflation until recently.

Summing up, basic facts found from data point out that the nature of oil price shocks or macroeconomic responses to such shocks have been changed in a way that the economy accommodates them better compared to the previous years. The following section will discuss the possible explanations in light of Korean circumstances.

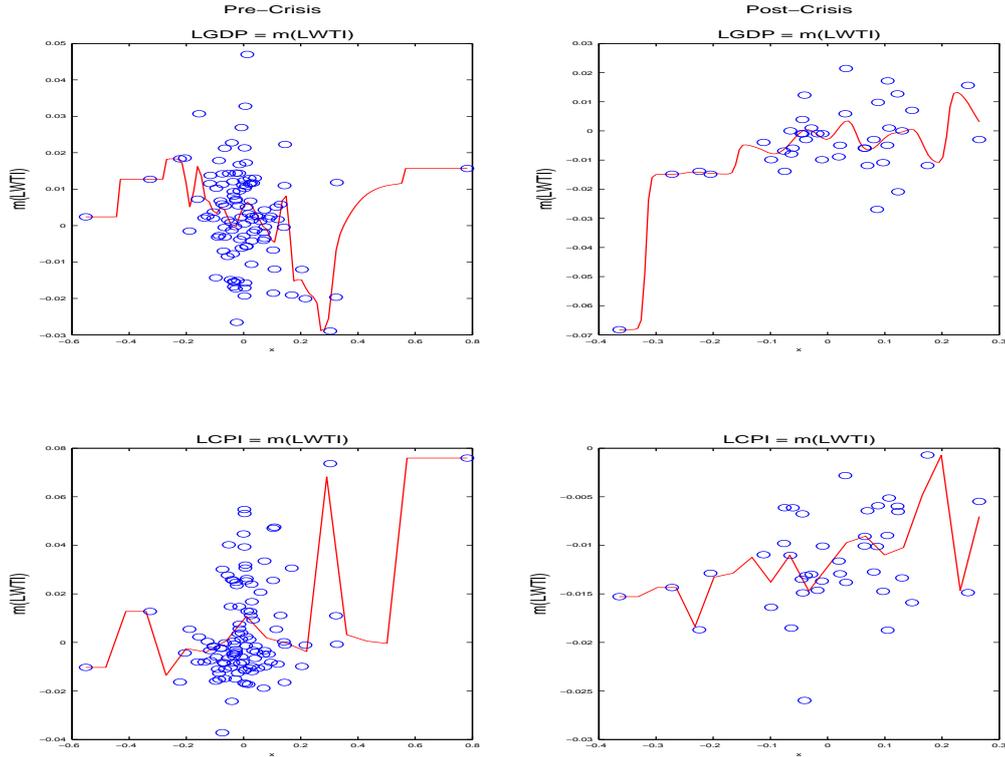
3 Dynamic Effects of Oil Price Shocks

3.1 A Structural VAR Model

In this section, we will use a 4-variable VAR model as our workhorse to quantify the response of real GDP and inflation to oil price shocks. These results will be used in assessing how macroeconomic transmission mechanism of oil price have changed before and after the 1998-1999 period. Even though the 4-variable VAR methodology has many limitations to evaluate the effect of oil price shock fully, adding more macroeconomic variables require additional identifying assumptions that may not be realistic and likely to be less precise in estimation. In our VAR model, we assume there exist 4 types of structural shocks that affect

⁹In estimation, we use a Gaussian Kernel regression with optimal bandwidth suggested by Bowman and Azzalini(1997).

Figure 3: NONPARAMETRIC GDP AND INFLATION RESPONSES TO OIL SHOCKS



Note: The solid line is kernel regression and circles indicate the data .

the Korean economy: the global supply shock, global demand shock, local supply shock and local demand shock.¹⁰ Since, these structural shocks cannot be observed directly, we need to employ identifying restrictions to break down those shocks. Our identification assumptions are based on long-run restrictions, which are (1) the oil price growth, expressed in WTI prices, is affected only by the global supply shock in the long run, (2) export is influenced by the global supply and demand shock in the long run, (3) real GDP growth is affected by both global shocks and local supply shock, but not by the local demand shock in the long run and (4) inflation will be affected by all shocks. The identification assumptions reflect that Korea is a small open economy.

The structural VAR can be represented by the following formula:

$$A_0 \Delta z_t = A_1 \Delta z_{t-1} + A_2 \Delta z_{t-2} + \dots + A_p \Delta z_{t-p} + \omega_t \quad (1)$$

¹⁰Readers are advised not to be deceived by our choice of the words, global supply and global demand shock. They can be simply understood as shocks which satisfy the identification assumption described below.

where $\Delta z_t = [\Delta O_t, \Delta X_t, \Delta Y_t, \Delta P_t]'$ denotes the log difference of oil price, export, real GDP, and price index. A_0 is 4×4 matrix restricting contemporaneous relations of 3 variables. $\omega_t = [\omega_t^{GS}, \omega_t^{GD}, \omega_t^{LS}, \omega_t^{LD}]'$ implies 4×1 column vector consisting of global supply shock(GS), global demand shock(GD), local supply shock(LS), and local demand shock(LD) respectively and $\mathbb{E}[\omega_t] = 0$ and $\mathbb{E}[\omega_t \omega_t'] = I_{4 \times 4}$. Alternatively, the structural VAR can be expressed as follows:

$$\Delta z_t = B_1 \Delta z_{t-1} + B_2 \Delta z_{t-2} + \dots + B_p \Delta z_{t-p} + C \omega_t = B(L) \Delta z_{t-1} + C \omega_t \quad (2)$$

where $B_j = A_0^{-1} A_j$ and $B(L) = [A_{i,j}(L)]$, $A_{i,j}(L) = a_{i,j}^0 + a_{i,j}^1 L + \dots + a_{i,j}^p L^p$, $i, j = 1, 2, 3, 4$. $C = A_0^{-1} \cdot C$, inverse of contemporaneous relations, is 4×4 matrix. If z_t is stationary process, the VAR system can be rewritten as a VMA(Vector Moving Average) system according to Wold representation theorem:

$$\Delta z_t = \omega_t + C_1 \Delta \omega_{t-1} + C_2 \Delta \omega_{t-2} + \dots = C(L) \omega_t \quad (3)$$

where $C(L) = \sum_{j=0}^{\infty} C_j L^j$. Since it is impossible to observe the structural shocks directly, we need to estimate the associate VAR system and then identify those shocks from the regression errors.

$$\Delta z_t = B(L) \Delta z_{t-1} + u_t \quad (4)$$

where $\mathbb{E}[u_t] = 0$ and $\mathbb{E}[u_t u_t'] = \Omega$. Note that this equation can be written as:

$$\Delta z_t = (I - B(L)L)^{-1} u_t \quad (5)$$

Comparing Eq.(2) and Eq.(4), the following condition holds:

$$u_t = C \omega_t \quad (6)$$

Also, comparing Eq.(3) and Eq.(5), we have:

$$C(L) = (I - A(L)L)^{-1} C \quad (7)$$

Calculating the variance and covariance matrix from Eq.(6), we obtain

$$\Omega = C \mathbb{E}[\omega_t \omega_t'] C' = C C' \quad (8)$$

If we know the C matrix, we can back out the structural shocks from the regression errors estimated from the reduced form VAR. However, Ω is symmetric variance and covariance

matrix and imposing only 6 restrictions on 9 undetermined parameters for C . Hence, three long-run restrictions discussed earlier is given to identify the structural shocks. Translating those restrictions using the above equation:

$$C_{1,2}(1) = C_{1,3}(1) = C_{1,4}(1) = C_{2,3}(1) = C_{2,4}(1) = C_{3,4}(1) = 0 \quad (9)$$

where $C_{i,j}(1) = c_{i,j}^0 + c_{i,j}^1 + c_{i,j}^2 + \dots$. $C_{i,j}(1)$ denotes the cumulative effects of shock j on variable i . Imposing these restrictions, the system can be rewritten in a matrix form:

$$\Delta z_t = \begin{bmatrix} \Delta O_t \\ \Delta X_t \\ \Delta Y_t \\ \Delta P_t \end{bmatrix} = \begin{bmatrix} C_{1,1}(1) & 0 & 0 & 0 \\ C_{2,1}(1) & C_{2,2}(1) & 0 & 0 \\ C_{3,1}(1) & C_{3,2}(1) & C_{3,3}(1) & 0 \\ C_{4,1}(1) & C_{4,2}(1) & C_{4,3}(1) & C_{4,4}(1) \end{bmatrix} \begin{bmatrix} \omega_t^{GS} \\ \omega_t^{GD} \\ \omega_t^{LS} \\ \omega_t^{LD} \end{bmatrix}$$

