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**Oil Price Shocks, Macroeconomic Stability and Welfare in a Small Open Economy**

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# Oil Price Shocks, Macroeconomic Stability and Welfare in a Small Open Economy\*

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## Abstract

Since the beginning of 2000s the world economy has witnessed a substantial increase in oil prices, which is seen to be an important source of economic fluctuations, causing high inflation, unemployment and low or negative growth rates. Recent experience, however, has not validated this view. Despite rising oil prices, world output growth has been strong, and although inflation has recently been increasing, it is relatively much lower compared with the 1970s. This paper focuses on the causes of oil price increases and their macroeconomic effects. Different from most of the recent literature on the subject, which understands the price of oil to be an exogenous process, we model the price of oil endogenously within a dynamic stochastic general equilibrium (DSGE) framework. Specifically, using a new Keynesian small open economy model, we analyse the effects of an increase in the price of oil caused by an oil supply shock and an oil demand shock. Our results indicate that the effects of an oil demand shock and an oil supply shock on the small open economy are quite different. In addition, we investigate the sensitivity of the general equilibrium outcomes to the degrees of oil dependence and openness, as well as the strength of the response of monetary policy authority to the inflation. Finally, we evaluate the welfare implications of alternative monetary policy regimes.

Keywords: Oil price, small open economy, demand and supply shocks

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# 1 Introduction

Macroeconomic effects of oil price shocks have been extensively investigated since the 1970s. Among the earlier contributions, Hamilton (1983) argues that exogenous oil price shocks were responsible for the post-war US recessions. More recently, Bernanke, Gertler and Watson (1997) have pointed out that macroeconomic effects of oil price shocks were aggravated by the wrong monetary policy decisions. On the other hand, starting with Hooker (1989), many empirical studies have revealed that the link between oil price and the output growth seems to break down after 1980. Recent developments in the world economy have supported these findings. At the end of 2007, the real oil prices have reached the level of the late 1970s, while the world output growth is still strong and inflation is at historically low levels (Figure 1).

Blanchard and Gali (2007) propose explanations for the observed change in the effects of the oil price shocks. First, they argue that labour markets are more flexible now than in the past, and hence some of the negative effects of the oil price shocks can be absorbed by the labour market. Second, more credible and stronger anti-inflationary stance of monetary policies of the 2000s may have kept inflation expectations relatively stable. In addition, they argue that the share of oil in production in the major economies has declined since 1970s. Data supports the last argument, showing that the oil intensity in the major economies has almost halved since the 1970s (Figure 2).

Woodford (2007) argues that the offered explanations are not convincing enough because they ignore the endogenous responses of the real price of oil (price of oil divided by the consumer price index) to the global economic conditions. Hamilton (2005), Kilian (2007) and Kilian (2008) show that global macroeconomic fluctuations have an impact on the price of oil. Therefore, when we analyse the effects of oil price shocks on the economy, we have to take into account the causes of the oil price increases and their effects on the macroeconomic variables as well. It is believed that the major source of oil price hikes in 1970s was the reduction in the oil supply. In the case of a pure supply shock, macroeconomic variables are affected by the oil supply disruption through higher oil prices. On the other hand, if an increase in oil price is caused by a demand shock, there might be additional transmission channels

that affect the macroeconomic variables. For example, if an increase in oil demand is caused by a foreign productivity shock, a small open economy will suffer from the higher oil import bills while also enjoying the cheaper consumption goods import, as well as higher exports due to the higher demand from the rest of the world. In other words, inflationary effects of oil price increases will be limited. We argue that the faster economic growth coming from higher productivity growth in developing countries ultimately raised oil demand of these countries, fostering the real price of oil in the world market.<sup>1</sup> Table 1 shows the trend of higher productivity growth of emerging markets, such as China, India, Turkey and other East European countries in the last decade.

Following Gali and Monacelli (2005) we develop a sticky-price, small open economy (SOE) dynamic stochastic general equilibrium (DSGE) model by which we can analyse the effects of foreign productivity shocks and oil supply shocks on oil prices, as well as the macroeconomic variables of a SOE. Specifically, we assume that the world economy is composed of a domestic SOE and a continuum of other small open economies (the rest of the world, or ROW). Effectively, a SOE has a negligible effect on the world economy, hence oil demand and price are determined by the ROW, which can be regarded as a closed economy. Oil price is determined endogenously in the model, hence the model enables us to investigate the channels through which shocks that cause oil price hikes and other macroeconomic variables interact. Oil supply is assumed to be exogenous and follows a first-order autoregressive (i.e. AR(1)) process. Production process involves labour and oil as factors of production. In this setting, we are able to analyse the effects of oil supply shocks and foreign productivity shocks on the SOE. Additionally, general equilibrium effects of stronger commitments of the central banks to the low and stable inflation, lower oil dependency and openness are analysed using our model. Finally, we analyze the welfare implications of alternative monetary policy regimes.

The remainder of the paper is organised as follows. In section two the basic structure of the model is laid out. The oil market equilibrium and the equilibrium conditions of the foreign economy are derived in section three. Impulse responses and sensitivity analysis are outlined in section four. Section five

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<sup>1</sup>Our point of view is supported by IMF staff reports (see, for example, World Economic Outlook, April 2007). See also Campolmi (2007).

compares the welfare outcomes of some alternative monetary policy regimes. Section six concludes.

## 2 The Small Open Economy Model

In this section, we develop an open economy DSGE model with staggered prices. It shares its basic features with many new Keynesian SOE models, including the benchmark models of Galí and Monacelli (2005) (GM thereafter) and Clarida, Galí and Gertler (2001) (CGG thereafter). In these models, the world economy is considered as consisting of a domestic SOE and a continuum of other SOEs (or ROW), all represented by a unit interval. The SOE has negligible effect on the ROW, hence ROW can be regarded as a single closed economy. We assume that the SOE and the ROW have preferences and technologies in common, and all the goods produced are traded. In order to highlight our interest in a single SOE and its interlinkages with the foreign economy, variables without superscripts refer to the home economy, while variables with a star indicate the foreign economy variables.

In order to capture oil shocks, we follow Blanchard and Galí (2007) by introducing a non-produced oil input in the production function. Contrary to their analysis, however, the price of oil is endogenously determined in our model.

### 2.1 Households

A representative household is infinitely-lived and seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \quad (1)$$

where  $U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$  is the period utility function,  $N_t$  denotes hours of work and  $C_t$  is a composite consumption index defined by

$$C_t = \left[ (1-\alpha)^{\frac{1}{\gamma}} C_{H,t}^{(\gamma-1)/\gamma} + \alpha^{\frac{1}{\gamma}} C_{F,t}^{(\gamma-1)/\gamma} \right]^{\gamma/(\gamma-1)}$$

where  $C_{H,t}$  and  $C_{F,t}$  are CES indices of consumption of domestic and foreign goods, given by

$$C_{H,t} = \left[ \int_0^1 C_{H,t}(j)^{(\varepsilon-1)/\varepsilon} dj \right]^{\varepsilon/(\varepsilon-1)} ; C_{F,t} = \left[ \int_0^1 (C_{i,t})^{(\gamma-1)/\gamma} di \right]^{\gamma/(\gamma-1)}$$

where  $C_{i,t} = \left[ \int_0^1 C_{i,t}(j)^{(\varepsilon-1)/\varepsilon} dj \right]^{\varepsilon/(\varepsilon-1)}$  is an index of the quantity of goods imported from country  $i \in [0, 1]$  and consumed by domestic households,  $j \in [0, 1]$  indicates the goods varieties and  $\varepsilon > 1$  is the elasticity of substitution among goods produced within a country.  $0 < \alpha < 1$  indicates the expenditure share of the imported goods in the consumption basket of households. We assume that the degree of substitutability between domestic and foreign goods ( $\gamma > 0$ ) is the same as the degree of substitutability between goods produced in different foreign countries. The period budget constraint of the household is given by

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj + \int_0^1 \int_0^1 P_{i,t}(j) C_{i,t}(j) dj di + E_t \{ Q_{t,t+1} D_{t+1} \} \leq D_t + W_t N_t + T_t. \quad (2)$$

Conditional on the optimal allocation of expenditures between domestic and imported goods  $\left( C_{H,t} = (1 - \alpha) \left( \frac{P_{H,t}}{P_t} \right)^{-\gamma} C_t \text{ and } C_{F,t} = \alpha \left( \frac{P_{F,t}}{P_t} \right)^{-\gamma} C_t \right)$ , the budget constraint can be written as

$$P_t C_t + E_t \{ Q_{t,t+1} D_{t+1} \} \leq D_t + W_t N_t + T_t \quad (3)$$

where  $P_t = [(1 - \alpha) P_{H,t}^{1-\gamma} + \alpha P_{F,t}^{1-\gamma}]^{1/(1-\gamma)}$  is the consumer price index (CPI) and the price indices for domestically produced and imported goods are

$$P_{H,t} = \left[ \int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right]^{1/(1-\varepsilon)} ; P_{F,t} = \left[ \int_0^1 P_{i,t}^{1-\gamma} di \right]^{1/(1-\gamma)}$$

where  $P_{i,t} = \left[ \int_0^1 P_{i,t}(j)^{1-\varepsilon} dj \right]^{1/(1-\varepsilon)}$  is a price index for goods imported from country  $i$ .  $Q_{t,t+1}$  is the stochastic discount factor,  $D_{t+1}$  is the nominal pay-off in period  $t + 1$  of the portfolio held at the end of period  $t$  including the shares in firms,  $W_t$  is the nominal wage and  $T_t$  is lump-sum transfers and/or taxes.

