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Document de Travail
Working Paper
2011-39

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External Shocks and Monetary Policy in a Small Open Oil Exporting Economy

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September 29, 2011

Abstract

To investigate the dynamic effect of external shocks on an oil exporting economy, we estimate, using Bayesian approach, a DSGE model based on the features of the Algerian economy. The main purpose is to investigate the dynamic effect of four external shocks (oil price shock, USD/EUR exchange rate shock, international inflation shock and international interest rate shock) and to examine the appropriate monetary policy strategy for Algerian economy, given its structural characteristics and the pattern of the external shocks. We analyze the impulse response functions of our external shocks according to alternative monetary rules. The welfare cost associated with each monetary policy rule has been considered. Our main findings show that, over the period 1990Q1-2010Q4, core inflation monetary rule allows better to stabilize both output and inflation. This rule also appears to be the best way to improve a social welfare.

Keywords: Monetary policy, external shocks, oil exporting economy, Algeria, DSGE model.

JEL codes: E3, E5, F4.

1 Introduction

Emerging and developing economies are especially vulnerable to external shocks. Many channels explain such vulnerability. First of all, these countries remain dependent from

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economic activity in industrialized countries (the trade channel) and from international capital markets -including international banking activity- to finance their investment (the financial channel). In addition, despite a declining trend since the last decade, domestic prices in emerging and developing countries remain influenced by exchange rates fluctuations (the pass-through channel). Within this group of economies, oil exporting countries are even more exposed to these shocks. Indeed, oil exporting economies rely heavily on oil for their exports earnings, and their growth portrays a strong dependence for imports. As a consequence, they tend to have more volatile business cycle and are more crisis prone than other small-open economies. In this paper, we focus our attention on a specific oil exporter: Algeria. Relatively to other upper middle countries, Algeria is a relatively opened economy. In 2009, the exports of goods and services in terms of GDP amounted to 40.4 percent in Algeria while this ratio was 27.4 for upper middle countries (World dataBank website). Trade openness is higher: 76.5 percent in Algeria against 52.6 percent in upper middle income countries[1]. In addition, as reported by Dib (2008b), this country has features that may intensify its responsiveness to external disturbances: (i) a managed exchange rate regime in which the dollar is the currency peg; (ii) a very strong concentration of its exports (oil accounts for more than 95% of its exports) with prices denominated in the U.S. dollar and set in the world markets; (iii) imports whose the major part (65%) is invoiced in euro; (iv) a net debtor position vis-à-vis the rest of the world; (v) a relatively diversified currency composition of its foreign debt since at least 60% of this debt has been issued in currencies other than the U.S. dollar; and (vi) a current account position highly dependent on oil-price fluctuations.

Over the period 2000-2010, despite significant oil revenues, economic performances in Algeria have been far from impressive. On the one hand, the average real GDP change amounted to 3.6 percent, consistently below growth performances in MENA region (5.6 percent)[2]. Interestingly, the activity rebound in 2010-relatively to the trough of 2009- has been significantly below in Algeria relative to MENA countries (0.8 percentage points and 2.6 respectively). On the other hand, in the aftermath of the 1994 stabilization program, Algerian inflation rate converged towards inflation levels in MENA region. Inflation has been stabilized in Algeria insofar as its inflation performances are close to the ones in other MENA countries (3.1 percent and 3.4 respectively over the period 2000-2010)[3].

[1] If we consider the Middle East & North Africa (MENA) region as a whole, the exports of goods and services in percentage of GDP amounted to 41.4 in 2009 while the trade openness was 79.2 percent during the same year.

[2] For a sample included Egypt, Jordan, Kuwait, Lebanon, Libya, Morrocco, Oman, Qatar, Saudi Arabia, Tunisia, and United Arab Emirates. Data are extracted from IMF, World Economic Outlook Database, September 2011.

[3] IMF World Economic Outlook Database, September 2011.

Since 2006, despite a significant increase in the inflation rate -the consumption price index increased from 0.3 in 2006Q1 to 7.3 in 2008Q2 leading to a significant decrease in the inflation differential- Algeria remains one the best performers in MENA region. But this outcome is not striking if we take into account the unimpressive growth performance.

The previous structural characteristics of the Algerian economy and its economic performances raise the question of the appropriate monetary policy for this country. Focusing on the pattern of external shocks, it is the main purpose of this paper. To investigate the dynamic effect of external shocks, several studies have used econometric models, in particular VAR models, to decompose the direct effects of external shocks on output and other variables, from those generated by the endogenous monetary policy response as in Hamilton (1983); Bernanke *et al.* (1997); Hamilton and Herrera (2004), among others. All of these studies have investigated the effect of oil price shocks on output for the U.S. and the role played by the monetary policy. Other studies like Leduc and Sill (2001), Medina and Soto (2005) and Devereux *et al* (2006) have developed DSGE models to study the macroeconomic implications of alternative monetary policy rules, after external shocks, for a small open economy. Medina and Soto (2005) analyzed the effects of oil price shocks under alternative monetary policy rules. The authors developed and estimated a DSGE model by Bayesian methods for Chilean economy. The main results show that an increase in the real price of oil leads to a fall in output and an increase in inflation. The contractionary effect of the oil shock is mainly due to the endogenous tightening of the monetary policy. Devereux *et al.* (2006) compared alternative monetary policies for an emerging market economy that experienced external shocks to interest rates and terms of trade. They investigated, in particular, the importance of exchange rate flexibility in implementing such rules (a fixed exchange rate rule; and two types of inflation targeting rules). Their main finding is that degree of pass-through in import prices is crucial in determining the stabilization properties of an inflation targeting regime. Also, financial distortions amplify external shocks but have little impact on the ranking of alternative policy regimes.