From Eqs.(3), (5), and (7), we obtain:

$$C(1)C(1)' = (I - A(1))^{-1}CC'((I - A(1))^{-1})' = (I - A(1))^{-1}\Omega((I - A(1))^{-1})' \quad (10)$$

Due to the triangular property of long run cumulative effects. $C(1)$ can be found from Cholesky decomposition of the third term in Eq.(10). Knowing $C(1)$ matrix, we can easily work out C from the following condition:

$$C = (I - A(1))C(1) \quad (11)$$

Once identification issues are resolved, we can back out the pure effects of the structural shocks on the three economic variables. The structural shocks are found from Eq.(6) as $\omega_t = C^{-1}u_t$. The reduced form of each shocks are defined as follows:

$$\begin{aligned} \nu_t^{GS} &= C \cdot [\omega_t^{GS}, 0, 0, 0]' \\ \nu_t^{GD} &= C \cdot [0, \omega_t^{GD}, 0, 0]' \\ \nu_t^{LS} &= C \cdot [0, 0, \omega_t^{LS}, 0]' \\ \nu_t^{LD} &= C \cdot [0, 0, 0, \omega_t^{LD}]' \end{aligned}$$

Once identification issues are resolved, we can conduct an impulse response analysis and forecasting error variance decomposition in a standard manner, suggested by Sims(1980). By setting $\omega_t^{GS} = 1$, i.e one time global supply shock amounting to one standard error, we obtain the impulse response of the system to a global supply shock. We can find the impulse

responses to a global demand shock by letting $\omega_t^{GS} = 1$. In the same vein, imposing $\omega_t^{LS} = 1$, we get the impulse response of the system to a local supply shock. If $\omega_t^{LD} = 1$, also we find the impulse response of the system to a local demand shock whose long run impact on oil prices and GDP growth dies out.

3.2 Empirical Results

Figure 4 displays the cumulative impulse responses based on the estimates using the pre-crisis sample. Each column represents one standard deviation of structural shocks and the response of three economic variables to the shocks can be read in row-wise.

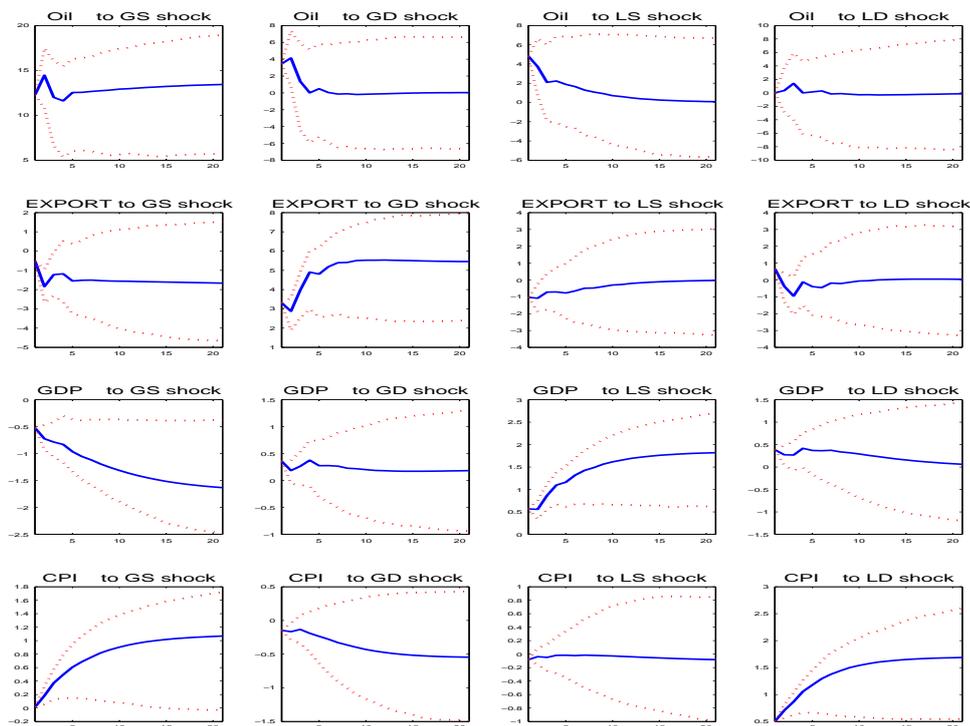
To begin with the first column, we show how the economy works when there is a global supply shock that increases oil prices. A temporary rise in the oil price decreases both export and real GDP immediately. Export declines as the increase in oil prices contracts the economic activities of foreign countries and their import demand will also shrink consequently. The adverse global supply shock tends to permanently lower the real GDP by 1.6%. This could be caused by higher marginal costs from energy inputs or lower consumption as consumer's disposable income is reduced after paying higher energy expenses. The price measured by CPI climbs up on the oil price shock for 12 quarters and after that it becomes flattened. One standard deviation increase of the oil prices raise the CPI by 1.1% permanently.

The second column is the response of macroeconomic variables to one standard deviation of a global demand shock. An increase in world demand will raise domestic exports and real GDP will also rise. One standard deviation of a global demand shock will raise exports and real GDP by 5.2% and 0.2%, respectively, permanently. The global demand shock will raise the oil price by 3.8% initially and slowly die out. The increase in oil price will last for 2 years and vanish, which is consistent with our long-run restrictions.

The third column is the response to one-standard deviation of a local supply shock. The local supply shock, leaving the global shocks absent, implies the Korean economy experiences technological shock, while the rest of the world is left status quo. When the shock arrives, the real GDP will be raised permanently by 1.8%. The local supply shock works as a deflationary factor and the long run price level declines slightly.

We also provide the response to a local demand shock in the last column. A temporary local demand shock will raise the real GDP but its impact dies out as time lapses. Also,

Figure 4: IMPULSE RESPONSES: BASED ON PRE-CRISIS ESTIMATES

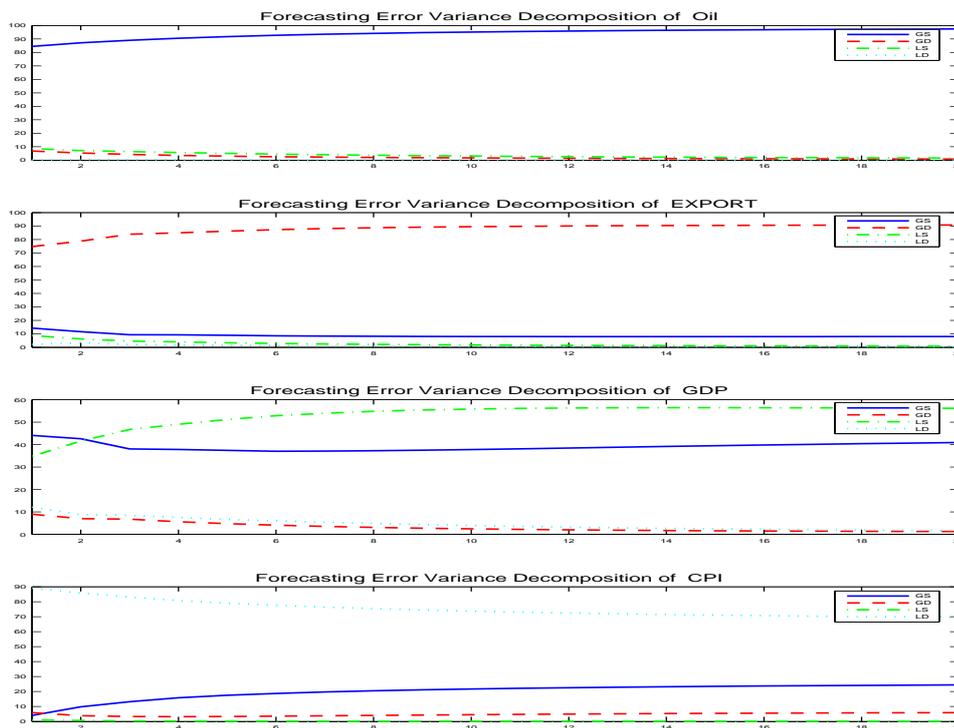


Note: The dotted lines are 90% confidence bands from bootstrapping with 10,000 iterations.

increase in local demand diverts resources from export to domestic consumption and export will decline for a short period, statistically insignificant though. Real GDP tends to increase for a short span, but eventually this effect is temporary and vanish eventually. This is due to the restrictions we laid out in the identification assumption. However, the local demand shock tends to raise the CPI permanently by around 1.7%.