The behaviour of household is also characterized by an intratemporal optimality condition

$$C_t^\sigma N_t^\varphi = \frac{W_t}{P_t} \quad (4)$$

and a Euler equation

$$\beta R_t E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \left( \frac{P_t}{P_{t+1}} \right) \right\} = 1 \quad (5)$$

where  $R_t = 1/E_t\{Q_{t,t+1}\}$  is the return on a riskless bond paying off one unit of domestic currency in period  $t+1$ . Equations (7) and (6) are the log-linearized forms of the equations (4) and (5).

$$w_t - p_t = \sigma c_t + \varphi n_t \quad (6)$$

$$c_t = -\frac{1}{\sigma} (r_t - E_t\{\pi_{t+1}\} - \rho) + E_t\{c_{t+1}\} \quad (7)$$

where lower case letters denote the logs of the respective variables (now and thereafter),  $\rho = -\log \beta$ ,  $\log R_t = \log(1 + r_t) \approx r_t$  is the nominal interest rate and  $\pi_{t+1} = p_t - p_{t-1}$  is the CPI inflation between  $t$  and  $t + 1$ .

## 2.2 Inflation, Real Exchange Rate and UIP Condition

The bilateral real exchange rate  $Q_{i,t}$  is defined as  $Q_{i,t} = \frac{E_{i,t}P_t^i}{P_t}$ , where  $E_{i,t}$  is the bilateral nominal exchange rate (domestic currency price of country  $i$ 's currency) and  $P_t^i$  is the aggregate price index for country  $i$ 's consumption goods. Therefore,  $Q_{i,t}$  is the ratio of the two country's CPI's, both expressed in domestic currency. The law of one price is assumed to hold for each good. Hence, the log-linearized real effective exchange rate can be written as

$$q_t = p_{F,t} - p_t \quad (8)$$

where  $q_t = \int_0^1 q_{i,t} di$  is the log effective real exchange rate. Then using the log-linearized formula for the CPI index around a symmetric steady state, the CPI, domestic price level and real exchange rate can be linked through the following equation

$$p_t = p_{H,t} + \frac{\alpha}{1 - \alpha} q_t. \quad (9)$$

We assume that households in foreign economy face exactly the same optimization problem with identical preferences. However, noting that the foreign economy as a whole is in fact a closed economy with the influence from the domestic economy being negligible,  $C_t^* = C_{F,t}^*$  and  $P_t^* = P_{F,t}^*$ . Equations (6) and (7) continue to hold for the foreign economy with each variable replaced by a corresponding starred variable. Under complete international financial markets assumption and no-arbitrage, Euler equations from both countries can be combined to achieve a risk sharing condition. Ignoring the irrelevant constant

that depends on the initial conditions<sup>2</sup>, the log-linearized version of the risk sharing equation can be written as

$$c_t = c_t^* + \frac{1}{\sigma} q_t. \quad (10)$$

The assumption of complete financial markets yields another important relationship. Using  $r_t = \log R_t = -\log Q_{t,t+1}$  and its foreign country counterpart for each country  $i$ , then aggregating over the countries, will yield the uncovered interest parity condition (UIP)

$$E_t \{\Delta e_{t+1}\} = r_t - r_t^* \quad (11)$$

where  $e_t$  is the (log) nominal effective exchange rate.

Combining this with the definition of the real exchange rate and log-linearizing around the steady state, one can write the UIP condition in terms of the real exchange rate as

$$E_t \{\Delta q_{t+1}\} = (r_t - E_t \{\pi_{t+1}\}) - (r_t^* - E_t \{\pi_{t+1}^*\}). \quad (12)$$

### 2.3 Firms

Each firm produces a differentiated good indexed by  $j \in [0, 1]$  with a production function

$$Y_t(j) = [A_t N_t(j)]^\eta O_t^d(j)^{1-\eta} \quad (13)$$

where  $O_t^d(j)$  is the amount of oil used in production by firm  $j$ , (log) productivity  $a_t = \log(A_t)$  follows an  $AR(1)$  process  $a_t = \rho_a a_{t-1} + \varepsilon_t^a$ ,  $\{\varepsilon_t^a\}$  is i.i.d. and  $\rho_a \in [0, 1)$ . Assuming that firms take the price of each input as given, cost minimization of the firm implies

$$(1 - \eta)(1 - \tau)W_t N_t(j) = \eta O_t^d(j) P_{O,t} \quad (14)$$

which holds for each firm  $j$ .  $P_{O,t}$  is the price of oil which is in fact determined endogenously in our model, as will be explored later.  $\tau$  is an employment subsidy, whose role is discussed in detail in GM and also in the appendix. The nominal marginal cost is

$$MC_t^m = \frac{(1 - \tau)W_t}{\eta A_t^\eta N_t(j)^{\eta-1} O_t^d(j)^{1-\eta}}.$$

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<sup>2</sup>See Gali and Monacelli (2005) for detailed derivations and explanation on this issue.



Utilising equation (14), the marginal cost can be written as

$$MC_t^m = \frac{(1 - \tau)^\eta W_t^\eta P_{O,t}^{1-\eta}}{\eta^\eta (1 - \eta)^{(1-\eta)} A_t^\eta}.$$

Therefore, one can derive the (log) real marginal cost in terms of domestic prices  $mc_t$ , which is identical for each firm, as (ignoring a constant)

$$mc_t = \eta w_t + (1 - \eta) p_{O,t} - \eta a_t - p_{H,t}. \quad (15)$$

$Y_t = \left[ \int_0^1 Y_t(j)^{(\varepsilon-1)/\varepsilon} dj \right]^{\varepsilon/(\varepsilon-1)}$  represents an index for the aggregate domestic output, like the one assumed for consumption goods. Aggregating (13) over all firms and log-linearizing to first order yields

$$y_t = \eta a_t + \eta n_t + (1 - \eta) o_t^d. \quad (16)$$

### 2.3.1 Price Setting

We assume that firms set prices according to Calvo (1983) framework, in which only a randomly selected fraction  $(1 - \theta)$  of the firms can adjust their prices optimally. Thus,  $\theta$  is the probability that firm  $j$  does not change its price in period  $t$ . Then the firm's optimal price setting strategy implies the following marginal cost-based Phillips Curve

$$\pi_{H,t} = \beta E_t \{ \pi_{H,t+1} \} + \lambda \widehat{mc}_t \quad (17)$$

where  $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$  and  $\widehat{mc}_t$  is the (log) deviation of real marginal cost from its flexible price equilibrium level.