We estimate, by using the Bayesian approach, a DSGE model for Algerian economy investigating the dynamic effect of four external shocks (oil price, real exchange rate, international interest rate and foreign inflation), and examining the appropriate monetary policy rule. To do so, we develop a Multisector Dynamic, Stochastic, General equilibrium (MDSGE) model with real and nominal rigidities. The aim is, first, to compare the importance of each shock as a source of fluctuations of the Algerian economy and their welfare implications and secondly, to define the appropriate monetary policy rule that insulates the economy from the impacts of these shocks. Our model is different from the previous literature in many aspects. First, given that in several oil exporting countries, government aims to smooth oil price changes, we assume that the domestic oil price is defined by a convex combination of the current world price expressed in local currency and the last period's domestic price. This rule allows us to replicate the subsidy of oil price that is a common practice in Algeria. Second, in our model there are two exchange rates: US dollar/Algerian dinar and the euro/US dollar real exchange rates. The first exchange rate is the exports' currency and the second represents a part of the imports' currency. Third, our model is a small open oil exporting economy model for a number of reasons: (i) the model is a multisector DSGE model with an oil sector; (ii) oil resource is used in the production function of the oil firm; (iii) the refined oil is used as an input in non-oil production, and (iv) oil price is subsidized.

In addition to these features, prices are sticky in the non-oil and import sectors. This allows monetary policy to play a role in our model. Indeed, this assumption is crucial in order to investigate the role of monetary policy in a DSGE model. We consider three alternative monetary policy rules: a fixed exchange rate rule, an headline inflation targeting rule, and a core inflation targeting rule. We adopt these rules for two main reasons: (i) they describe the conduct of monetary policy in a large number of developing and emerging market economies; and (ii) in the oil exporting economy, the presence of the oil component in headline CPI inflation engenders the question whether the measure of inflation in Algeria should be the headline inflation or the core inflation. In other words, does monetary policy in Algeria react to the headline inflation or the core inflation?

Our main findings show that, over the period 1990Q1-2010Q4, core inflation monetary rule allows better to stabilize both output and inflation. This rule also appears to be the best way to improve a social welfare.

The rest of the paper is organized as follows. In section 2 we present the details of the model. Section 3 discusses the parameters calibration, data and priors. Section 4 presents the estimation results. Section 5 measures the welfare effect of the external shocks under alternative monetary policy rules. Section 6 concludes.

2 The model

In this section we model an oil exporting economy based on the features of the Algerian economy. To do so, we assume that the economy is inhabited by seven agents: household, oil producing firm, non-oil goods producers, intermediate foreign goods import, final good producer, a central bank and a government.

The household has access to international financial markets where it can buy or sell foreign non-state contingent bonds. In oil sector, there is a single perfectly competitive firm producing oil output, while in the non-oil goods and imports sectors, there are a continuum of monopolistically-competitive firms. This firms set their prices à la Calvo (1983) and Yun (1996). As to the final good producer, it operates under perfect competition.

It is assumed that the central bank adjusts the short-term nominal interest rate in response to fluctuations in inflation in the non-oil goods sector (core inflation), CPI inflation, and nominal exchange rate, using Taylor-type monetary policy rule. The government is considered as the owner of the oil firm.

2.1 Household

The representative household derives utility from consumption c_t and leisure $(1-h_t)$.The preference of household is described by the following expected utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \ U\left(c_t, h_t\right), \tag{1}$$

where β denotes the subjective discount factor $(0 < \beta < 1)$.We assume that, $u\left(.\right)$, the instantaneous utility function, is specified by:

$$u\left(.\right) = \frac{c_t^{1-\gamma}}{1-\gamma} - \frac{h_t^{1+\sigma}}{1+\sigma}, \tag{2}$$

where the preference parameters γ and σ are strictly positive. The first parameter, γ, is the inverse of the elasticity of intertemporal substitution of consumption and the second parameter, σ, denotes the inverse of the wage elasticity of labor supply. The single utility function, $u(.)$, is supposed to be strictly concave, strictly increasing in c_t and strictly decreasing in h_t.We also assume that h_t is defined by the following Cobb-Douglas technology:

$$h_t = h_{o,t}^{\alpha_{ho}} h_{no,t}^{\alpha_{hno}}, \tag{3}$$

where $h_{o,t}$ and $h_{no,t}$ represent hours worked by the household at time t in oil and non-oil sectors respectively. The parameters α_{ho} and α_{hno} denote the labor elasticity of substitution in the oil and non-oil sectors respectively, where $\alpha_{ho} + \alpha_{hno} = 1$.

The representative household has access to domestic and international financial markets. It enters in period t with holdings of domestic bonds denominated in units domestic currency (Algerian dinar), B_{t-1}^d, and foreign non-state contingent bonds, B_{t-1}^f, denominated in foreign currency.

During period t, the household pays a lump-sum tax, ϖ, to finance government spending and sell or buy, B_t^f, at a price that depends on a country specific risk premium and the international interest rate $\left(R_t^f \kappa_t\right)^{-1}$. In other words, buying foreign bonds entails paying a risk premium, κ_t, whose the functional form is given by:

$$\kappa_t = \exp\left(-\phi \frac{e_t \xi_t \widetilde{B_t^f}/P_t^f}{P_t Y_t}\right), \tag{4}$$

where ϕ denotes the parameter measuring the risk premium, e_t and ξ_t are two exchange rates[4]: the US dollar/ Algerian dinar (USD/DZD hereafter) and the euro/US dollar (EUR/USD hereafter) respectively and $\widetilde{B_t^f}$ is the average nominal stock of external debt which takes either a positive value if the domestic economy is a net borrower or negative value if the domestic economy is a net lender[5]. In our case, we assume that $B_t^f < 0$ to the extent that the Algerian economy is net borrower. Note finally that Y_t is the total real GDP and P_t^f is the foreign price index. By following this functional form, the model would not have a unit root because the holding bond would not follow a random walk[6]. The risk premium also ensures that the model has a unique steady state.

The representative household, in period t, earns nominal wages, $W_{o,t}$ and $W_{no,t}$ for their labor supply, respectively in the oil and non-oil sectors. It also receives dividend payments from both non-oil, $D_{no,t}$,and import, $D_{I,t}$,sectors so that $D_t = D_{no,t} + D_{I,t}$.

At last, the household accumulates $k_{o,t}$ and $k_{no,t}$ units of capital stocks, used in the oil and non-oil sectors for nominal rental $Q_{o,t}$ and $Q_{no,t}$ respectively. The evolution of capital stock in each sector is given by:

$$k_{j,t+1} = (1-\delta)k_{j,t} + i_{j,t} - \Psi_j\left(k_{j,t+1}, k_{j,t}\right), for j = o, no \tag{5}$$

where δ is the common depreciation rate to all sectors $(0 < \delta < 1)$ and $\Psi_{j,t}(k_{j,t+1}, k_{j,t})$ is capital-adjustment cost paid by household and satisfy $\psi_j(0) = 0, \psi_j^{'}(.) > 0$ and $\psi_j^{''}(.) < 0$.The functional form of $\Psi_j(.)$ is given, following Ireland (2003), by:

[4] As in Dib (2008b), we consider the euro as an invoicing currency of a part of imports.