In order to quantify the importance of each shock, we present forecast error variance decomposition in Figure 5. Forecasting error variance decomposition displays the proportions of movement of the variables explained by four types of structural shocks. The horizontal axis denotes the forecasting horizons and the vertical axis is the percentage contribution of each shock to the variance of the macroeconomic variables. The third row is the results of variance decomposition of real GDP. The contribution from the local demand shock is around 12% in the short run and becomes around 2% in the long run. Two major shocks contributing to the variance of real GDP is global supply shock and local supply shock, 41% and 57%, respectively. The large contribution of the global supply shock can be explained by the

Figure 5: VARIANCE DECOMPOSITION: BASED ON PRE-CRISIS ESTIMATES



export-driven economic growth policy advocated by the Korean government in these periods. The Korean government encouraged exports and various national resources, including tax and financial subsidies, were devoted to support export sectors and heavy industries which depend on crude oil and other production intermediated from outside. Lacking resources in industrial intermediates and technologies, export sectors relied most of their production inputs from the outside world. These explain why the global supply shock is an important factor in explaining the variation of real GDP in this sample. The fourth row shows the result of variance decomposition on CPI. The local demand shock explains 70% of long-run variation and the global supply shock accounts for 24%. Again the global supply shock is an important component in explaining the price variations.

So far, we have described how the Korean economy has absorbed 4 identified shocks in the pre-crisis period. Our next task is to see whether the impact from the global supply shock delivered by rises in oil prices has any different dynamics after the Korean economy went through a structural change. Figure 6 illustrates the impulse response based on the estimates from the post-crisis sample.

What stands out from this exercise is the impulse response of export to the global supply shock. Export increases to the global supply shock, unlike the previous case. This might be partly due to the fact that the shock we identify is not the true global supply shock or part of the global supply shock are concocted with global demand shock due to our identification assumption. However, the point is that the impulse responses of export to the global price shock show a different pattern compared to those in the pre-crisis sample. Real GDP rises immediately after the arrival of a global supply shock but it declines as the lapse of time and eventually dies out.¹¹ The price rises with the global supply shock. The global supply shock raises the price by 0.14% permanently. However, the effect of the global supply shock on the price is quite subdued compared to the pre-crisis sample, which is consistent with our basic findings in the earlier section. This picture can be understood as the dynamic effects of oil price shocks have changed and the interactions between oil prices and macroeconomic aggregates build a different pattern.¹²

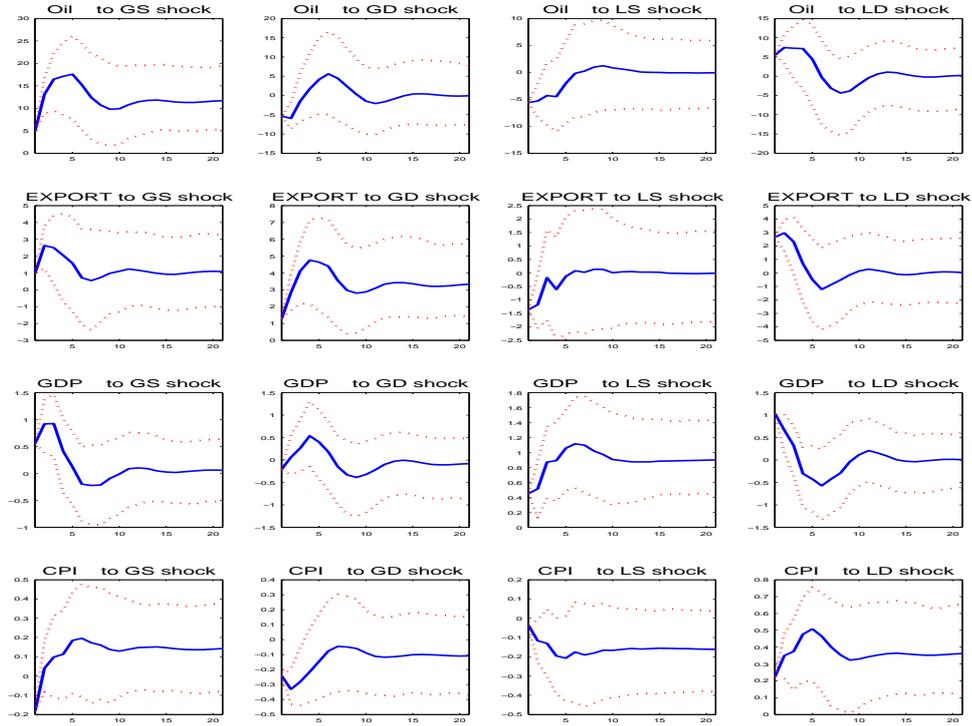
The impulse responses to a local supply shock are presented in the third column in the figure. The local supply shock raises real GDP and lower the price. The local supply shock in the post-crisis sample has a less pronounced effect on real GDP compared to that in the pre-crisis sample. It can be ascribed to the fact that the Korean economy is on different growth stages in the two periods. In the pre-crisis period, Korea has experienced high growths, average of 7%, which is no longer enjoyed in the recent period.

The forecasting error variance decomposition results also make the point that the Korean economy faces quite a different picture compared to the earlier sample as shown in Figure 7. The percentage contribution of the global supply shock to the long-run variance of real GDP stands at 10%, a huge decrease from 41% in the pre-crisis sample. In contrast, the contribution from the local demand shock has increased. In the short run, 50% of real GDP variation is explained by the local demand shock and 10% in the long run, almost 5-fold compared to that in the pre-crisis period. In explaining the price variation, still the local demand shock is predominantly important. In this period, the contribution of local supply shocks to the variance of the price has increased to 10% and that of global supply shock has declined by 10%. One of the candidate explanations for this is the exchange rate system. Before 1998, Korea has maintained a fixed or managed floating system in an effort to support export companies, the then national flagship. A fixed exchange rate set at a favorable condition dissipates business uncertainty surrounding the price of export goods, which encouraged the

¹¹Similar results are found in Hooker(1996) when he used 1973:IV-1994:II U.S. sample.

¹²Blanchard and Gali(2007) found that the impulse response of the U.S GDP and CPI to oil price shocks has changed considerably between the periods before and after 1983. They suggested that the U.S. economy has faced an improved tradeoff in the post 1983 periods.

Figure 6: IMPULSE RESPONSES: BASED ON POST-CRISIS ESTIMATES

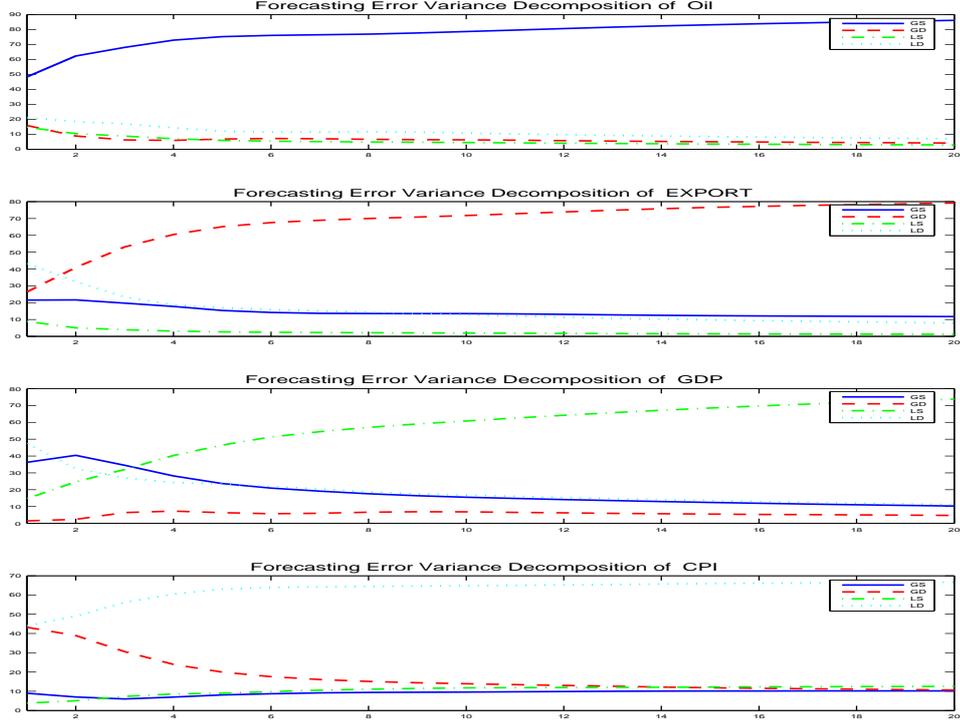


Note: The dotted lines are 90% confidence band from bootstrapping with 10,000 iterations.

growth of exporting sectors. However, the Korean government discarded the old regime and shifted towards freely floating exchange rate exchange system after 1998, which is conducive in insulating the economy from outside shocks.