## 2.4 Equilibrium Conditions

### 2.4.1 Goods Market Equilibrium

The equilibrium condition in the goods market requires that the production of domestic goods satisfies

$$Y_t(j) = C_{H,t}(j) + \int_0^1 C_{H,t}^i(j) di$$

where,  $C_{H,t}^i(j)$  is country  $i$ 's demand for good  $j$  produced in the home country. Using the optimal allocation of expenditures for the SOE and the ROW,

the real exchange rate definition and the assumption of symmetric preferences and aggregating across goods, we obtain

$$Y_t = \left( \frac{P_{H,t}}{P_t} \right)^{-\gamma} C_t \left[ (1 - \alpha) + \alpha \int_0^1 Q_{i,t}^{\gamma - \frac{1}{\sigma}} di \right].$$

First order log-linearization around the symmetric steady state yields

$$y_t = c_t + \gamma(p_t - p_{H,t}) + \alpha\left(\gamma - \frac{1}{\sigma}\right)q_t. \quad (18)$$

Using equation (9), one can write the goods market equilibrium as

$$y_t = c_t + \alpha \left[ \frac{(2 - \alpha)\gamma}{1 - \alpha} - \frac{1}{\sigma} \right] q_t. \quad (19)$$

Equation (19) can be combined with  $c_t^* = y_t^*$  and equation (10) to obtain

$$y_t = y_t^* + \left[ \frac{\sigma(1 - \alpha)}{\alpha\sigma\gamma(2 - \alpha) - (1 - \alpha)^2} \right] q_t \quad (20)$$

Combining equation (19) with Euler equation and (9) gives (ignoring a constant)

$$y_t = E_t \{y_{t+1}\} - \frac{1}{\sigma}(r_t - E_t \{\pi_{H,t+1}\}) - \left[ \frac{\alpha(2 - \alpha)(\gamma\sigma - 1)}{\sigma(1 - \alpha)} \right] E_t \{\Delta q_{t+1}\}. \quad (21)$$

### 2.4.2 Marginal Cost and Inflation Dynamics

Within a general equilibrium framework, the relation between marginal cost and economic activity can be established by combining the labour supply and demand relations with the market clearing condition in the goods market, as stressed by GM and CGG. Equation (15) can be written as

$$\begin{aligned} mc_t &= -\eta a_t + \eta(w_t - p_t) + (1 - \eta)(p_{O,t} - p_t) - (p_{H,t} - p_t) \\ &= -\eta a_t + \eta(\sigma c_t + \varphi n_t) + (1 - \eta)\tilde{p}_{O,t} + \left(\frac{\alpha}{1 - \alpha}\right)q_t \end{aligned} \quad (22)$$

where we make use of equations (6), (9).  $\tilde{p}_{O,t} = p_{O,t} - p_t$  is the real price of oil (the relative price of oil with respect to CPI). Then using (16) and cost minimization condition for firms, and finally (10), we can write the previous equation for the real marginal cost in terms of the domestic output and productivity, world output, real exchange rate, and the real price of oil

$$mc_t = -\Psi_1 a_t + \Psi_2 y_t^* + \Psi_3 y_t + \Psi_4 \tilde{p}_{O,t} + \Psi_5 q_t \quad (23)$$

where  $\Psi_1 = \frac{\eta(1+\varphi)}{1+(1-\eta)\varphi}$ ,  $\Psi_2 = \frac{\eta\sigma}{1+(1-\eta)\varphi}$ ,  $\Psi_3 = \frac{\eta\varphi}{1+(1-\eta)\varphi}$ ,  $\Psi_4 = \frac{(1-\eta)(1+\varphi)}{1+(1-\eta)\varphi}$ ,  $\Psi_5 = \frac{\eta}{1+(1-\eta)\varphi} + \frac{\alpha}{1-\alpha}$ .

Since the price of oil is determined in the ROW, the SOE takes the price of oil as given. Hence

$$p_{O,t} = p_{O,t}^* + e_t$$

where is  $e_t$  the (log) nominal effective exchange rate, or

$$\tilde{p}_{O,t} = \tilde{p}_{O,t}^* + q_t.$$

Using equation (9), equation (23) becomes

$$mc_t = -\Psi_1 a_t + \Psi_2 y_t^* + \Psi_3 y_t + \Psi_4 \tilde{p}_{O,t}^* + \frac{1}{1-\alpha} q_t \quad (24)$$

using  $\Psi_4 + \Psi_5 = \frac{1}{1-\alpha}$ .

Substituting for the real exchange rate using equation (20) gives

$$mc_t = -\Psi_1 a_t + (\Psi_2 - \Psi_6) y_t^* + (\Psi_3 + \Psi_6) y_t + \Psi_4 \tilde{p}_{O,t}^* \quad (25)$$

where  $\Psi_6 = \frac{\sigma}{\alpha\sigma\gamma(2-\alpha)+(1-\alpha)^2}$ .

Supposing that all firms adjust their prices optimally in each period under flexible price setting, the desired mark-up will be common across firms and constant over time. Thus, one can write

$$\overline{mc}_t = -\mu$$

where  $\overline{mc}_t$  is the flexible price equilibrium marginal cost, and  $\mu = \log(\frac{\varepsilon}{\varepsilon-1})$ . If we denote  $\bar{y}$  as the flexible price level of output  $y$ , using the equation (25) and the condition above, we obtain  $\bar{y}_t$  as follows

$$\bar{y}_t = \frac{-\mu + \Psi_1 a_t - (\Psi_2 - \Psi_6) y_t^* - \Psi_4 \tilde{p}_{O,t}^*}{(\Psi_3 + \Psi_6)} \quad (26)$$

Defining the output gap as  $x_t = y_t - \bar{y}_t$ , we have  $\widehat{mc}_t = (\Psi_3 + \Psi_6) x_t$ . Hence, using equation (17), the new Keynesian Phillips Curve in our model can be written in terms of output gap as

$$\pi_{H,t} = \beta E_t \{ \pi_{H,t+1} \} + \lambda (\Psi_3 + \Psi_6) x_t. \quad (27)$$

Moreover, using the definition of output gap, equations (21), (26) and the AR(1) process that we previously defined for  $a_t$ , we can derive the new Keynesian IS curve as

$$\begin{aligned}
x_t = & E_t \{x_{t+1}\} - \frac{1}{\sigma}(r_t - E_t \{\pi_{H,t+1}\}) - \left[ \frac{\alpha(2-\alpha)(\gamma\sigma-1)}{\sigma(1-\alpha)} \right] E_t \{\Delta q_{t+1}\} \\
& - \frac{\Psi_1}{(\Psi_3 + \Psi_6)}(1 - \rho_a)a_t - \frac{(\Psi_2 - \Psi_6)}{(\Psi_3 + \Psi_6)} E_t \{\Delta y_{t+1}^*\} \\
& - \frac{\Psi_4}{(\Psi_3 + \Psi_6)} E_t \{\tilde{\pi}_{O,t+1}^*\}. \tag{28}
\end{aligned}$$

In the baseline model, we assume that monetary policy in the SOE is conducted according to the following simple CPI based rule

$$r_t = \phi_\pi \pi_t.$$

### 3 Oil Market Equilibrium and the Foreign Economy

Apart from being asymmetric in size, SOE and ROW share the same preferences, technology and market structure. Contrary to the conventional method of taking the foreign economy variables as exogenous processes, we explicitly model the foreign economy. The price of oil depends on the macroeconomic developments in the ROW. Therefore, an appropriate modelling for the ROW is needed to analyse its effects on oil prices and the SOE.

We assume that at each point in time there is a world oil endowment ( $o_t^{S*}$ ), which is subject to i.i.d. shocks  $\varrho_t$ , and constant otherwise.<sup>3</sup> Following Backus and Crucini (1998), the process for the (log) oil supply is defined by an AR(1) process

$$o_t^{S*} = \rho_O o_{t-1}^{S*} + \varrho_t$$

where  $\rho_O \in [0, 1)$ .

Using the (log-linearized) cost minimization condition for foreign firms and substituting the equilibrium level of employment yields

$$o_t^{d*} = \left[ \frac{\eta\sigma + 1 + \varphi}{1 + (1 - \eta)\varphi} \right] y_t^* - \left[ \frac{\eta(1 + \varphi)}{1 + (1 - \eta)\varphi} \right] a_t^* - \left[ \frac{\eta}{1 + (1 - \eta)\varphi} \right] \tilde{p}_{O,t}^*. \tag{29}$$

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<sup>3</sup>We assume that the profits from selling oil are distributed evenly among world consumers and are included in the  $T_t$  and  $T_t^*$  in the budget constraints of both small open economy and foreign economy. See also Campolmi 2007.

Then equating the demand for oil to the supply of oil,  $o_t^{d*} = o_t^{S*}$ , we can derive the optimum real price of oil in the foreign country as follows

$$\widehat{p}_{O,t}^* = \Gamma_1 y_t^* - \Gamma_2 a_t^* - \Gamma_3 o_t^{S*} \quad (30)$$

where  $\Gamma_1 = \sigma + \frac{(1+\varphi)}{\eta}$ ,  $\Gamma_2 = 1 + \varphi$  and  $\Gamma_3 = \frac{1+(1-\eta)\varphi}{\eta}$  respectively. Equation (30) indicates that while an increase in world output pushes world real oil prices up, productivity and oil supply increases drive down the world real oil price.