[5] If the domestic economy is a net lender households receive a lower remuneration on their saving. If the economy is a net lender, households charge a premium on the foreign interest rate.

[6] See Schmitt-Grohé and Uribe (2003) for alternative ways of ensuring stationary paths in small open economy.

$$\Psi_{j,t}(.) = \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right)^2 k_{j,t}, \tag{6}$$

for j=o,no

The presence of the capital adjustment cost implies that, out of the steady state, the price of newly installed capital differs from the price of investment goods. In other words, the Tobin's Q is different from 1. This form allows to have both total and marginal costs of adjusting capital equal to zero in the steady state equilibrium.

The expenditure and revenues presented above give the following household's budget constraint:

$$P_t(c_t + i_t) + \frac{B_t^d}{R_t} + \frac{e_t \xi_t B_t^f}{R_t^f \kappa_t} \preceq B_{t-1}^d + e_t \xi_t B_{t-1}^f + \sum_{j=o,no} Q_{j,t} k_{j,t}$$
$$+ (1-\varpi) \sum_{j=o,no} W_{j,t} h_{j,t} + D_t, \tag{7}$$

for j=o, no

where $P_t i_t = P_{o,t} i_{o,t} + P_{no,t} i_{no,t}$ is total investment in the oil and non-oil sectors respectively, and P_t is the consumption price index (CPI) that will be define bellow.

Given initial value, the representative household chooses $\{c_t$, $k_{o,t+1}$, $k_{no,t+1}$, B_t^d and $B_t^f\}$ to maximize its lifetime utility function subject to capital accumulation equation, the budget constraint and the no-Ponzi game restriction.

The solution gives the following first order conditions:

$$\lambda_t = c_t^{-\gamma}, \tag{8}$$

$$\lambda_t = \alpha_{hj} \frac{h_t^{1+\sigma}}{h_{j,t}(1-\varpi) w_{j,t}}, \tag{9}$$

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)\frac{k_{j,t+2}}{k_{j,t+1}} - \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right)^2 + q_{j,t+1} + 1 - \delta\right)\right]}{\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right) + 1}, \tag{10}$$

$$\lambda_t = \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right) R_t, \tag{11}$$

$$\frac{\lambda_t s_t \Xi_t}{R_t^f \kappa_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1} \Xi_{t+1}}{\pi_{t+1}^f} \right), \tag{12}$$

for j=*o, no*

where $q_{j,t} = \frac{Q_{j,t}}{P_t}, \pi_{t+1} = \frac{P_{t+1}}{P_t}, \pi_{t+1}^f = \frac{P_{t+1}^f}{P_t^f}$, $s_t = e_t \frac{P_t^f}{P_t}$ and $\Xi_t = \xi_t \frac{\widetilde{P}_t^f}{P_t^f}$ represent the real capital return in each sector, the CPI inflation rate, the world inflation rate, the USD/DZD real exchange rate and the EUR/USD real exchange rate respectively with P_t^f and $\widetilde{P}_t^f$ denoting the foreign GDP deflator expressed in U.S dollar and euro respectively. Also λ_t denotes the budget multiplier associated with the budget constraint.

By combining equations (11) and (12) we obtain equation (13) which represents the uncovered interest rate parity (UIP) condition:

$$\frac{R_t}{R_t^f \kappa_t} = \frac{s_{t+1} \Xi_{t+1} \pi_{t+1}}{s_t \Xi_t \pi_{t+1}^f}, \tag{13}$$

Finally, note that variables R_t^f, π_t^f and ξ_t which represent respectively the foreign interest rate, the world inflation rate and the EUR/USD exchange rate evolve exogenously according to the following AR(1) process:

$$\log(R_t^f) = (1 - \rho_{R^f}) \log(R^f) + \rho_{R^f} \log(R_{t-1}^f) + \varepsilon_{R^f,t} \tag{14}$$

$$\log(\pi_t^f) = (1 - \rho_{\pi^f}) \log(\pi^f) + \rho_{\pi^f} \log(\pi_{t-1}^f) + \varepsilon_{\pi^f,t} \tag{15}$$

$$\log(\xi_t) = (1 - \rho_\xi) \log(\xi) + \rho_\xi \log(\xi_{t-1}) + \varepsilon_{\xi,t} \tag{16}$$

where R^f, π^f and ξ are steady state values of R_t^f, π_t^f, and ξ_t. ρ_{R^f}, ρ_{π^f} and ρ_ξ are the autocorrelation coefficients, and $\varepsilon_{R^f,t}$, $\varepsilon_{\pi^f,t}$ and $\varepsilon_{\xi,t}$ are uncorrelated and normally distributed innovations with zero mean and standard deviations σ_{R^f}, σ_{π^f} and σ_ξ respectively.

2.2 Oil sector

To model oil production, we assume that oil firm operating in perfect competition uses technology, $A_{o,t}$,capital, $k_{o,t}$, labor, $h_{o,t}$, and oil factor, O_t, for the crude oil production. Oil output is totally exported abroad at the international price $P_{o,t}^f$ denominated in the US dollar.

Firms seeking to maximize profit should solve the following maximization problem:

$$\max_{k_{o,t},h_{o,t},O_t} \left[e_t P^f_{o,t} Y_{o,t} - Q_{o,t}k_{o,t} - W_{o,t}h_{o,t} - P_{O,t}O_t\right], \tag{17}$$

where $e_t P^f_{o,t} Y_{o,t}$ is an oil producer's revenues in terms of domestic currency.

To resolve (17), firms must consider their function of production given by the following Cobb-Douglas technology:

$$Y_{o,t} \preceq A_{o,t} k^{\alpha_o}_{o,t} h^{\beta_o}_{o,t} O^{\theta_o}_t, \tag{18}$$

where α_o, β_o and $\theta_o \in (0,1)$ and $\alpha_o+\beta_o+\theta_o = 1$. These coefficients denote respectively shares of capital, $k_{o,t}$, labor, $h_{o,t}$ and oil resource, O_t, in the production of oil.