In order to find out the differences in the nature of shocks in both periods, we estimate dynamic correlations between real GDP and price in both periods based on a reduced-form VAR with the same ordering in the structural VAR, suggested by Den Haan(1996). If the correlations between real GDP and price are positive, we can infer that demand shocks are dominant as the shift in demand schedule will move price and real GDP in the same direction. On the contrary, negative correlations between real GDP and price imply supply shocks are dominant as the shift in supply schedule will drive price and real GDP in the opposite

Figure 7: VARIANCE DECOMPOSITION: BASED ON POST-CRISIS ESTIMATES



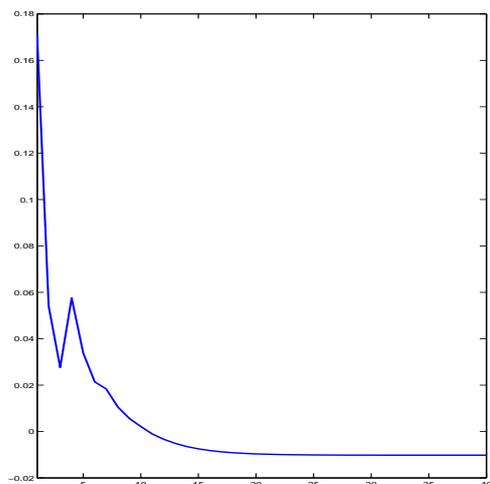
direction. The j -period ahead dynamic correlation at time t can be found as follows:

$$\begin{aligned}
 Corr(\Delta Y_{t+j}, \Delta P_{t+j} | \Omega_t) &= \frac{(\Delta Y_{t+j} - \mathbb{E}[\Delta Y_{t+j} | \Omega_t])(\Delta P_{t+j} - \mathbb{E}[\Delta P_{t+j} | \Omega_t])}{\sigma(\Delta Y_{t+j} | \Omega_t) \sigma(\Delta P_{t+j} | \Omega_t)} \\
 &= \frac{\eta_{\Delta Y_{t+j}} \eta_{\Delta P_{t+j}}}{\sigma(\Delta Y_{t+j} | \Omega_t) \sigma(\Delta P_{t+j} | \Omega_t)}
 \end{aligned}$$

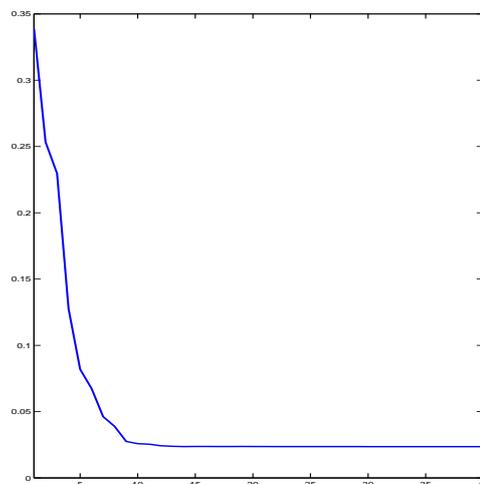
where $\eta_{\Delta \xi_{t,t+j}}$ is the j -period ahead forecasting error of $\xi (= \Delta Y_t, \Delta P_t)$ and Ω_t is information set up to time t .

The dynamic correlations in the pre- and post-crisis periods are presented in Figure 8. From this exercise, we can evaluate the relative importance of demand supply shocks. In the short-run, demand shocks are dominant forces to real GDP and prices in both periods. However, comparing the magnitude of the short-run correlations, the post-crisis correlations is more than two-fold of the pre-crisis counterpart. This implies that demand shocks become stronger in the post-crisis period compared to the pre-crisis years. The difference in the nature of the shock is more pronounced when one looks into the long-run correlations. In the

Figure 8: DYNAMIC CORRELATION BETWEEN REAL GDP AND PRICE



(a) $\text{CORR}(\Delta Y_t, \Delta P_t)$: PRE-CRISIS



(b) $\text{CORR}(\Delta Y_t, \Delta P_t)$: POST-CRISIS

pre-crisis period, long-run correlations between real GDP and price are negative, indicating supply shocks are prevailing in this period. In contrast, long-run correlations are positive in the post-crisis sample, implying demand shocks are major driving forces in this period. This observation explains why the real GDP are less affected in the post-crisis period.

The oil price changes, especially upward movements, have brought many economic difficulties in the past. It's still a problem but its macroeconomic impacts have been quite subdued in recent periods, as shown in our VAR evidence. We argue the nature of the shock has been changed in the recent oil price run-up. Unlike the previous year when most of the oil shocks are believed to have been driven by supply disruptions, the recent oil price rise stemmed from the increase in demand for oil. A demand-driven oil price hike keeps the Korean economy buoyant in contrast to the macroeconomic troubles experienced in the past years.

So far, we have shown the macroeconomic impacts of the oil price change and put aside the macroeconomic policies which is essential in understanding the propagation mechanism of external shocks. In the next section, we try to find out whether monetary policy in the post-crisis years has been conducted in a way that can stabilize macroeconomy.

4 Nominal Rigidities with the Oil Sector

4.1 A Model

In this section, we construct a nominal rigidities model with two sectors, oil and non-oil sectors and extend one sector models with oil consumption as in Bodenstein et al.(2008).

We start with the production side of the non-oil sector. The non-oil sector is denoted by subscript n and the oil sector by subscript o in the following equations. Firms produce final non-oil goods by aggregating intermediate goods. Namely,

$$y_{n,t} = \left[\int y_{n,t}(i)^{\frac{1}{\mu_n}} di \right]^{\mu_n}, \quad \mu_n \geq 1 \quad (12)$$

where $y_{n,t}$ is the final good and $y_{n,t}(i)$ is the i th intermediate good in the non-oil sector. Final non-oil goods market is competitive and thus final non-oil goods price ($P_{n,t}$) is

$$P_{n,t} = \left[\int P_{n,t}(i)^{\frac{1}{1-\mu_n}} di \right]^{1-\mu_n} \quad (13)$$

where $P_{n,t}(i)$ is the i th intermediate non-oil good price. The demand for the i th intermediate good is

$$y_{n,t}(i) = y_{n,t} \left[\frac{P_{n,t}(i)}{P_{n,t}} \right]^{\frac{\mu_n}{1-\mu_n}} \quad (14)$$

Production technology for the i th intermediate good is given as

$$y_{n,t}(i) = \zeta_{z,t} (n_{n,t}(i))^{\alpha_n} (o_t(i))^{\alpha_o} \quad (15)$$

where $n_{n,t}(i)$ is labor input, $o_t(i)$ is oil usage and $\zeta_{z,t}$ is aggregate technology shock, which follows the law of motion given as

$$\ln \zeta_{z,t} = \rho_{\zeta_z} \ln \zeta_{z,t-1} + \varepsilon_{z,t}, \quad \varepsilon_{z,t} \sim N(0, \sigma_z) \quad (16)$$

Intermediate goods producers behave as monopolistic competitors and set prices with Calvo mechanism. Namely, intermediate goods producers set new prices with probability $1 - \theta_n$ or adjust prices just as much as the trend inflation rate with probability θ_n in each period. The

i th intermediate good producer in the non-oil sector solves

$$\max_{P_{n,t}^N} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_n)^s v_{t+s} [\pi_n^s P_{n,t}^N y_{n,t+s}(i) - MC_{n,t+s}(i) y_{n,t+s}(i)] \quad (17)$$

subject to the demand for the i th intermediate good in Eq.(14). π_n is trend inflation rate in the non-oil sector, $P_{n,t}^N$ is newly set price, $y_{n,t}(i)$ is i th intermediate good, and $MC_{n,t}(i)$ is nominal marginal cost given as

$$MC_{n,t}(i) = \frac{W_t n_{n,t}(i)}{\alpha_n y_{n,t}(i)} \quad (18)$$

where W_t is nominal wage rate and $P_{o,t}$ is final oil sector goods price. The input ratio to minimize costs is

$$\frac{o_t}{n_t} = \frac{\alpha_o W_t}{\alpha_n P_{o,t}} \quad (19)$$

Also, v_t is the marginal value of a dollar to the household. The first-order condition with respect to $P_{n,t}^N$ is

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_n)^s v_{t+s} y_{n,t+s}(i) [\pi_n^s P_{n,t}^N - \mu_n MC_{n,t+s}(i)] = 0 \quad (20)$$