The foreign economy version of equation (23) is

$$\begin{aligned} mc_t^* &= -\Psi_1 a_t^* + (\Psi_2 + \Psi_3) y_t^* + \Psi_4 \widehat{p}_{O,t}^* \\ &= -\Theta_1 a_t^* + \Theta_2 y_t^* + \Theta_3 o_t^{S*} \end{aligned} \quad (31)$$

where  $\Theta_1 = \Psi_1 + \Psi_4(1 + \varphi)$ ,  $\Theta_2 = \Psi_2 + \Psi_3 + \Psi_4(\sigma + \frac{(1+\varphi)}{\eta})$ ,  $\Theta_3 = \Psi_4(\frac{(1-\eta)(1+\varphi)}{\eta})$ . Using the corresponding relation between the deviations of marginal cost from its flexible price equilibrium and output gap,  $\widehat{mc}_t^* = \Theta_2 x_t^*$ .

Equilibrium dynamics (IS and Phillips curves) are

$$x_t^* = E_t \{x_{t+1}^*\} - \frac{1}{\sigma} (r_t^* - E_t \{\pi_{t+1}^*\}) + E_t \{\Delta \bar{y}_{t+1}^*\} \quad (32)$$

$$\pi_t^* = \beta E_t \{\pi_{t+1}^*\} + \lambda \Theta_2 x_t^* \quad (33)$$

respectively, where  $\bar{y}_t^* = (1/\Theta_1)(-\mu + \Theta_2 a_t^* + \Theta_3 o_t^{S*})$ .

The foreign productivity is assumed to follow an AR(1) process

$$a_t^* = \rho_a^* a_{t-1}^* + \varepsilon_t^{a^*}$$

where  $\varepsilon_t^{a^*}$  are i.i.d. and  $\rho_a^* \in [0, 1)$ .

The monetary policy in the ROW, as in the SOE, follows a CPI based rule

$$r_t^* = \phi_\pi^* \pi_t^*.$$

## 4 Impulse Response Analysis

### 4.1 Baseline Calibration

In our paper, we mainly follow the baseline calibration used in GM.

### 4.1.1 *Preferences*

Time is measured in quarters. Along with the related literature we set  $\beta = 0.99$ , implying a riskless annual return of approximately 4% in the steady state. The inverse of the elasticity of intertemporal substitution is taken as  $\sigma = 1$ , which corresponds to log utility. The inverse of the elasticity of labour supply  $\varphi$  is set to 3 since it is assumed that 1/3 of the time is spent on working. We set the degree of openness ( $\alpha$ ) to be 0.4.

### 4.1.2 *Technology*

The share of labour in the production ( $\eta$ ) is taken as 0.98, so that the share of oil in the production ( $1 - \eta$ ) is 2%<sup>4</sup>. The Calvo probability ( $\theta$ ) is assumed to be 0.75 which implies an average period of one year between price adjustments. The elasticity of substitution between differentiated goods (of the same origin)  $\varepsilon$  is 6, implying a flexible price equilibrium mark-up of  $\mu = 1.2$ .

### 4.1.3 *Monetary Policy*

We use a CPI inflation-based rule and set  $\phi_\pi = 1.5$ .

### 4.1.4 *Exogenous Processes*

The persistence of the productivity shock ( $\rho_a$ ) and the persistence of the oil supply shock ( $\rho_o$ ) are set to 0.9.<sup>5</sup>

## 4.2 **Dynamic Responses to Shocks**

### 4.2.1 **Transmission Channels of the Oil Supply Shock**

A 10 percent unexpected decline in the world oil supply leads to an immediate, almost one-for-one, jump in real world oil prices<sup>6</sup>. World output is affected by the oil supply shock through two different channels. First, the decline in

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<sup>4</sup>There is no consensus in the literature about the share of oil in the production. For example, Fiore et. al. (2006) calculate the parameter as 1.96% for US. On the other hand, Blanchard and Gali (2007) set the share of oil in production as 1.5% for the 1970s and 1.2% for the end of 1990s. We later try two different parametrizations for the share of oil, which are, 5% and 0.5%.

<sup>5</sup>Using two different data types, Backus and Crucini (1998) estimate the persistence of the OPEC oil supply shock as 0.882 and 0.977 for the period 1961 to 1991.

<sup>6</sup>For ease of exposition, we analyse the effects of a 10% change in the oil supply instead of a 1% change.

oil supply directly reduces world output through production function. Second, increase in oil price pushes up the CPI of the ROW due to increasing marginal cost of production. Increasing consumer price inflation forces monetary authority to raise interest rate according to the monetary policy rule and higher interest rate depresses world output further.

Since the oil supply shock is exogenous to both countries and the technologies are the same, under the baseline calibration, the marginal cost of production in both countries are affected in the same way. For simplicity, we assume that the oil revenue is distributed among the world consumers equally, hence, an increase in the price of oil does not create asymmetric wealth effects in the SOE and the ROW. As a result, in case of an exogenous oil supply shock, the responses of both countries are symmetric and the real exchange rate does not change.

#### **4.2.2 Transmission Channels of the ROW Productivity Shock**

An unexpected productivity increase in the ROW reduces the marginal cost of production through equation (31). On the other hand, higher productivity of labour brings about higher output growth, which increases the demand for oil. In equation (30) the impact of the increasing oil demand dominates the labour-oil substitution effect, leading to higher oil prices and therefore higher marginal cost of production. Therefore, there are two forces that affect the CPI of the ROW in opposite ways. Essentially, effect of the productivity shock on the CPI of ROW depends on the parameters  $\Gamma_2$ ,  $\Psi_1$  and  $\Psi_4$  and deflationary effect of productivity shock exceeds its inflationary effect according to our baseline calibration of the model.

Positive productivity shock in the ROW affects the SOE through different channels. First, higher output in ROW implies the appreciation of the domestic currency through equation (20) because of the fact that, under complete markets assumption, the real exchange rate is determined through the international risk sharing equation. As a result, cheaper import prices reduce the CPI in SOE. On the other hand, dynamic path of domestic inflation depends on the output gap. Equation (28) implies that output gap is determined by expected output gap as well as dynamic interactions of foreign output growth,

change in the real exchange rate and real price of oil in domestic currency. Increase in real oil price in domestic currency together with positive output growth in the ROW and gradual depreciation of domestic currency drives down the output gap in SOE. Negative output gap implies domestic price deflation through Phillips curve. Expected real interest rate turns into negative in the SOE which stimulates the output growth through IS equation.

Figure 4 shows the dynamic paths of selected macroeconomic variables after positive productivity shock in the ROW. The main conclusion that can be drawn from this experiment is that, productivity shocks that improve the productivity of one factor of production (labour) might lead to an increase in the price of the other factor of production (oil). In our case, increase in oil demand due to positive output growth exceeds the decline in oil demand due to substitution effect between factors of production, hence oil price increases. On the other hand, higher labour productivity implies lower marginal cost of production which spreads to the world as lower import prices. As a result, increase in output growth is accompanied by low consumer price inflation but high oil price inflation throughout the world economy.

### 4.3 Sensitivity Analysis

In this section we carry out the same experiments by using different parameter values in order to see how robust our baseline calibration outcomes are.

#### 4.3.1 Strength of Monetary Policy

First, we set the monetary policy rule parameters to  $\phi_\pi = \phi_\pi^* = 1.1$ , in order to analyse the effects of a relatively looser policy. Figures 5 and 6 show that a stronger anti-inflationary stance of monetary policy reduces the volatility of inflation but increases the volatility of output against the shocks. Therefore, low inflation and low output volatilities observed recently, despite the rising oil prices, cannot only be attributable to the strong anti-inflationary stance of the monetary policy.



### 4.3.2 Degree of Openness

The degree of openness  $\alpha$  is set to 0.2 and 0.6 in order to analyse the effects of a productivity shock in a relatively more closed and open SOE (Figure 7)<sup>7</sup>. Higher degree of openness reduces the CPI of the SOE at an increased rate against the ROW productivity shocks. This is because the degree of openness increases the share of foreign goods in the consumption basket of the households in SOE. Hence, in the case of a productivity shock in the ROW and higher degree of openness, cheaper imported goods reduce the CPI of the SOE even more.