Thus, given $e_t, P^f_{o,t}, Q_{o,t}, W_{o,t}$ and $P_{O,t}$,the oil producing firm chooses $\{k_{o,t},h_{o,t},O_t\}$ to maximize (17) subject to (18).

The first order conditions are:

$$q_{o,t} = \alpha_o s_t p^f_{o,t} \frac{Y_{o,t}}{k_{o,t}}, \tag{19}$$

$$w_{o,t} = \beta_o s_t p^f_{o,t} \frac{Y_{o,t}}{h_{o,t}}, \tag{20}$$

$$p_{O,t} = \theta_o s_t p^f_{o,t} \frac{Y_{o,t}}{O_t}, \tag{21}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p^f_{o,t} = \frac{P^f_{o,t}}{P_t}$ and $p_{O,t} = \frac{P_{O,t}}{P_t}$ denote respectively the real capital return, the real wage, the real oil price and the real price of the oil resource.

The equations (19)-(21) represent the demand for $k_{o,t}, h_{o,t}$ and O_t respectively. These results can be interpreted as the optimal choices of input that maximize oil producer's profit whose the value is equal to zero because of the perfect competition's assumption and the constant-return-to-scale production function.

Note, finally, that foreign oil's price, $P^f_{o,t}$, oil resource, O_t, and technology shock, $A_{o,t}$, evolutions are given by the following stochastic process:

$$\log(P^f_{o,t}) = (1-\rho_{P^f_o})\log(P^f_o) + \rho_{P^f_o}\log(P^f_{o,t-1}) + \varepsilon_{P^f_o,t}, \tag{22}$$

$$\log(O_t) = (1-\rho_O)\log(O) + \rho_O \log(O_{t-1}) + \varepsilon_{O,t}, \tag{23}$$

$$\log(A_{o,t}) = (1 - \rho_{A_o})\log(A_o) + \rho_{A_o}\log(A_{o,t-1}) + \varepsilon_{A_{o,t}}, \tag{24}$$

where P_o^f, O and A_o are steady state values of $P_{o,t}^f$, O_t and $A_{o,t}$. $\rho_{P_o^f}$, ρ_O and ρ_{A_o} are the autocorrelation coefficients, and $\varepsilon_{P_o^f,t}$, $\varepsilon_{O,t}$ and $\varepsilon_{A_{o,t}}$ are uncorrelated and normally distributed innovations with zero mean and standard deviations $\sigma_{P_o^f}, \sigma_O$ and σ_{A_o} respectively.

2.3 Non-oil sector

In this sector, we assume that the non-oil producers operate under monopolistic competition. Under this assumption, it's assumed that there is a continuum of firms indexed by $i \in (0,1)$. Each firm i, produces non-oil goods using the following production function:

$$Y_{no,t}(i) \preceq A_{no,t} k_{no,t}^{\alpha_{no}}(i)\, h_{no,t}^{\beta_{no}}(i)\, Y_{o,t}^{I^{\theta_{no}}}(i), \tag{25}$$

where $k_{no,t}(i), h_{no,t}(i)$ and $Y_{o,t}^I(i)$ are used by firms to produce the non-oil goods. $A_{no,t}$ is a technology shock specific to the non-oil sector. This shock follows the stochastic process given by:

$$\log(A_{no,t}) = (1 - \rho_{A_{no}})\log(A_{no}) + \rho_{A_{no}}\log(A_{no,t-1}) + \varepsilon_{A_{no,t}}, \tag{26}$$

Note also that α_{no}, β_{no} and $\theta_{no} \in (0,1)$ and $\alpha_{no} + \beta_{no} + \theta_{no} = 1$.These coefficients denote respectively a share of capital, $k_{no,t}$, labor, $h_{no,t}$ and refined oil, $Y_{o,t}^I$, used as an input in the production of non-oil goods.

To maximize its profit, the producer i chooses $\left\{K_{no,t}(i), h_{no,t}(i) \text{ and } Y_{o,t}^I(i)\right\}$ and sets its price, $\widetilde{P}_{no,t}(i)$ à la Calvo (1983) and Yun (1996). Following a stochastic time dependent rule of Calvo (1983), the producer faces, in each period, a constant probability of changing its price. This probability is given by $(1 - \phi_{no})$.Therefore, on average, the non-oil price remains unchanged for $\frac{1}{1-\phi_{no}}$ periods. As in Yun (1996), we assume that if non-oil goods producers are not able to change their price, they index them to the steady state CPI inflation rate according to the following rule:

$$P_{no,t} = \pi P_{no,t-1},$$

where π is the long run average gross rate of inflation.

The non-oil firms' maximization problem can be written as follow:

$$\max_{k_{no,t}(i),h_{no,t}(i),P_{no,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta\phi_{no})^s \lambda_{t+s} D_{no,t+s}(i)/P_{t+s}], \tag{27}$$

subject to (25) and the following demand function

$$Y_{no,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-\vartheta} Y_{no,t+s}, \tag{28}$$

where $D_{no,t+s}(i)$ is the profit function:

$$D_{no,t+s}(i) = \pi^s \widetilde{P}_{no,t}(i) Y_{no,t+s}(i) - Q_{no,t+s} k_{no,t+s}(i) - W_{no,t+s} h_{no,t+s}(i) - P_{o,t} Y^I_{o,t+s}(i),$$

with $(\beta^s \lambda_{t+s})$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$.

The first order conditions of the maximization problem are:

$$q_{no,t} = \alpha_{no} \frac{Y_{no,t}(i)}{k_{no,t}(i)} mc_{no,t}, \tag{29}$$

$$w_{no,t} = \beta_{no} \frac{Y_{no,t}(i)}{h_{no,t}(i)} mc_{no,t}, \tag{30}$$

$$p_{o,t} = \theta_{no} \frac{Y_{no,t}(i)}{Y^I_{o,t}(i)} mc_{no,t}, \tag{31}$$

where $q_{no,t} = \frac{Q_{no,t}}{P_t}$, $w_{no,t} = \frac{W_{no,t}}{P_t}$, $mc_{no,t} = \frac{MC_{no,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real domestic oil price.