The oil sector works similar to the non-oil sector. Firms in the oil sector produce final oil goods by aggregating intermediate goods. Namely,

$$y_{o,t} = \left[\int y_{o,t}(i)^{\frac{1}{\mu_o}} di \right]^{\mu_o}, \quad \mu_o \geq 1 \quad (21)$$

where $y_{o,t}$ is the final good and $y_{o,t}(i)$ is the i th intermediate good in the oil sector. The final oil goods price ($P_{o,t}$) is given as

$$P_{o,t} = \left[\int P_{o,t}(i)^{\frac{1}{1-\mu_o}} di \right]^{1-\mu_o} \quad (22)$$

where $P_{o,t}(i)$ is the i th intermediate oil good price. The demand for the i th intermediate good in the oil sector is

$$y_{o,t}(i) = y_{o,t} \left[\frac{P_{o,t}(i)}{P_{o,t}} \right]^{\frac{\mu_o}{1-\mu_o}} \quad (23)$$

Production technology for the i th intermediate good is

$$y_{o,t}(i) = \zeta_{z,t} (c r_t(i))^{\alpha_{cr}} \quad (24)$$

where $cr_t(i)$ is crude oil input. Intermediate goods producers in the oil sector also behave as monopolistic competitors and set prices with Calvo mechanism. The first order condition is

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_o)^s v_{t+s} y_{o,t+s}(i) [\pi_o^s P_{o,t}^N - \mu_o MC_{o,t+s}(i)] = 0 \quad (25)$$

$MC_{o,t}$ is nominal marginal cost given as

$$MC_{o,t}(i) = \frac{P_{cr,t}}{\zeta_{z,t} \alpha_{cr} cr_t(i)^{\alpha_{cr}-1}} \quad (26)$$

where $P_{cr,t}$ is crude oil price. We assume real crude oil supply follows an exogenous process given as

$$\ln cr_t = \rho_{cr} \ln cr_{t-1} + \varepsilon_{cr,t}, \quad \varepsilon_{cr,t} \sim N(0, \sigma_{cr}) \quad (27)$$

Next, we consider the household problem. Household i maximizes expected utility

$$\mathbb{E}_t \left[\sum_{s=0}^{\infty} \beta^s (U(c_{t+s}) - V(n_{t+s}(i))) \right] \quad (28)$$

subject to the budget constraint

$$P_{n,t} c_{n,t} + P_{o,t} c_{o,t} + B_t \leq W_t(i) n_t(i) + \Pi_t + T_t + (1 + R_{t-1}) B_{t-1} \quad (29)$$

where c_t is final consumption good, n_t is labor hours, B_t is nominal savings, Π_t is transfer from firms, T_t is transfer from government, and R_t is nominal interest rate. The final consumption good (c_t) is a composite of non-oil consumption good ($c_{n,t}$) and oil consumption good ($c_{o,t}$) given as

$$c_t(i) = (c_{n,t}(i))^{1-w_o} (c_{o,t}(i))^{w_o} \quad (30)$$

The parameter w_o is the share of oil in total consumption. We drop subscript i except for household i 's wage and labor supply assuming symmetric equilibrium.

First-order conditions except for wage setting are

$$U_{c_{n,t}} = v_t P_{n,t} \quad (31)$$

$$U_{c_{o,t}} = v_t P_{o,t} \quad (32)$$

$$\frac{1}{1 + R_t} = \beta E_t \frac{v_{t+1}}{v_t} \quad (33)$$

where $U_{c_{n,t}}$ ($U_{c_{o,t}}$) is the derivative of the utility function with respect to $c_{n,t}$ ($c_{o,t}$) and v_t is the marginal value of a dollar to the household. We assume the utility function takes a form as

$$U(c_t) = \zeta_{c,t} \ln c_t, \quad V(n_t(i)) = \zeta_{n,t} n(i)^2 \quad (34)$$

where $\zeta_{c,t}$ and $\zeta_{n,t}$ are consumption preference shock and labor supply shock and they respectively follow the law of motion given as

$$\ln \zeta_{c,t} = (1 - \rho_{\zeta_c}) + \rho_{\zeta_c} \ln \zeta_{c,t-1} + \varepsilon_{c,t}, \quad \varepsilon_{c,t} \sim N(0, \sigma_c) \quad (35)$$

$$\ln \zeta_{n,t} = (1 - \rho_{\zeta_n}) + \rho_{\zeta_n} \ln \zeta_{n,t-1} + \varepsilon_{n,t}, \quad \varepsilon_{n,t} \sim N(0, \sigma_n) \quad (36)$$

Households set wages with Calvo mechanism. Labor used for production is an aggregate of differentiated labor supply by households given as

$$n_t = \left[\int n_t(i)^{\frac{1}{\mu_w}} di \right]^{\mu_w}, \quad \mu_w \geq 1 \quad (37)$$

The wage associated with n_t is given as

$$W_t = \left[\int W_t(i)^{\frac{1}{1-\mu_w}} di \right]^{1-\mu_w} \quad (38)$$

Demand for the i th household's labor is

$$n_t(i) = n_t \left[\frac{W_t(i)}{W_t} \right]^{\frac{\mu_w}{1-\mu_w}} \quad (39)$$

In each period, household i sets a new wage with probability $1 - \theta_w$ or adjusts its wage just as much as the trend inflation rate times the trend growth rate with probability θ_w . The household wage setting problem is then

$$\max_{W_t^N} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta \theta_w)^s [-V(n_{t+s}(i)) + v_{t+s} (\pi_c \cdot z)^s W_t^N n_{t+s}(i)] \quad (40)$$

where π_c is final consumption goods trend inflation rate and z is economy-wide trend growth rate. The first-order condition with respect to W_t^N is given as

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta \theta_w)^s n_{t+s}(i) v_{t+s} \left[-\mu_w \frac{V'(n_{t+s}(i))}{v_{t+s}} + (\pi_c)^s W_t^N \right] = 0 \quad (41)$$

We note that the final consumption good price ($P_{c,t}$) is given as

$$P_{c,t} = \left(\frac{1}{w_o}\right)^{w_o} \left(\frac{1}{1-w_o}\right)^{1-w_o} P_{n,t}^{1-w_o} P_{o,t}^{w_o} \quad (42)$$

and $\pi_{c,t}$ is given as $\frac{P_{c,t}}{P_{c,t-1}}$. Then the final consumption goods trend inflation rate π_c is $(1 - w_o)\pi_n + w_o\pi_o$.

Market clearing conditions are

$$y_{n,t} = c_{n,t} \quad (43)$$

$$y_{o,t} = o_t + c_{o,t} \quad (44)$$

$$n_t = n_{n,t} \quad (45)$$

We define the real GDP of the economy as

$$y_t = \frac{P_{n,t}}{P_{c,t}} y_{n,t} + \frac{P_{o,t}}{P_{c,t}} y_{o,t} - \frac{P_{cr,t}}{P_{c,t}} cr_t \quad (46)$$

assuming all crude oil is imported from abroad.

Monetary policy follows a Taylor-type interest rate rule given as

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)(\rho_{\pi_n}(1 - w_o)\pi_{n,t-1} + \rho_{\pi_o}w_o\pi_{o,t-1} + \rho_y\tilde{y}_{t-1}) + \varepsilon_{m,t} \quad (47)$$

where \tilde{y}_{t-1} is the deviation of the real GDP from its trend (output gap) and $\varepsilon_{m,t} \sim N(0, \sigma_m)$.

4.2 Estimation

In this section, we estimate the nominal rigidities model constructed above using Bayesian methods as in Smets and Wouters (2007). We estimate the model with Korean data for the post-crisis period, i.e. 2000:I-2009:I.¹³

We fix some deep parameters by calibration which are likely to be poorly determined in a model that only considers deviations from the steady state. The remaining parameters are then estimated by Bayesian methods. We set the subjective discount rate β as $0.98^{1/4}$. The non-oil sector production function parameters α_n and α_o are set as 0.448 and 0.062, respectively, using the labor and intermediate oil (petroleum) share out of total value-added

¹³The central bank of Korea started to operate monetary policy independently since after the currency crisis in 1998. Hence, we confine our analysis in the post-crisis sample.

plus intermediate oil input in the non-oil (non-petroleum) sector obtained from 2005 Korean input-output table. We also set α_{cr} as 0.657 using the intermediate crude oil share out of total value-added plus intermediate crude oil input in the oil (petroleum) sector obtained from the input-output table. We set the price and wage markup parameters, μ_n , μ_o , and μ_w as 1.1 as in the literature. We calibrate the share of oil (petroleum) in consumption w_o as 0.027 using the oil (petroleum) expenditure share out of total private consumption expenditure obtained from the input-output table.