### 4.3.3 Oil Dependency

We compare two different parameterisations for the share of oil in production (0.05% and 5%) in order to see the effects of a negative supply shock and a ROW productivity shock with different oil dependency levels (Figure 8). The response of output in the SOE is much higher against a negative supply shock when the degree of oil dependency is higher. Intuitively, as the oil dependency decreases, the volatility levels for output and inflation are much lower in case of an oil supply shock.

Changes in oil dependency do not change the responses to a foreign productivity shocks in a significant manner. The reason is that the relative effect coming from a different oil dependency level is very small compared to the effect of the productivity shock due to the small share of oil in the production.

## 5 Welfare Implications of Alternative Monetary Policy Regimes

### 5.1 Measuring the Welfare Costs

While deriving the welfare function, it is assumed that the objective of the monetary authority is to minimise the utility losses of the domestic representative consumer resulting from shocks that hit the economy . A second order approximation of the utility losses of the domestic consumer can be driven by

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<sup>7</sup>The responses to a negative oil supply shock do not depend on the degree of openness in our model, since the shares of oil in the production functions of the SOE and the ROW are identical.

assuming log utility of consumption and unit elasticity of substitution between goods of different origin. In the appendix, it is shown that the second order approximation to the utility based welfare loss function of domestic household can be written as

$$W_t = -\frac{(1-\alpha)}{2} \sum_0^{\infty} \beta^t \left( \frac{\varepsilon}{\lambda} \pi_{H,t}^2 + \frac{1+\varphi}{1+\varphi(1-\eta)} x_t^2 \right) \quad (34)$$

Expected welfare losses of shocks can be driven in terms of variances of domestic inflation and output gap by taking the unconditional expectations of equation (34) while  $\beta \rightarrow 1$ .

$$V_t = -\frac{(1-\alpha)}{2} \left( \frac{\varepsilon}{\lambda} \text{var}(\pi_{H,t}) + \frac{1+\varphi}{1+\varphi(1-\eta)} \text{var}(x_t) \right) \quad (35)$$

Let,  $\Lambda_\pi = \frac{(1-\alpha)\varepsilon}{2\lambda}$  and  $\Lambda_x = \frac{(1-\alpha)}{2} \frac{1+\varphi}{1+\varphi(1-\eta)}$ , then ,

$$V_t = -\Lambda_\pi \text{var}(\pi_{H,t}) - \Lambda_x \text{var}(x_t) \quad (36)$$

## 5.2 Performance of Alternative Monetary Policy Rules against Oil Supply and Productivity Shocks

In this section, we select ten different monetary policy rules and compare their performances.

1. Strict domestic inflation targeting: Optimal monetary policy requires that the government eliminates distortions that are caused by price rigidities (see the Appendix). Therefore, real marginal cost will be zero and output will be equal to the flexible price equilibrium output level,  $y_t = \bar{y}_t$ , for all  $t$ , which means that output gap will be equal to zero all the time ( $x_t = 0$ ). From Phillips curve equation we can infer that  $\pi_{H,t} = 0$ . Therefore, optimal monetary policy is to stabilise the domestic inflation at zero.

2. Domestic inflation targeting (DI targeting):

$$r_t = \phi_\pi \pi_{H,t}$$

In this setting, monetary authority responds only to the changes in prices of domestically produced goods. The main advantage of this rule is that  $\pi_{H,t}$  does not include the direct effects of exchange rate movements hence monetary authority need not give response to the short-term fluctuations of the CPI.

Therefore, it is expected that targeting domestic inflation, instead of CPI, results in less volatility in other macroeconomic variables.

3. CPI targeting:

$$r_t = \phi_\pi \pi_t$$

The common practice in the real world is to target CPI instead of the domestic inflation. This is because  $\pi_t$  represents the consumption basket of consumers better than  $\pi_{H,t}$ , and it is well known by the public. Therefore, it is easier for the monetary authority to explain its interest rate decisions.

4. Exchange rate peg:

$$\Delta e_t = 0$$

We include the exchange rate peg policy in order to observe the volatility of macroeconomic variables when the exchange rate does not respond to exogenous shocks.

5. Taylor rule with domestic inflation (DI Taylor):

$$r_t = \phi_\pi \pi_{H,t} + \phi_x x_t$$

We set parameters as  $\phi_\pi = 1.5$  and  $\phi_x = 0.5$  following Taylor (1993).

6. Taylor rule with CPI inflation (CPI Taylor):

$$r_t = \phi_\pi \pi_t + \phi_x x_t$$

We replace the  $\pi_{H,t}$  in the Taylor rule with  $\pi_t$ .

7. Forward looking domestic inflation targeting (FL\_DI targeting):

$$r_t = \phi_\pi E_t \pi_{H,t+1}$$

In this setting, we assume that monetary authority sets interest rate at time  $t$  according to the rational domestic goods inflation forecast of  $t + 1$ .

8. Forward looking CPI targeting (FL\_CPI targeting):

$$r_t = \phi_\pi E_t \pi_{t+1}$$

Rational forecast of CPI is used by the monetary authority while setting the interest rate.

9. Forward looking Taylor rule with domestic inflation (FL\_DI Taylor):

$$r_t = \phi_\pi E_t \pi_{t+1} + \phi_x x_t$$

10. Forward Looking Taylor rule with CPI inflation (FL\_CPI Taylor):

$$r_t = \phi_\pi E_t \pi_{H,t+1} + \phi_x x_t$$

### 5.2.1 Volatilities of Selected Variables with Alternative Monetary Policy Rules

**Oil Supply Shock** Panel A in Table 2 presents the standard deviations of selected variables after a 10 percent oil supply shock, with different monetary policy rules. Standard deviation of output is highest when the monetary authority uses a forward looking DI based Taylor rule. On the other hand, forward looking DI targeting leads to the lowest output volatility. Among the sub-optimal monetary policy rules, the CPI based Taylor rule produces the lowest CPI and domestic goods inflation volatility. While optimal monetary policy causes highest exchange rate volatility, DI targeting and CPI targeting eliminate the volatility of exchange rate almost completely. Forward looking DI based Taylor rule gives rise to the highest real price of oil volatility. Volatility of real oil price is lowest when the monetary authority tries to keep the domestic inflation at zero.

**Productivity Shock** Panel B summarises the volatility of selected variables after the 1% foreign productivity shock. Monetary authority can achieve very low output and domestic goods inflation volatilities against the productivity shock by selecting any monetary policy rule among the optimal policy, DI targeting, DI Taylor, FL\_DI targeting and FL\_DI Taylor. Volatilities of CPI and the change in nominal exchange rate are highest when the monetary authority implements forward looking CPI targeting. While forward looking CPI targeting leads to lowest real oil price volatility, exchange rate peg leads to highest real oil price volatility.

### 5.2.2 Unconditional Welfare Losses

We use equation (36) to calculate the welfare losses of household against the exogenous shocks. The two coefficients in the welfare loss function of the representative household show the relative weights of the volatilities of domestic inflation and output gap. The baseline parameters of our model imply  $\Lambda_\pi = 20.97$  and  $\Lambda_x = 1.13$ . Therefore, according to our baseline calibration,

weight of the domestic inflation is much higher than the output gap in our loss function. Contrary to the GM, our welfare loss function includes the share of oil in the production process:  $(1 - \eta)$ . Since  $(1 - \eta)$  is in the denominator of the parameter of the output gap volatility, when the share of oil in the production process decreases, the relative weight of the volatility of the output gap in the loss function increases.

Table 3 shows the contributions of the volatilities of the domestic inflation and the output gap to the welfare losses of the representative household caused by a 10 percent oil supply shock and 1 percent productivity shock under alternative monetary policy rules. CPI Taylor rule ensures the lowest welfare loss among the sub-optimal rules in the case of an oil supply shock. Welfare losses of productivity shocks are highest when the monetary authority implements exchange rate peg. On the other hand, forward looking CPI targeting causes the highest welfare loss in the case of oil supply shock. Poor performance of forward looking CPI targeting against exogenous shocks is also reported in Basak (2007), Levin et al. (2003) and Rodebusch and Svensson (1998).

## 6 Conclusion

Our purposes in this paper are to examine the effects of the increases in the price of oil caused by two types of shocks, namely negative oil supply shocks and positive foreign productivity shocks, and derive the welfare implications for a small open economy. Unlike most of the existing literature, we embodied the price of oil as an endogenous variable determined by the oil demand and supply conditions. In context of the small open economy model, we compare the effects of an oil price increase caused by a negative oil supply shock and an increase in world productivity, i.e. higher oil demand. We argue that, among other reasons, one reason for the decline in the responsiveness of the economies to the oil price hikes could be the offsetting positive effects of productivity increases on the negative effects of the rising oil price.