The real marginal cost, $mc_{no,t}$, can be obtain by replacing Eqs. (29)-(31) in (25):

$$mc_{no,t} = \frac{q_{no,t}^{\alpha_{no}} w_{no,t}^{\beta_{no}} p_{o,t}^{\theta_{no}}}{\alpha_{no}^{\alpha_{no}} \beta_{no}^{\beta_{no}} \theta_{no}^{\theta_{no}}}. \tag{32}$$

The optimal pricing condition is given by the maximization of (27):

$$\widetilde{p}_{no,t}(i) = \left(\frac{\vartheta}{\vartheta - 1} \right) \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} mc_{no,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{33}$$

where $p_{no,t+s} = \frac{P_{no,t+s}}{P_{t+s}}, mc_{no,t+s} = \frac{MC_{no,t+s}}{P_{t+s}}, \widetilde{p}_{no,t}(i) = \frac{\widetilde{P}_{no,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ denote respectively the relative price of non-oil goods, the real marginal cost in non-oil sector, the real optimized price for non-oil goods and the CPI inflation rate.

The aggregate nominal non-oil price index evolves according to the following recursive form:

$$(P_{no,t})^{1-\vartheta} = \phi_{no} (\pi P_{no,t-1})^{1-\vartheta} + (1-\phi_{no}) \left(\widetilde{P}_{no,t}\right)^{1-\vartheta}, \tag{34}$$

Dividing (34) by P_t yields the following real non-tradable price index:

$$(p_{no,t})^{1-\vartheta} = \phi_{no} \left(\pi \frac{p_{no,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_{no}) (\widetilde{p}_{no,t})^{1-\vartheta}. \tag{35}$$

2.4 Import sector

The final good producer uses, for its production needs, an imported composite good, $Y_{I,t}$, purchased in a domestic monopolistically competitive market. To produce $Y_{I,t}$, the firm uses differentiated goods, $Y_{I,t}(i)$, that are produced by a continuum of domestic importers, indexed by $i \in (0,1)$, using a homogeneous intermediate good produced abroad and imported for the world price P_t^f. A part μ of these imported goods is denominated in euro, while another part $(1-\mu)$ is invoiced in U.S dollar. The differentiated goods are sold at price $P_{I,t}(i)$ which is supposed to be sticky *à la* Calvo (1983) and Yun (1996). Therefore, the importer faces, in each period, a constant probability, $(1-\phi_I)$, of changing its price as in Calvo (1983). Following Yun (1996), we assume that if importers are not able to change their price, they index them to the steady state CPI inflation rate.

The maximization problem of importers can be written as follows:

$$\max_{\widetilde{P}_{I,t}(i)} E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} \left(\pi^s \widetilde{P}_{I,t}(i) - e_{t+s} (\mu + (1-\mu)\xi_t) P_{t+s}^f\right) Y_{I,t+s}(i), \tag{36}$$

where $Y_{I,t+s}(i)$ is chosen by firms to maximize their profit:

$$Y_{I,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{I,t}(i)}{P_{I,t+s}}\right)^{-\vartheta} Y_{I,t+s}, \tag{37}$$

The zero profit condition gives the importer price index:

$$P_{I,t+s} = \left(\int_0^1 \pi^s \widetilde{P}_{I,t}\left(i\right)^{1-\vartheta} di \right)^{\frac{1}{1-\vartheta}}, \tag{38}$$

replacing (37) in (36) and following the same steps than for the non-oil sector, we get the optimal pricing condition given by:

$$\widetilde{p}_{I,t}\left(i\right) = \frac{\vartheta}{\vartheta-1} \frac{E_0 \sum_{s=0}^{\infty} \left(\beta\phi_I\right)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} mc_{I,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} \left(\beta\phi_I\right)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{39}$$

where $p_{I,t+s} = \frac{P_{I,t+s}}{P_{t+s}}$ is the relative price of imports, $mc_{I,t+s} = s_{t+s}\left(\mu + \left(1-\mu\right)\Xi_t\right)$ is the real marginal cost, $\widetilde{p}_{I,t}\left(i\right) = \frac{\widetilde{P}_{I,t}(i)}{p_t}$ is the optimized price in import sector and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ is the CPI inflation rate.

The aggregate nominal import price index evolves according to the following recursive form:

$$\left(P_{I,t}\right)^{1-\vartheta} = \phi_I \left(\pi P_{I,t-1}\right)^{1-\vartheta} + \left(1-\phi_I\right)\left(\widetilde{P}_{nT,t}\right)^{1-\vartheta}, \tag{40}$$

Dividing (40) by P_t yields the following real import price index:

$$\left(p_{I,t}\right)^{1-\vartheta} = \phi_I \left(\pi \frac{p_{I,t-1}}{\pi_t}\right)^{1-\vartheta} + \left(1-\phi_I\right)\left(\widetilde{p}_{I,t}\right)^{1-\vartheta}. \tag{41}$$

2.5 Final good producer

We assume that the producer of final good operates under perfect competition. It uses the following CES technology that includes non-oil output, $Y_{no,t}$, which is domestically-produced, and imports, $Y_{I,t}$:

$$z_t = \left[\chi_{no}^{\frac{1}{\tau}} Y_{no}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}} Y_I^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}}, \tag{42}$$

where $\tau > 0$ denotes the elasticity of substitution between non-oil output and imported goods and χ_{no}, χ_I represent respectively the share of non-oil and imported goods in the final good, where $\chi_{no} + \chi_I = 1$. To maximize its profit, the final good producer chooses $\{Y_{I,t} \text{ and } Y_{no,t}\}$.

Resolving this problem, we get the following demand function:

$$Y_{I,t} = \chi_I \left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t, \quad \text{and} \;\; Y_{no,t} = \chi_{no} \left(\frac{P_{no,t}}{P_t}\right)^{-\tau} z_t, \tag{43}$$

where $P_t, P_{I,t}, P_{no,t}$ are given. Note also that the zero profit condition implies that the price of final good is given by:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_{no} P_{no,t}^{1-\tau}\right]^{\frac{1}{1-\tau}}. \tag{44}$$

Note finally that the final good is divided between total consumption and total investment so that $z_t = c_t + i_{o,t} + i_{no,t}$.