We estimate parameters concerning sectoral price as well as wage stickiness, shock processes and monetary policy rule using Bayesian methods after log-linearizing the model around the steady states. We set the prior distributions of the price and wage stickiness parameters, θ_n , θ_o and θ_w , as uniform distributions on the interval $[0, 1]$ placing equal prior weights on the possible stickiness parameter values. We set the prior distributions of the parameters concerning the weight on the non-oil inflation rate, ρ_{π_n} , as normal distribution with a mean of 1.5 and a standard deviation of 0.4 and set the prior distributions of the parameters concerning the weight on output gap, ρ_y , as a beta distribution with a mean of 0.125 and a standard deviation of 0.1 following the literature. We set the prior distributions of the parameters concerning the weight on the oil inflation rate, ρ_{π_o} , as normal distribution with a mean of 0 and a standard deviation of 4. The large standard deviation reflects prior uncertainty about the distribution of the parameter value. We assume the prior distributions of all parameters concerning shock persistence as beta distributions with a mean of 0.85 and a standard deviation of 0.1 and set the prior distributions of all parameters concerning shock standard deviation as inverse gamma distribution with a mean of 0.02 and a standard deviation of 2. All the assumptions on prior distribution are summarized in Table 4.2.

We use linearly-detrended log GDP, core inflation rate (as the non-oil sector inflation rate), energy inflation rate (as the oil sector inflation rate), overnight call rate (as the nominal interest rate) and WTI crude oil price in dollar terms times nominal exchange rate divided by CPI (as relative price for crude oil) as observables for the estimation. We obtain data from the Korea National Statistical Office except WTI crude oil price in dollar terms which is obtained from Datastream. The five observable variables match five structural shocks and we can identify the model.

The result of the posterior estimates are presented in Table 4.2. The estimated mode of the non-oil price stickiness parameter, θ_n , is 0.966 and the oil price stickiness parameter, θ_o , is 0.481. Thus, oil sector price stickiness is lower than non-oil sector price stickiness. The

Table 3: PRIORS

Parameters	Priors			
		Type	Mean	Std. Dev.
Non-oil price stickiness	θ_n	Uniform	0.5	$1/\sqrt{12}$
Oil price stickiness	θ_o	Uniform	0.5	$1/\sqrt{12}$
Wage stickiness	θ_w	Uniform	0.5	$1/\sqrt{12}$
Monetary policy non-oil inflation response	ρ_{π_n}	Normal	1.5	0.4
Monetary policy oil inflation response	ρ_{π_o}	Normal	0.0	2.0
Monetary policy output gap response	ρ_y	Beta	0.125	0.1
Interest rate smoothing	ρ_R	Beta	0.85	0.1
Aggregate tech. shock persistence	ρ_{ζ_z}	Beta	0.85	0.1
Crude oil supply shock persistence	ρ_{cr}	Beta	0.85	0.1
Consumption preference shock persistence	ρ_{ζ_c}	Beta	0.85	0.1
Labor supply shock persistence	ρ_{ζ_n}	Beta	0.85	0.1
Monetary policy shock std. dev.	σ_m	Inv. Gamma	0.02	2
Aggregate tech. shock std. dev.	σ_z	Inv. Gamma	0.02	2
Crude oil supply shock std. dev.	σ_{cr}	Inv. Gamma	0.02	2
Consumption preference shock std. dev.	σ_c	Inv. Gamma	0.02	2
Labor supply shock std. dev.	σ_n	Inv. Gamma	0.02	2

degree of oil price stickiness is, however, different from zero as we can see from the lower 10th percentile of the posterior distribution of the parameter. Concerning the monetary policy Taylor rule parameters, the posterior mode of the monetary policy non-oil inflation response parameter, ρ_{π_n} , is 1.401 slightly lower than the prior mode. The posterior mode of the monetary policy output gap response parameter, ρ_y , is 0.074 lower than the prior mode. The posterior mode of the monetary policy oil price inflation response parameter, ρ_{π_o} , is -0.360 and shows the so-called accommodating monetary policy response to oil price inflation as mentioned in Dhawan and Jestke (2007). The posterior distribution of the parameter is, however, not precisely estimated and the posterior standard deviation of the parameter is as large as 1.531.

4.3 Impulse Response and Historical Decomposition

We now consider the effects of exogenous shocks in the model. The impulse-response functions to innovations of 5 structural shocks are presented in Figure 9. The column-wise variables are output(y), CPI inflation(π_c) and nominal interest rate(R), and each shock is laid out in row-wise. For example, the first graph in the figure can be read as the respond of output(y) to monetary shock(ε_m). We depict the median and the 5th and 95th percentiles as calculated from 1,000 draws from the posterior distributions.

Table 4: POSTERIORS FROM THE MODEL ESTIMATION

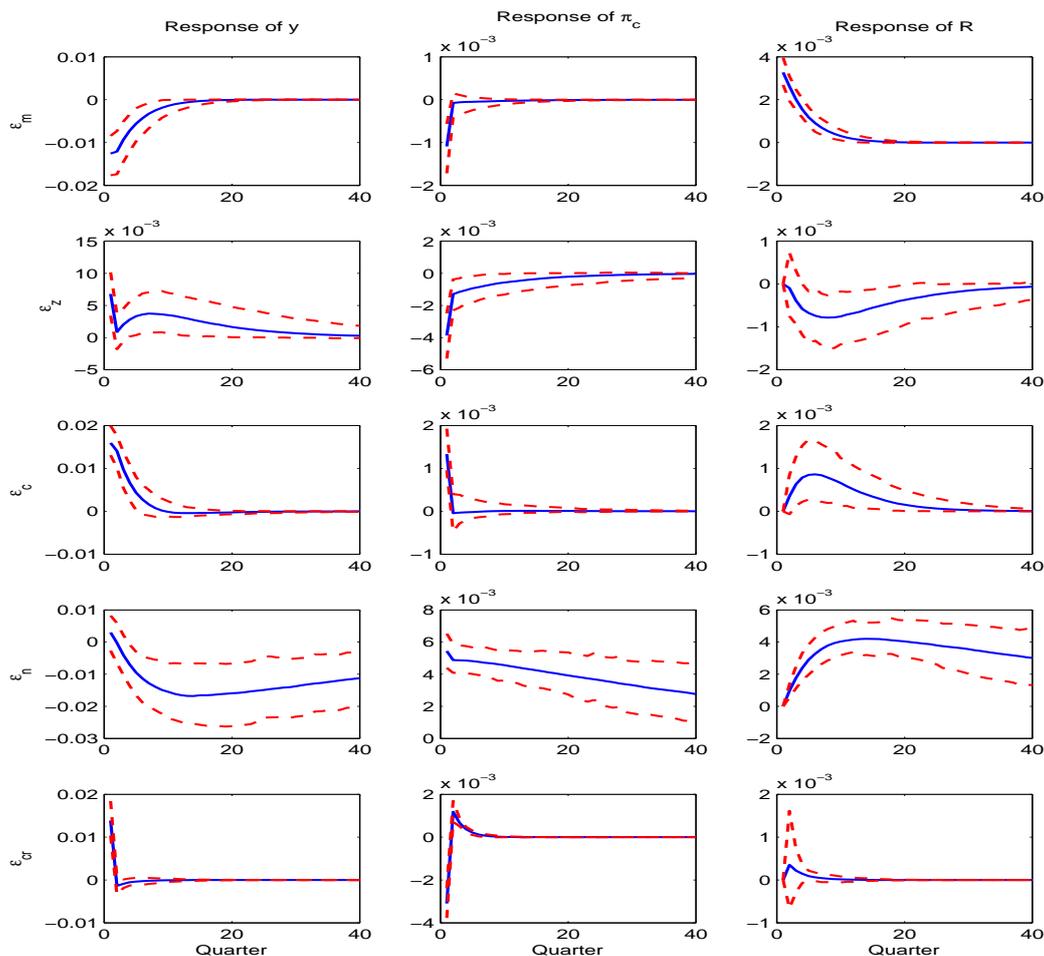
Parameters	Posteriors				
		Mode	Std. Dev.	10th Per.	90th Per.
Non-oil price stickiness	θ_n	0.966	0.015	0.930	0.980
Oil price stickiness	θ_o	0.481	0.026	0.423	0.517
Wage stickiness	θ_w	0.748	0.155	0.492	0.912
Mon. policy non-oil response	ρ_{π_n}	1.401	0.330	1.174	2.051
Mon. policy oil response	ρ_{π_o}	-0.360	1.531	-2.980	2.483
Mon. policy output gap response	ρ_y	0.074	0.073	0.018	0.299
Interest rate smoothing	ρ_R	0.868	0.043	0.822	0.932
Aggregate tech. shock per.	ρ_{ζ_z}	0.950	0.035	0.843	0.975
Crude oil supply shock per.	ρ_{cr}	0.597	0.090	0.424	0.737
Cons. preference shock per.	ρ_{ζ_c}	0.812	0.087	0.684	0.931
Labor supply shock per.	ρ_{ζ_n}	0.992	0.008	0.951	0.999
Monetary policy shock std. dev.	σ_m	0.003	3.84e-4	0.003	0.004
Aggregate tech. std. dev.	σ_z	0.028	0.005	0.022	0.040
Crude oil supply shock std. dev.	σ_{cr}	0.139	0.019	0.118	0.189
Cons. preference shock std. dev.	σ_c	0.025	0.005	0.020	0.040
Labor supply shock std. dev.	σ_n	0.192	0.099	0.058	0.563
Marginal likelihood		416.0			

A monetary policy interest rate hike shock lowers output and CPI inflation and raises nominal interest rate due to the rise of the interest rate after the shock. An aggregate technology shock increases output and lower CPI inflation and nominal interest rate due to increased productivity after the shock. A consumption preference shock increases output, inflation and nominal interest rate due to increased desire to consume. A labor supply shock lowers output and raises CPI inflation and nominal interest rate due to increased disutility of labor after the shock. A crude oil supply shock increases output and lower CPI inflation due to increased supply of crude oil. The response of nominal interest rate to the crude oil shock is not decisively different from zero.