In addition, we derive the welfare loss function of the representative household in order to measure the welfare costs of the mentioned exogenous shocks under alternative monetary policy settings. Our results show that, among the sub-optimal rules, Taylor rules outperform other simple rules in the case of

an oil supply shock. On the other hand, oil supply shocks cause considerably more welfare losses if the monetary authority pursues forward looking inflation targeting. In the case of external productivity shocks, minimum welfare losses are achieved by implementing Taylor rules and targeting rules with domestic inflation. Exchange rate peg leads to highest welfare loss against productivity shocks.

To sum up, our experiments with alternative monetary policy rules show that the welfare implications depend substantially on the chosen monetary policy rule. Therefore, the appropriate monetary policy response against oil price shocks should in turn depend on the nature of the shock itself.

## Appendix: Derivation of the Welfare Loss Function

In this appendix, we derive the second order approximation to the welfare function. We assume that the benevolent policy maker seeks to maximize the utility of the representative household. The household's welfare (utility) function to be approximated is

$$U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$$

As in GM, we analyse monetary policy under the special case where  $\sigma = \gamma = 1$ . Under this parameterisation, the first order approximations of the equilibrium conditions hold exactly. The period utility can also be written as

$$U(C_t, N_t) = \log C_t - \frac{N_t^{1+\varphi}}{1+\varphi}$$

The steady state is assumed to be efficient. Hence, the optimal allocation requires

$$N_t = \{(1-\alpha)[1+\varphi(1-\eta)]\}^{1/(1+\varphi)}$$

On the other hand, the flexible price equilibrium level of labour is

$$N_t = \left\{ \frac{(\varepsilon-1)\eta}{\varepsilon(1-\tau)} \right\}^{1/(1+\varphi)}$$

Fiscal authority is assumed to subsidize the wages at a constant rate  $\tau$  so that the distortion caused by the imperfect competition is eliminated, and the steady state prices are at marginal cost and profits are zero<sup>8</sup>. Therefore, the amount of employment subsidy  $\tau$  that ensures efficiency is

$$\tau = 1 - \left[ \frac{(\varepsilon-1)\eta}{\varepsilon(1-\alpha)[1+\varphi(1-\eta)]} \right]$$

The optimal monetary policy is the one that replicates the flexible price equilibrium. Taking the second order approximation to the households welfare (utility) function around the efficient flexible price equilibrium, we get

$$U_t - U = U_C C (\hat{c}_t + \frac{1}{2} \hat{c}_t^2) + U_N N (\hat{n}_t + \frac{1}{2} \hat{n}_t^2) + \frac{1}{2} U_{CC} C^2 (\hat{c}_t^2) + \frac{1}{2} U_{NN} N^2 (\hat{n}_t^2) + o(\|a\|^3).$$

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<sup>8</sup>For a detailed discussion, see Woodford (2003).

Noticing that  $U_{CC}C = -U_C$ ,  $U_{NN}N = \varphi U_N$ ,  $U_C C = 1$ , and  $U_N N = -N^{1+\varphi} = -(1-\alpha)[1+\varphi(1-\eta)]$

$$U_t - U = \widehat{c}_t - (1-\alpha)[1+\varphi(1-\eta)]\widehat{n}_t - \frac{1}{2}(1-\alpha)(1+\varphi)[1+\varphi(1-\eta)]\widehat{n}_t^2 + o(\|a\|^3)$$

or

$$U_t - U = -(1-\alpha)z_t - \frac{1}{2} \frac{(1-\alpha)(1+\varphi)}{[1+\varphi(1-\eta)]} x_t^2 + t.i.p. + o(\|a\|^3)$$

where  $z_t$  is the price dispersion term from the production function, *t.i.p.* stands for "terms independent of policy", which include the exogenous and constant terms. Making use of Lemma 1 in GM which shows that the price dispersion term is of second order, i.e.,  $z_t = (\varepsilon/2)var_i\{p_{H,t}(i)\} + o(\|a\|^3)$ , and the proof in Woodford (2003), page 400, which demonstrates that  $\sum_{t=0}^{\infty} \beta^t var_i\{p_{H,t}(i)\} = \frac{1}{\lambda}$

$\sum_{t=0}^{\infty} \beta^t \pi_{H,t}^2 + t.i.p. + o(\|a\|^3)$ , the welfare function is written as

$$W_t = -\frac{(1-\alpha)}{2} \left\{ \frac{\varepsilon}{\lambda} \sum_{t=0}^{\infty} \beta^t \pi_{H,t}^2 + \frac{(1+\varphi)}{[1+\varphi(1-\eta)]} \sum_{t=0}^{\infty} \beta^t x_t^2 \right\} + t.i.p. + o(\|a\|^3)$$

Therefore, the average loss per period is

$$V_t = -\frac{(1-\alpha)}{2} \left\{ \frac{\varepsilon}{\lambda} var(\pi_{H,t}) + \frac{(1+\varphi)}{[1+\varphi(1-\eta)]} var(x_t) \right\} + t.i.p. + o(\|a\|^3).$$

Since  $(1-\eta)$  is in the denominator of the parameter of the output gap volatility, the relative weight of the domestic inflation volatility increases with the share of oil in the production.



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Table 1. Productivity Growths of Selected Countries

	1987-1995	1995-2006	2000-2006	2004	2005	2006
<b>Australia</b>	1.4	1.9	1.6	0.7	0.2	0.7
<b>United States</b>	1.2	2.2	2.3	2.7	1.7	1.5
<b>Belgium</b>	2.2	1.4	1.1	3.6	-0.9	1.6
<b>Canada</b>	1.1	1.5	1.3	0.5	2.3	0.8
<b>France</b>	2.2	1.7	1.4	0.4	1.8	0.9
<b>Germany</b>	2.5	1.7	1.4	0.7	1.3	2.2
<b>Greece</b>	0.8	2.4	3.2	5.0	2.9	3.1
<b>Ireland</b>	4.1	3.9	2.6	1.2	1.3	2.3
<b>Italy</b>	2.1	0.5	0.0	0.7	0.4	1.0
<b>U.K.</b>	2.0	2.2	2.2	2.9	1.1	2.4
<b>Iceland</b>	0.5	2.8	3.3	8.0	4.5	-2.2
<b>Mexico</b>	-0.3	0.9	0.9	0.7	0.4	4.1
<b>South Korea</b>	5.9	4.7	4.6	4.5	4.6	5.8
<b>Turkey</b>	1.5	3.2	4.2	7.2	6.2	4.8
<b>China</b>	6.2	7.2	10.5	9.0	9.4	9.8
<b>India</b>	3.8	4.5	4.8	5.7	6.6	6.7
<b>Czech Republic</b>	--	3.3	4.5	3.4	4.4	5.0
<b>Hungary</b>	--	2.3	2.2	5.6	4.2	3.4
<b>Latvia</b>	--	6.4	6.9	10.5	8.0	7.3
<b>Lithuania</b>	--	5.6	6.5	6.0	1.5	6.6
<b>Poland</b>	--	4.4	3.5	4.1	0.7	2.7
<b>Romania</b>	--	3.9	7.8	10.2	3.1	5.2

Source: The Conference Board and Groningen Growth and Development Centre, Total Economy Database, November 2007, <http://www.conference-board.org/economics>

Table 2. Standard Deviations under Alternative Regimes

Panel A: Oil Supply Shock (10%)					
	Output	Domestic inflation	CPI inflation	Nominal depreciation	Real price of oil
Optimal	1.12	0.00	0.01	0.18	21.23
DI Targeting	1.12	0.19	0.19	0.00	22.55
CPI Targeting	1.07	0.18	0.18	0.00	21.57
Peg	1.10	0.18	0.18	0.00	22.18
DI Taylor	1.14	0.15	0.15	0.04	22.80
CPI Taylor	1.11	0.14	0.14	0.04	22.23
FL_DI Targeting	1.06	0.24	0.24	0.06	21.86
FL_CPI Targeting	1.08	0.24	0.24	0.06	22.21
FL_DI Taylor	1.16	0.18	0.18	0.01	23.45
FL_CPI Taylor	1.12	0.18	0.18	0.01	22.59