2.6 Monetary policy

We assume that the central bank adjusts the short-term nominal interest rate, i_t, in response to fluctuation in inflation in the non-oil goods sector (core inflation), $\pi_{no,t}$, CPI inflation, π_t, and exchange rate, Δe_t according to the following Taylor-type monetary policy rule:

$$\frac{(1+R_{t+1})}{(1+\overline{R})} = \left(\frac{P_{no,t}}{P_{no,t-1}} \frac{1}{\overline{\pi}_{no}}\right)^{\mu_{\pi no}} \left(\frac{P_t}{P_{t-1}} \frac{1}{\overline{\pi}}\right)^{\mu_\pi} \left(\frac{\Delta e_t}{\Delta \overline{e}}\right)^{\mu_e} \exp(\varepsilon_R), \tag{45}$$

where $\overline{R}, \overline{\pi}_{no}, \overline{\pi}$, and $\Delta\overline{e}$ are the steady state values of $R_t, \pi_{no,t}, \pi_t$,and Δe_t. The policy coefficient, $\mu_{\pi_{no}}, \mu_\pi$,and μ_e measuring central bank response to deviation of $\pi_{no,t}, \pi_t$,and Δe_t from their steady state levels.

When the central bank adopts a CPI inflation targeting regime (IT rule), $\mu_{\pi_{no}} = \mu_e = 0$ and $\mu_\pi \to \infty$. In this case, the central bank only responds to inflation movement. When $\mu_\pi = \mu_e = 0$ and $\mu_{\pi_{no}} \to \infty$, the central bank controls the inflation rate in the non-oil goods sector (CIT rule). Finally, when $\mu_\pi = \mu_{\pi_{no}} = 0$ and $\mu_e \to \infty$, the central bank strictly target the nominal exchange rate (ER rule).The serially uncorrelated monetary policy shock, ε_R, is normally distributed with zero mean and standard deviation σ_R.

2.7 Government

In an oil exporting economy[7], the oil domestically used (refined oil), $Y_{o,t}^I$, is produced abroad. As a result, we assume that government, which is the owner of the oil firm, buys it from the world market for the international price, $P_{o,t}^f$, denominated in the foreign currency.

[7] It's the case of Algeria and other countries as Iran.

The refined oil is sold domestically to the non-oil firms at price $P_{o,t}$ which can be considered as the domestic fuel price. The latter is supposed to be subsidized by the government. For this purpose, we assume according to Bouakez *et al.* (2008) and Benkhodja (2011), that the domestic oil price, $P_{o,t}$ is given by a convex combination of the current world price,$P^f_{o,t}$, expressed in local currency and last period's domestic price. It follows the following functional form:

$$P_{o,t} = (1 - \upsilon)P_{o,t-1} + \upsilon e_t \xi_t P^f_{o,t}, \tag{46}$$

where $\upsilon \in (0, 1)$, and $P^f_{o,t}$ denotes the world price of oil that is determined in the world market and denominated in the foreign currency.

Following the oil price rule, when $\upsilon = 1$, there is no subsidy and the pass-through from the world oil price is complete. However, when $\upsilon = 0$, this means that the domestic oil price is fully subsidized and there is no pass-through. Thus, all domestic firms will buy the oil at a price $P_{o,t}$.

Finally, the government's budget constraint is given by:

$$\varpi \sum_{j=o,T,nT} W_{j,t} h_{j,t} + s_t p^f_{o,t} Y_{o,t} = \left(s_t \Xi_t p^f_{o,t} - p_{o,t} \right) Y^I_{o,t} + w_{o,t} h_{o,t} + q_{o,t} k_{o,t}, \tag{47}$$

where the left hand side represents the government's revenue that includes a lump-sum tax, ϖ, and receipts from selling oil $\left(s_t p^f_{o,t} Y_{o,t} \right)$. The right hand side represents the government spending that include payment both wages and capital return $(w_{o,t} h_{o,t} + q_{o,t} k_{o,t})$ in the oil sector and the amount of oil's subsidies$\left(s_t \Xi_t p^f_{o,t} - p_{o,t} \right) Y^I_{o,t}$.

2.8 Aggregation and Equilibrium

In a symmetric equilibrium, all importers and non-oil goods producers make the same decision so that: $Y_{no,t}(i) = Y_{no,t}$, $Y^I_{o,t}(i) = Y^I_{o,t}$, $\widetilde{p}_{no,t}(i) = \widetilde{p}_{no,t}$, $Y_{I,t}(i) = Y_{I,t}$, $\widetilde{p}_{I,t}(i) = \widetilde{p}_{I,t}$ for all $i \in (0, 1)$ .Thus, a symmetric equilibrium for this economy is composed of an allocation $\{c_t,\ i_t,\ i_{o,t},\ i_{no,t},\ Y_{o,t},\ Y_{no,t},\ Y^{va}_{no,t},\ Y^I_{o,t},\ Y_{I,t},\ Y_t,\ z_t,\ k_{o,t},\ k_{no,t},\ h_t,\ h_{o,t},\ h_{no,t},\ b^f_t, \kappa_t\}^\infty_{t=0}$ and a sequence of prices and co-state variables $\{w_{o,t},\ w_{no,t},\ q_{o,t},\ q_{no,t},\ p_{o,t},\ p_{no,t},\ \widetilde{p}_{no,t},\ \widetilde{p}_{I,t},\ p_{I,t},\ p_{O,t},\ \pi_t,\ \pi_{no,t},\ \pi_{I,t},\ s_t,\ e_t,\ R_t,\ \lambda_t,\ mc_{no,t},\ mc_{I,t}\}^\infty_{t=0}$ satisfying household, oil and non-oil first order conditions, the aggregate resources constraints, the monetary policy rules, the current account equation and the stochastic processes $\{A_{o,t}, A_{no,t}, p^f_{o,t}, O_t,\ \xi_t,\ R^f_t,\ \pi^f_t\}^\infty_{t=0}$ of the shocks and the following market clearing conditions $b_t = b_{t-1} = 0$, $b^f_t = \widetilde{b}^f_t$ and:

$$Y_t = p_{no,t} Y_{no,t}^{va} + s_t p_{o,t}^f Y_{o,t}, \tag{48}$$

where Y_t, and $Y_{no,t}^{va}$ are the aggregate GDP and value-added output in non-oil goods sector respectively. The variable, $Y_{no,t}^{va}$, is constructed by subtracting oil input as follow[8]:

$$Y_{no,t}^{va} = Y_{no,t} - s_t p_{o,t}^f \frac{Y_{o,t}^T}{p_{no,t}}, \tag{49}$$

Combining the households' budget constraint, the single period profit functions of non-oil goods producing firms and foreign good importers and the first order conditions of the three sectors and applying the market clearing conditions yields the following current account equation:

$$\frac{b_t^f}{\kappa_t R_t^f} = \frac{b_{t-1}^f}{\pi_t^f} + p_{o,t}^f Y_{o,t}/\Xi_t - p_{o,t}^f Y_{o,t}^I - (\mu + (1-\mu)\,\Xi_t)\, Y_{I,t}/\Xi_t. \tag{50}$$

3 Model estimation

In this section, we estimate the model by using the Bayesian method. To do so, we will describe the methodology to use, data and prior distributions.