Figure 10 presents smoothed crude oil shocks and historical decompositions of output, CPI inflation and nominal interest rate with and without crude oil shocks. The drop of crude oil supply shock around 2008:I reflects the recent hike in crude oil prices. The impacts of crude oil supply shock on CPI inflation and nominal interest rate are not much noticeable as we can see from the historical decompositions. The output would have been higher around 2008:I if crude oil supply shocks were not negative.

We also report forecast error variance decompositions of output, CPI inflation and nominal interest rate at the posterior modes of the parameters in Table 3. As we can see from the table, crude oil supply shocks contribute 18.0 and 11.9 per cent to the one quarter

Figure 9: IMPULSE RESPONSES



Note: The dotted lines are 90% confidence bands.

ahead forecast error variance of output and CPI inflation, respectively and contribute just 0.1 percent to the one quarter ahead forecast error variance of nominal interest rate. The contributions of crude oil shocks decrease as we consider longer period ahead forecast error variance decompositions.

We can summarize our findings from the Bayesian estimation of the model as follows. First, the degree of oil sector price stickiness is relatively lower than non-oil sector price stickiness as in the literature. The oil sector price is not, however, completely flexible somewhat different from the theoretical model as in Aoki(2001) and Bodenstein et al.(2008). Second, the posterior mode of the monetary policy response to oil sector inflation parameter shows a negative sign indicating accommodating monetary policy response. The posterior distri-

Table 5: FORECASTING ERROR VARIANCE DECOMPOSITION AT POSTERIOR MODES

1st quarter						4th quarter					
	ε_m	ε_z	ε_c	ε_n	ε_{cr}		ε_m	ε_z	ε_c	ε_n	ε_{cr}
y	34.5	4.6	42.3	0.6	18.0	y	33.5	5.3	36.5	14.0	10.6
π_c	1.5	20.2	1.9	64.5	11.9	π_c	0.8	13.5	0.9	78.4	6.4
R	95.0	0.3	0.2	4.4	0.1	R	59.5	3.0	1.3	36.1	0.0
8th quarter						12th quarter					
	ε_m	ε_z	ε_c	ε_n	ε_{cr}		ε_m	ε_z	ε_c	ε_n	ε_{cr}
y	22.1	7.1	22.7	41.8	6.3	y	14.4	7.3	14.6	59.7	4.0
π_c	0.5	10.2	0.6	84.9	3.9	π_c	0.3	8.4	0.4	88.1	2.8
R	28.2	5.0	1.5	65.3	0.0	R	16.2	5.1	1.1	77.5	0.0

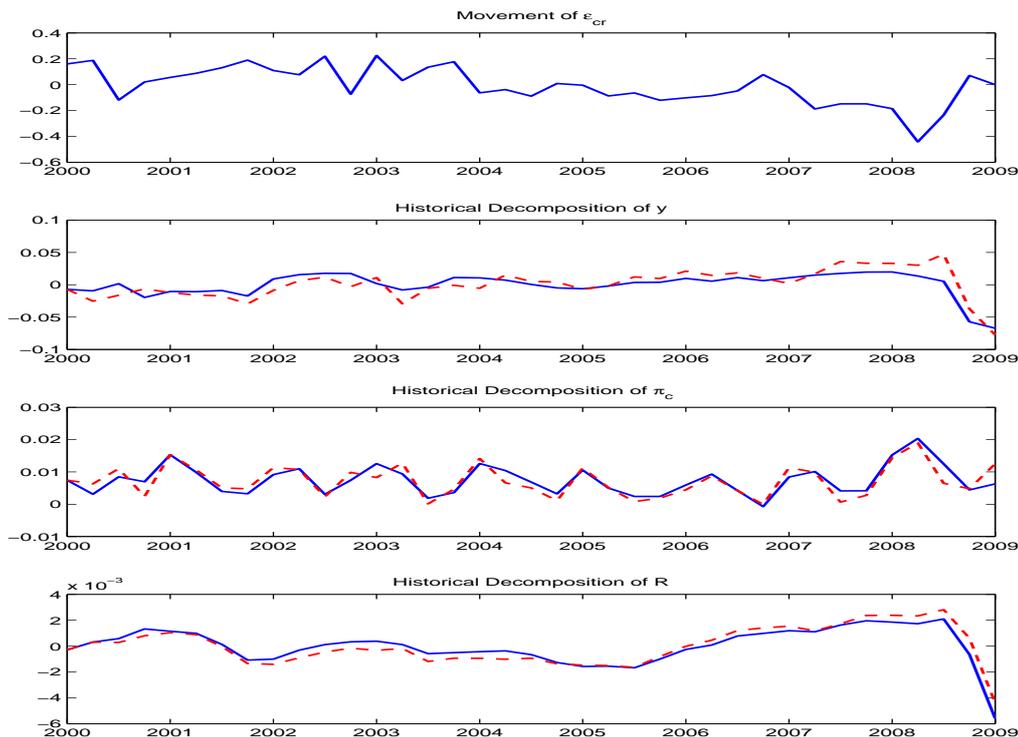
bution of the parameter is, however, not precisely estimated as shown in its large standard deviation. Third, oil supply shocks reduce output around 2008:I but their impacts on CPI inflation and nominal interest rate are not significant from the historical decompositions. Also the contributions of oil supply shocks to the forecast error variances of output and CPI inflation are larger in the short-run. The contributions of oil supply shocks to the forecast error variances of nominal interest rate is negligible throughout the horizons.

5 Optimal Monetary Policy Rule

In the following, we consider varying degrees of monetary policy responses toward oil price inflation and examine the effects of monetary policies on output gap and CPI inflation volatilities. It would be necessary to consider different values for ρ_{π_o} since the posterior distribution of oil price inflation, ρ_{π_o} , is rather imprecisely estimated. We also consider the monetary policy effects in a model with flexible oil prices in addition to the estimated model with sticky oil prices since some theoretical papers such as Aoki(2001) and Bodenstein et al.(2008) assume flexible oil prices and we can compare the results. We further separately consider cases when the model economy is perturbed by all the structural shocks and by crude oil supply shocks only to see the effects of monetary policies in response to different shocks. The other parameter values are set at their posterior modes.

We simulate the model by setting ρ_{π_o} equal to -1.4014, -0.36, 0.0, 0.36 and 1.4014, respectively. The policies respectively represent an accommodating policy toward oil price inflation as much as the anti-inflation policy toward non-oil price inflation at the posterior mode, an accommodating policy toward oil price inflation at the posterior mode, no response policy toward oil price inflation, an anti-inflation policy toward oil price inflation as much as the

Figure 10: HISTORICAL DECOMPOSITION



accommodating policy toward oil price inflation at the posterior mode and an anti-inflation policy toward oil price inflation as much as the anti-inflation policy toward non-oil price inflation at the posterior mode.

We report the results in Table 5. When the model economy is simulated with all the structural shocks, there is a clear trade off between volatility of output gap and CPI inflation. As the monetary policy becomes more anti-inflationary toward oil price inflation, oil price inflation volatility decreases and output gap volatility increases. The trade off of volatility increase in output gap for a unit volatility decrease in CPI inflation is -2.887 with sticky oil prices when θ_o is 0.4807 and -2.845 with flexible oil prices when θ_o is 0.0001. Thus monetary policy makers face trade off between output gap volatility and CPI inflation volatility and need to choose an appropriate policy weight toward output gap and CPI inflation stabilization considering their policy objective priorities as in Erceg et al (2000).