Panel B: Foreign Technology Shock (1%)					
	Output	Domestic inflation	CPI inflation	Nominal depreciation	Real price of oil
Optimal	0.01	0.00	0.38	0.95	0.43
DI Targeting	0.01	0.00	0.39	0.96	0.43
CPI Targeting	0.34	0.20	0.24	0.48	0.53
Peg	0.66	0.43	0.33	0.00	0.70
DI Taylor	0.01	0.00	0.37	0.92	0.40
CPI Taylor	0.25	0.15	0.26	0.59	0.48
FL_DI Targeting	0.01	0.00	0.38	0.93	0.41
FL_CPI Targeting	0.08	0.28	0.54	0.99	0.35
FL_DI Taylor	0.01	0.00	0.38	0.94	0.41
FL_CPI Taylor	0.06	0.20	0.48	0.96	0.37

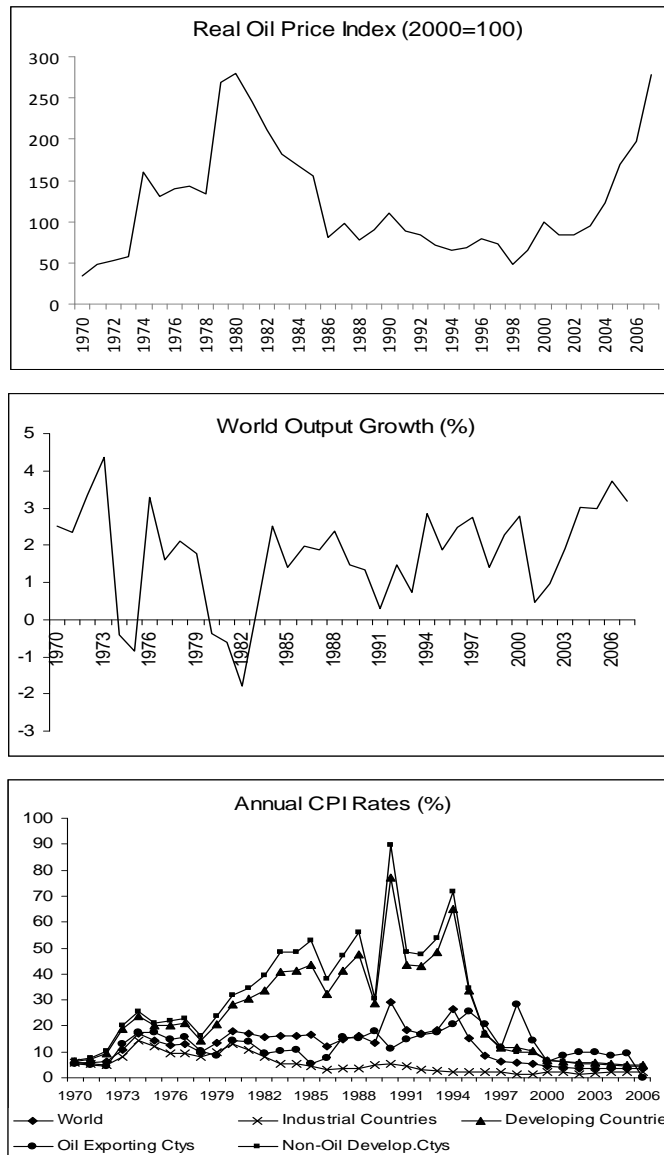
*Note: Standard deviations are in percentages*

Table 3. Contributions to Welfare Losses

	Oil Supply Shock (10%)			Foreign Technology Shock (1%)		
	Domestic inflation	Output Gap	Total W.Loss	Domestic inflation	Output Gap	Total W.Loss
Optimal	0.00	0.00	0.00	0.00	0.00	0.00
DI Targeting	0.72	0.01	0.73	0.00	0.00	0.00
CPI Targeting	0.66	0.00	0.67	0.82	0.12	0.95
Peg	0.70	0.01	0.71	3.84	0.48	4.32
DI Taylor	0.45	0.00	0.45	0.00	0.00	0.00
CPI Taylor	0.42	0.00	0.42	0.49	0.07	0.56
FL_DI Targeting	1.16	0.01	1.17	0.00	0.00	0.00
FL_CPI Targeting	1.23	0.01	1.24	1.63	0.01	1.64
FL_DI Taylor	0.71	0.01	0.71	0.00	0.00	0.00
FL_CPI Taylor	0.66	0.00	0.66	0.88	0.01	0.88

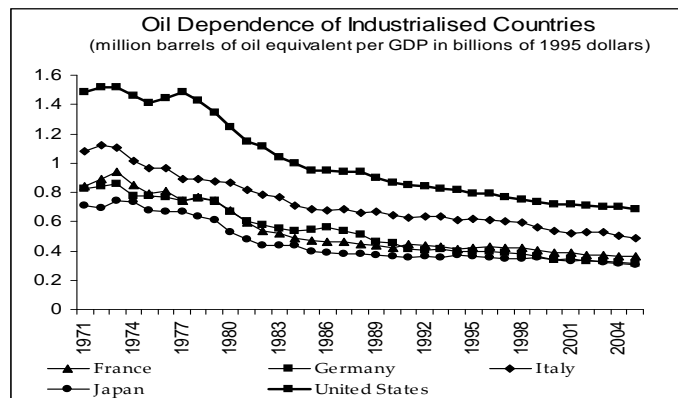
*Note: Magnitudes are shares in steady state consumption*

Figure 1.



Sources: 1. IMF, IFS Database, 2. IMF, World Economic Outlook, April 2007

Figure 2.