3.1 Calibration, data and priors

The model is estimated by using the Bayesian method as in Sungbae and Schorfheide (2007), Fernández-Villaverde (2010) and Del Negro and Schorfheide (2008, 2010).

There are 30 parameters to be estimated gathered in Θ=$\{\phi_{no}$, ϕ_I, ψ_o, ψ_{no}, ϑ, χ_I, χ_{no}, α_o, β_o, θ_o, α_{no}, β_{no}, θ_{no}, $\mu_{\pi_{no}}$, μ_π, μ_e, ρ_{R^f}, ρ_{a_o}, $\rho_{a_{no}}$, ρ_{π^f}, $\rho_{p_o^f}$, ρ_O, ρ_ξ, σ_{R^f}, σ_{a_o}, $\sigma_{a_{no}}$, σ_{π^f}, $\sigma_{p_o^f}$, σ_O, $\sigma_\xi\}$.

The rest of the parameters are calibrated, as commonly done in the DSGE literature. This procedure helps to cope with the problem of identification from which DSGE models commonly suffer, arising from the fact that the data used in the estimation may contain little information about some parameters.

As in Almeida (2009), the parameters we chose to calibrate pertain mostly to three aspects: (i) those crucial to determine the steady-state; (ii) those for which we have

[8] As in Dib (2008a and b), our model supposes that non-oil firms use refined oil as material inputs in their productions which is defined as gross output. Thus, value added output in each sector can be constructed by substracting commodity inputs.

Table 1: Calibration of structural parameters

Description	Parameters	Values
Structural Parameters		
Subject discount factor	β	0.99
The inverse of the elasticity of intertemporal substitution of consumption	γ	2
The inverse of the Frish wage elasticity of labour supply	σ	1
Parameter measuring the risk premium	ϕ	0.0015
The depreciation rate of capital	δ	0.025
Lump-sum tax parameter	ϖ	0.2
Price elasticity of demand for imported and non-oil goods	τ	0.8
Share of import invoiced in the US dollar	μ	0.3
Oil price rule parameter	υ	0.3
Labor elasticity of substitution in the oil sector	α_{ho}	0.31
Labor elasticity of substitution in the non-oil sector	α_{hno}	0.69
Steady state values		
Gross steady-state domestic inflation rate	π	1.101
Gross steady-state foreign inflation rate	π^f	1.023
Steady state domestic interest rate	R	1.134
Steady state foreign interest rate	R^f	1.040

reliable estimations from other sources; and (iii) those whose values are crucial to replicate the main steady-state key ratios of the Algerian economy[9]. Table 1 reports the calibration values.

The subjective discount factor, β, is set at $0,99$ which implies an annual steady state real interest rate of 4%. As in Bouakez *et al.* (2008) and Dib (2008a) the curvature parameter in the utility function, γ, is set at 2 implying an elasticity of intertemporal substitution of consumption of 0.5. Following Devereux *et al.* (2006) among others, the inverse of the elasticity of the intertemporal substitution of labor, σ, is set at 1. The capital depreciation rate, δ, is set at $0,025$. This value is common to the two sectors of production (oil and non-oil sectors).

The price elasticity of demand for imported, and non-oil goods, τ, is set at 0,8 as in Dib (2008a). Lump-sum tax parameter, ϖ, and the share of import invoiced in the US dollar, μ, are set at 0.2 and 0.35 respectively. Indeed, following the annual economic reports of the Bank of Algeria (2009), the share of Algerian imports from the Euro Area is about 65% of total imports. Finally, we set values of the labor elasticity of substitution to match the shares of wages in the two sectors of Algerian economy (oil and non-tradable), so that, α_{h_o} and $\alpha_{h_{no}}$ are equal to $0,31$ and 0.69 respectively.

The steady-state of gross inflation and nominal interest rates, π, π^f, R, and R^f are

[9] To compute the Algerian economy steady state ratios, we use annual data, over the period 1990-2010.

set equal to 1.101, 1.023, 1.134, and 1.040, respectively. These values are the annual observed averages in the data of the Algerian and Euro Area economies for the period $1990-2010$. The parameter in the risk-premium terms, ϕ, is set equal to 0.0015 implying an annual risk premium of 1.35% (135 basis points). This value is consistent with the average interest rates differential between Algeria and the Euro Area, and implies a steady-state foreign-debt-to-GDP ratio of 30%, which is close to that observed average ratio in the data.

To estimate the model, we use seven series of quarterly Algerian and US data from 1990-Q1 to 2010-Q4: oil production, consumption, domestic inflation, the domestic real interest rate, USD/DZD real exchange rate, domestic GDP and real oil price. The oil price is the international price of WTI oil. The domestic interest rate is the discount rate computed by the Bank of Algeria to manage its monetary policy. All of these variables are deflated by an index of prices for the Algerian economy.

The model implies that all variables are stationary and fluctuate around constant means, but the series used in the estimation are non-stationary. Thus, to render them stationary, we applied an HP-filter and used the detrended series instead of the original ones.

To reflect our beliefs about structural parameters, we specify prior distributions for the entire vector Θ. As studies on the Algerian economy are unavailable, we choose priors based on evidence from previous studies for oil exporting economies (like Medina and Soto (2005) and Dib (2008a)). These priors are summarized in Table 2.