When the model economy is simulated with crude oil shocks only and oil price are sticky with θ_o equal to 0.4807, accommodating policies toward oil price inflation works better as

Table 6: MONETARY POLICY RULES, OUTPUT GAP AND CPI INFLATION VOLATILITIES

All Shocks, $\theta_o = 0.4807$			All shocks, $\theta_o = 0.0001$		
ρ_{π_o}	$\sigma(y)$	$\sigma(\pi_c)$	ρ_{π_o}	$\sigma(y)$	$\sigma(\pi_c)$
-1.4014	0.1914	0.0432	-1.401	0.1914	0.0432
-0.3600	0.1966	0.0414	-0.360	0.1999	0.0402
0.0000	0.1983	0.0408	0.000	0.1982	0.0408
0.3600	0.2000	0.0402	0.360	0.1999	0.0402
1.4014	0.2047	0.0386	1.401	0.2045	0.0386
All Shocks, $\theta_o = 0.4807$			All shocks, $\theta_o = 0.0001$		
ρ_{π_o}	$\sigma(y)$	$\sigma(\pi_c)$	ρ_{π_o}	$\sigma(y)$	$\sigma(\pi_c)$
-1.4014	0.0136	0.0031	-1.4014	0.0027	0.0031
-0.3600	0.0137	0.0031	-0.3600	0.0026	0.0030
0.0000	0.0138	0.0031	0.0000	0.0026	0.0030
0.3600	0.0139	0.0031	0.3600	0.0027	0.0030
1.4014	0.0142	0.0030	1.4014	0.0031	0.0030

we can reduce output gap volatilities without increasing CPI inflation volatilities very much. This finding resembles the result from Dhawan and Jeske(2007).

Once the model economy is simulated with crude oil shocks only and oil price are flexible with θ_o equal to 0.0001, no response policies toward oil price inflation or the so-called core inflation policies works better as we can reduce output gap volatilities to the minimum and keep CPI inflation volatilities also to the minimum. This resembles the results in Aoki(2001).

In this section, we consider various monetary policy responses to oil price inflations under flexible and sticky prices combined with all the structural shocks and crude oil shocks only cases. From this exercise, we find the currently estimated posterior mode of policy response toward oil price inflation with ρ_{π_o} equal to -0.36 seems to be a reasonably good policy in terms of the output gap and CPI inflation volatilities in response to crude oil shocks(and possibly to all the structural shocks considering unobserved policy objectives). We conclude that the accommodating monetary policy toward oil price inflation works better in the estimated model and the Bank of Korea, which targets CPI inflation currently, seem to follow such a rule. However, we are a little cautions with this conclusion as the posterior distribution of ρ_{π_o} is rather imprecisely estimated.

6 Conclusion

The price of crude oil has shown an increasing trend since 2002, but failed to draw much attention due to its subdued effects on economic activities before its sharp increase at the end of 2007. Since then, prices have started to inch up and real GDP contracted. Policymakers become concerned with the rising oil prices as the memory of the past specters resurfaced.

This paper investigates the changing nature of macroeconomic responses to oil price shocks and evaluates whether the monetary policy is directed to stabilize the Korean economy. The key findings are that unlike the previous two oil shocks, the recent run-up in oil price are induced by the increase in demand for oil and monetary policy in Korea is more or less operated optimally in a manner to stabilize economic activities.

Naturally, there are other possible explanations for the declining importance of oil price shocks. One may ascribe mild impacts of oil prices to macroeconomy to declining shares of oil in consumption and production. We look into the time series for both consumption and production shares of oil but fail to find any conspicuous changes in the shares, which is consistent with the findings in Kilian(2008).¹⁴ We also investigate whether the wage inflation has shown any significant differences in the pre- and post-crisis periods but persuasive results cannot be found either. What we haven't tried is the role of futures market. Increased efficiency in futures market for oil could be helpful to stabilize the economy. Nonetheless, we doubt whether the futures market alone can make dramatic changes in the response of output and price for such a long period of time. However, this is the area which needs a further scrutiny and left for future topic.

¹⁴However, Blanchard and Gali(2008) find the decline in the share of oil in consumption and production results in a quantitatively significant implications for the recent U.S. economy.

References

- ALQUIST, RON, AND KILIAN, LUTZ 2009. "What Do We Learn from the Price of Crude Oil Futures?," *Journal of Applied Econometrics* forthcoming.
- AOKI, K. 2001. "Optimal monetary policy responses to relative-price changes," *Journal of Monetary Economics* 48, 55–80.
- BARSKY, ROBERT B., AND KILIAN, LUTZ 2004. "Oil and the Macroeconomy Since the 1970s," *Journal of Economic Perspectives* 18(4), 115–134.
- BLINDER, ALAN S., AND REIS, RICARDO 2005. "Understanding the Greenspan Standard," In *The Greenspan Era: Lessons for the Future*, 11-96.
- BODENSTEIN, MARTIN, ERCEG, CHRISTOPHER J., AND GUERRIERI, LUCA 2008. "Optimal Monetary Policy with Distinct Core and Headline Inflation Rates," *Journal of Monetary Economics* 55, 18–33.
- BOWMAN, ADRIAN W., AND AZZALINI, ADELCHI 1997. "Applied Smoothing Techniques for Data Analysis," *Oxford Statistical Science Series* 18.
- CHEUNG, CALISTA 2009. "Are Commodity Prices Useful Leading Indicators of Inflation," *Bank of Canada Discussion Paper No.2009-5*.
- COGLEY, TIMOTHY 2002. "A Simple Adaptive Measure of Core Inflation," *Journal of Money, Credit and Banking* 34, 94-113.
- DEN HAAN, WOUTER J. 1996. "The Comovements between Real Activity and Prices at Different Business Cycle Frequencies," *NBER WP 5553*.
- DHAWAN, R. AND JESKE, K. 2007. "Taylor rules with headline inflation: A bad idea," *Federal Reserve Bank of Atlanta Working paper* 2007-14.
- ERCEG, C. J., HENDERSON, D. W. AND LEVIN, A. T. 2000. "Optimal monetary policy with staggered wage and price contracts," *Journal of Monetary Economics* 46, 281–313.
- GUO, HUI, AND KLIESEN, KEVIN L. 2005. "Oil Price Volatility and U.S. Macroeconomic Activity," *Federal Reserve Bank of St. Louis Review* November/December, 669–683.
- HAMILTON, JAMES D. 2003. "What is an Oil Shock?," *Journal of Econometrics* 113, 363–398.

- HAMILTON, JAMES D. 2005. "Oil and the Macroeconomy," *New Palgrave Dictionary of Economics*(2nd eds.).
- HAMILTON, JAMES D. 2008. "Understanding Crude Oil Prices," *NBER Working Paper N0. 14492*.
- HARRIS, ETHAS S, KASMAN, BRUCE C., SHAPIRO, MATTHEW D., AND WEST, KENNETH D. 2009. "Oil and the Macroeconomy: Lessons for Monetary Policy," *Unpublished Working Paper*.
- HOOVER, MARK A. 1996. "What Happened to the Oil Price-Macroeconomy Relationship?," *Journal of Monetary Economics* 38, 195–213.
- KILIAN, LUTZ 2008. "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature* 46(4), 871–909.
- KIM, MIN-SU, AND KANG, KYU-HO 2004. "Do Supply Shocks Matter in the Korean Economy," *Financial Studies* 18, 1–37.
- MISHKIN, FREDERIC S. 2007. "Inflation Dynamics," *A Speech delivered at the Annual Macro Conference*.
- OH, HYUNG-SEOK 2005. "Structural Break in Potential GDP and Business Cycle after Korean Currency Crisis," *Financial Studies* 21, 19–53.
- RICH, ROBERT, AND STEINDEL, CHARLES 2005. "A Review of Core Inflation and an Evaluation of its Measures," *Federal Reserve Bank of New York Staff Report No.236*.
- SCHOTTFHEIDE, FRANK 2000. "Loss Function-Based Evaluation of DSGE Models," *Journal of Applied Econometrics* 15(6), 645–670.
- SMETS, F., WOUTERS, R. 2007. "Shocks and frictions in US business cycles: a Bayesian DSGE approach," *American Economic Review* 97, 586–606.
- SOLOW, ROBERT M. 1980. "What to Do (Macroeconomically) When OPEC Comes," In *Rational Expectations and Economic Policy*, Stanley Fischer, ed., University of Chicago Press, 249–267.
- STOCK, JAMES H., AND WATSON, MARK W. 2001. "Vector Autoregressions," *Journal of Economic Perspectives* 15(4), 101–115.
- STOCK, JAMES H., AND WATSON, MARK W. 2007. "Why Has U.S. Inflation Become

Harder to Forecast?," *Journal of Money, Credit and Banking* 39(1), 3–33.