Source: IMF, World Economic Outlook, April 2007

Figure 3. Responses to a 10% Negative Oil Supply Shock

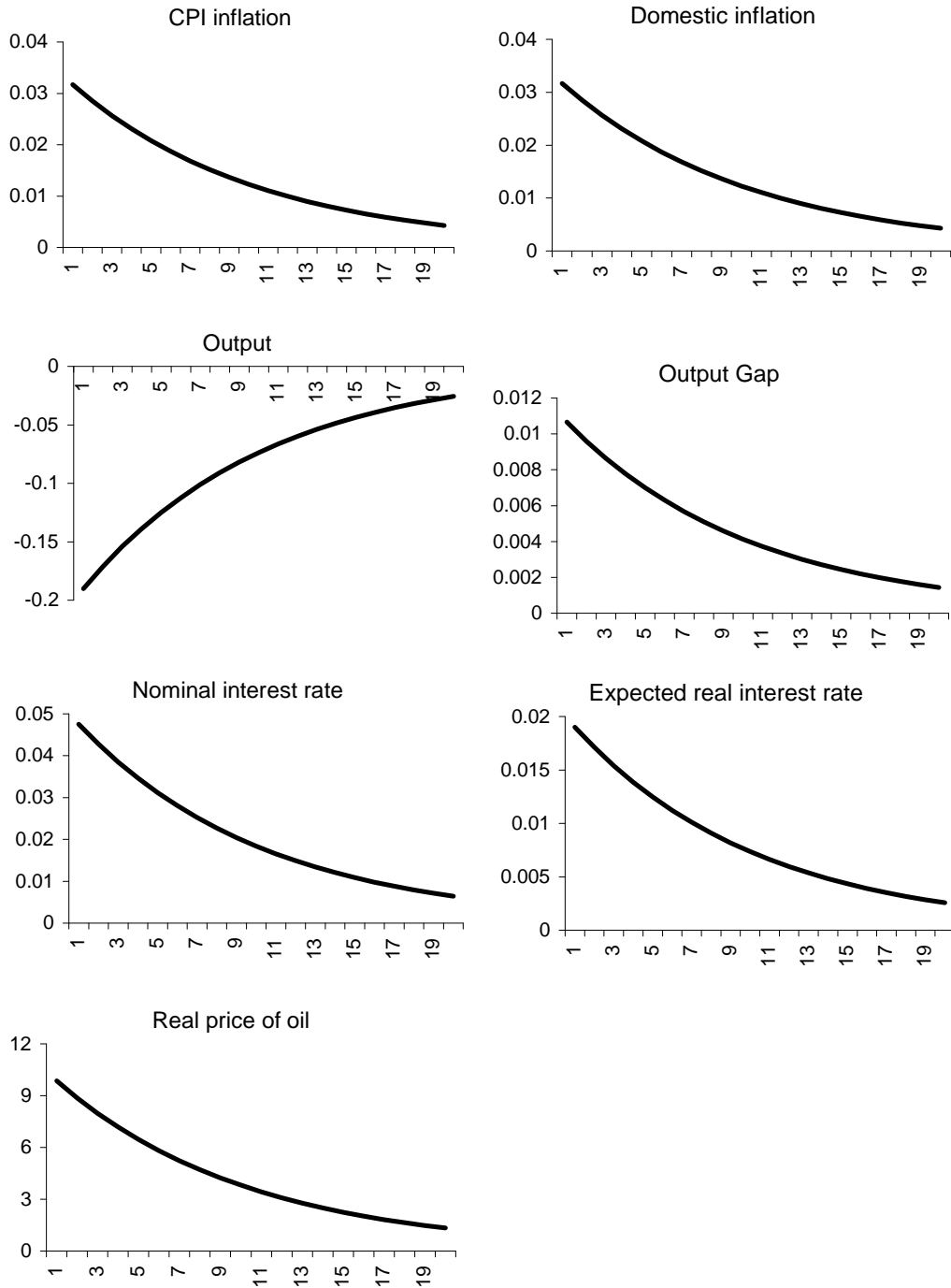


Figure 4. Responses to a 1% ROW Productivity Shock

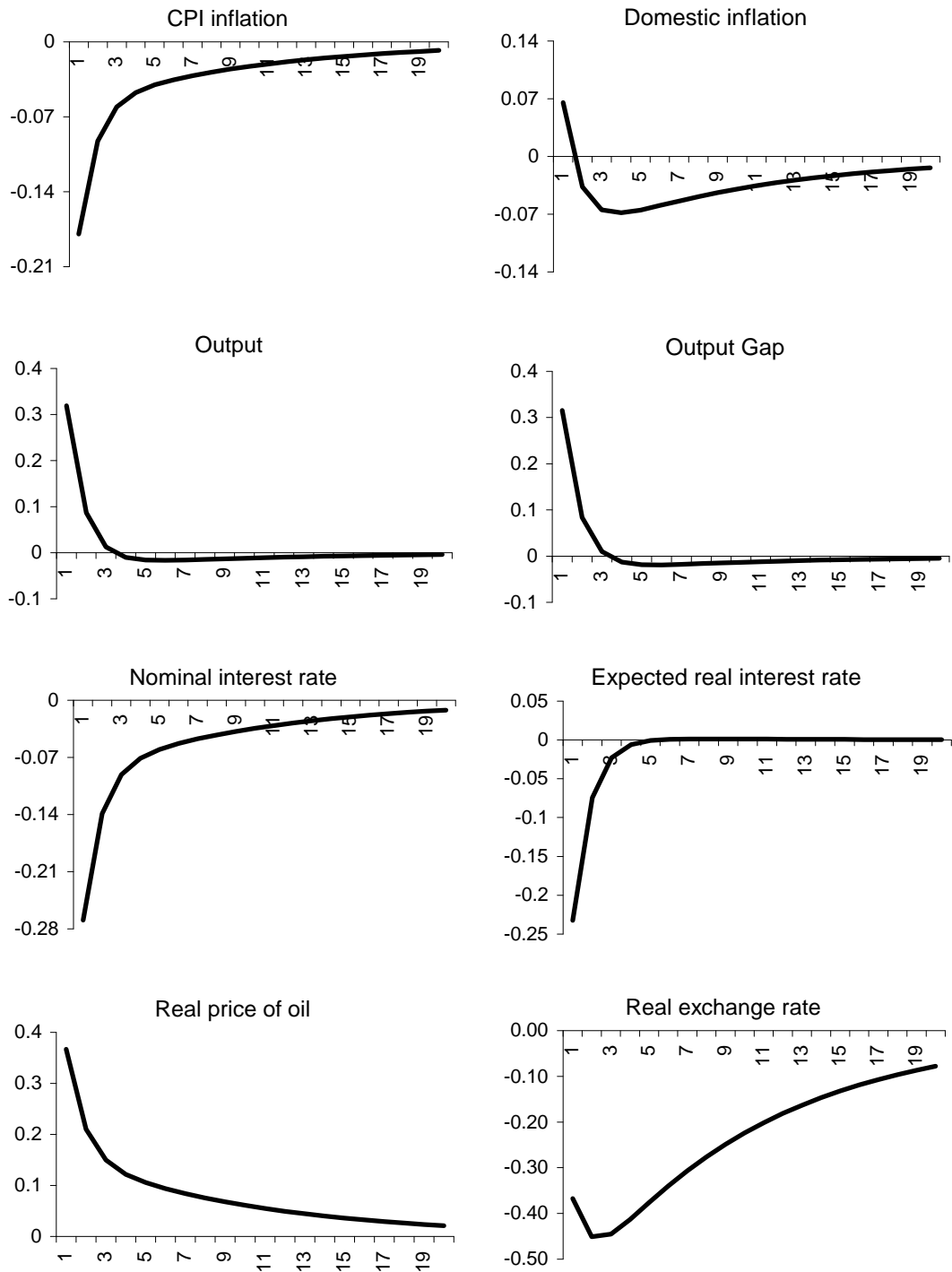




Figure 5. Monetary Policy and a 10% Negative Oil Supply Shock

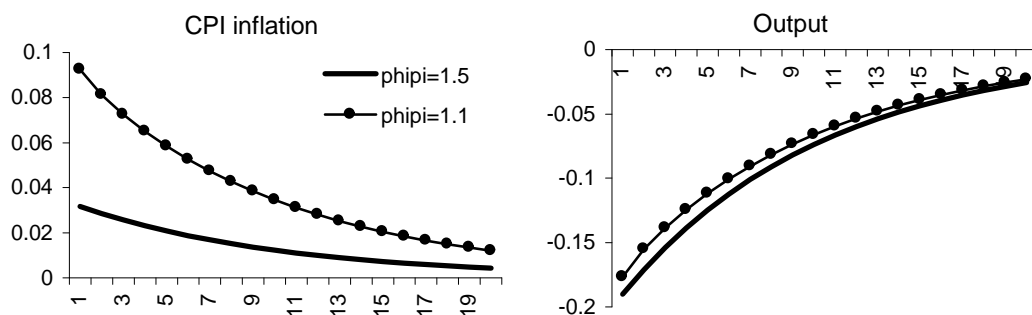


Figure 6. Monetary Policy and a 1% ROW Productivity Shock

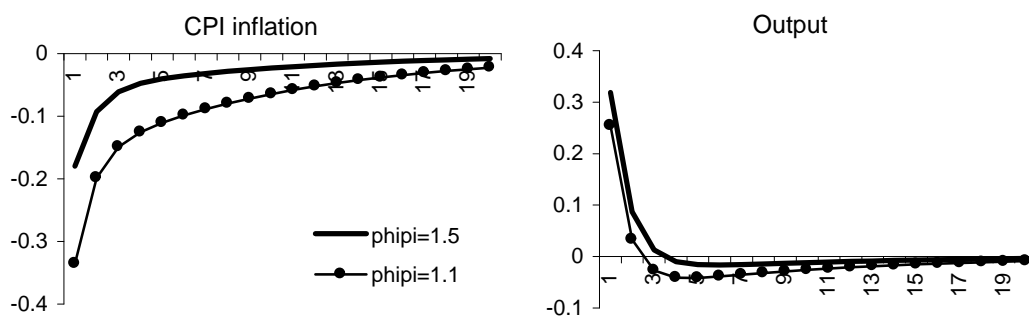


Figure 7. Degree of Openness and a 1% ROW Productivity Shock

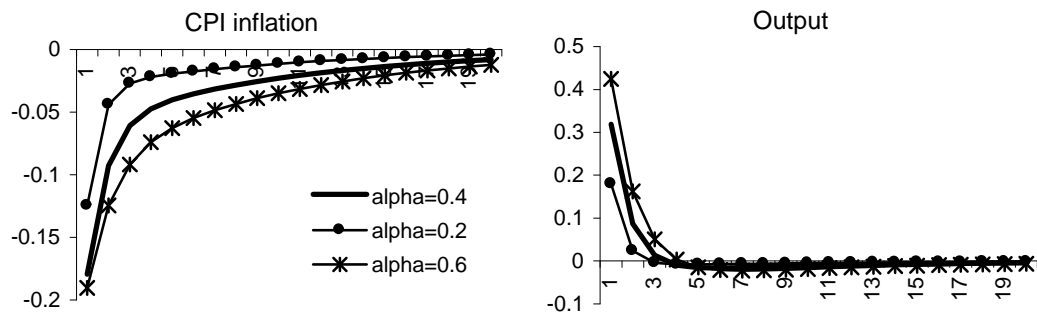


Figure 8. Oil Dependency and a 10% Negative Oil Supply Shock