We assume Beta distribution for those parameters that must lie in the [0 1] interval. This applies to the persistence parameters of the exogenous stochastic processes which are assumed to follow a beta distribution with a mean of 0.65 and a standard deviation of 0.03. The Beta distribution is also assigned to the parameters of price stickiness with a mean of 0.67 that corresponds to changing price every 3 quarters on average. We also assume that the mean of parameters $(\alpha_o, \beta_o, \theta_o)$ and $(\alpha_{no}, \beta_{no}, \theta_{no})$, which are associated with the shares of capital, labor and a fraction of oil output in the output of each sector, are set to match the average ratios observed in the Algerian data for the 1990-2010 period. We set the shares of capital, α_o, labor, β_o, and oil resources, θ_o, in the production of oil to $0,31$, $0,24$ and $0,45$ respectively. We also set to $0,23$, $0,52$ and $0,25$ the share of capital, α_{no}, labor, β_{no}, and a fraction of oil output, θ_{no},in the production of non-oil goods. The standard deviations of these parameters are assumed to follow Beta distribution and a standard error of 0.05.

Table 2: Prior distribution of estimated parameters.

Coefficient	Description	Domain	Density	Priors Mean	Std.
ϕ_{no}	Calvo-price-non-oil	[0 1]	Beta	0.67	0.05
ϕ_I	Calvo-price-import	[0 1]	Beta	0.67	0.05
ψ_o	Cap-adjust-oil	$\mathbb{R}$	Normal	5	2.00
ψ_{no}	Cap-adjust-non-oil	$\mathbb{R}$	Normal	5	2.00
ϑ	Inter-goods elasticity	$\mathbb{R}^+$	Gamma	6	1.00
χ_I	Share of imports	[0 1]	Beta	0.7	0.10
χ_{no}	Share of non-oil	[0 1]	Beta	0.3	0.10
α_o	Share of capital-oil	[0 1]	Beta	$0,31$	0.05
β_o	Share of labor-oil	[0 1]	Beta	$0,24$	0.05
θ_o	Share of oil-resource	[0 1]	Beta	$0,45$	0.05
α_{no}	Share of cap-non-oil	[0 1]	Beta	$0,23$	0.05
β_{no}	Share of lab-non-oil	[0 1]	Beta	$0,52$	0.05
θ_{no}	Share of oil-non-oil	[0 1]	Beta	$0,25$	0.05
$\mu_{\pi_{no}}$	Core inf pol-rule	$\mathbb{R}$	Normal	0.70	0.30
μ_π	Inflation pol-rule	$\mathbb{R}$	Normal	0.50	0.30
μ_e	Exch-rate pol-rule	$\mathbb{R}$	Normal	0.60	0.30
ρ_{R^f}	AR inter-interest rate	[0 1]	Beta	0.65	0.20
ρ_{a_o}	AR oil produc	[0 1]	Beta	0.65	0.20
$\rho_{a_{no}}$	AR non-oil produc	[0 1]	Beta	0.65	0.20
ρ_{π^f}	AR world inflation	[0 1]	Beta	0.65	0.20
$\rho_{p_o^f}$	AR oil price	[0 1]	Beta	0.65	0.20
ρ_O	AR oil resource	[0 1]	Beta	0.65	0.20
ρ_ξ	AR EURO/USD	[0 1]	Beta	0.65	0.20
σ_{R^f}	s.d inter-interest rate	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{a_o}	s.d oil produc	$\mathbb{R}^+$	InvGamma	0.5	inf
$\sigma_{a_{no}}$	s.d non-oil produc	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{π^f}	s.d world inflation	$\mathbb{R}^+$	InvGamma	0.5	inf
$\sigma_{p_o^f}$	s.d oil price	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_O	s.d oil resource	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_ξ	s.d EURO/USD	$\mathbb{R}^+$	InvGamma	0.5	inf

We also assume Gamma and inverted Gamma distributions for the parameters that must be positive. This is the case of the standard errors of various innovations which are assumed to follow the inverse Gamma distribution, with a mean of 0.5 and a standard error of 2. The remaining parameters have a normal distribution. Thus, we use a normal distribution for the capital adjustment costs in each sector with a mean of 5 and a standard deviation of 2. Also, as in Rabanal and Rubio-Ramirez (2005) and Medina and Soto (2005) we do not impose non-negativity restrictions on the policy rule coefficients. Thus, we assume a normal distribution for all monetary policy coefficients with a mean of 0.50, 0.70 and 0.60 for core inflation, inflation and exchange rate coefficients respectively. A standard deviation of 0.3 is assigned to these parameters.

3.2 Estimation results

In order to study the robustness of our baseline model, we begin the analysis of our results by focusing on posterior means (Table 3). Then we analyze the impulse response functions of the external shocks according to the alternative monetary policy rules. Finally, we study the business properties of our model, included variance decomposition.

3.2.1 The baseline model

Table 3 reports the bayesian estimation results of the structural parameters of the baseline model. As in several econometric studies of DSGE models, we estimate the model by computing the posterior mode and constructing the posterior distribution with the Metropolis-Hastings algorithm by generating 100.000 draws. Recall that prior means are mainly based on previous studies dedicated to oil exporters economies since few studies consider the case of Algeria.

Posterior means suggest a weaker price rigidity in the non-oil sector relatively to the import sector (Table 3.a). More precisely, the estimated Calvo probabilities of not resetting optimally prices are 0.64 and 0.76 respectively. That means that prices are adjusted every 2.77 quarters in the non-oil sector and every 4.16 quarters in the import sector suggesting the presence of nominal prices rigidities in the later sector. More precisely, price rigidities may be highest in Algeria relatively to other primary commodity exporters such as Chile owing to the greater influence of state concerning prices determination. In addition, it seems to us relevant to consider that the state exerts a stronger influence on the import sector than the non-oil one for two main reasons. Firstly, public and parapublic companies tend to own to the import sectors. Secondly, as stressed above, authorities subsidy the domestic price of oil, price that exert a direct influence on prices in the import sector. All this induces more rigidity in the former relative to the later. Finally, some import sectors-such as the food one-have monopolistic structures that favor prices rigidity.

The estimates of capital-adjustment cost parameters are 6.32 and 5.85 respectively in oil and non-oil sectors. Posterior means are significantly close to our prior means. High capital-adjustment costs means that the capital stock can not change quickly from period to period.

Table3.a: Estimation results

Parameters	Prior mean	Post mode	S.D	Post mean	[5%	95%]
ϕ_{no}	0.67	0.7111	0.0095	0.6448	0.5957	0.6852
ϕ_I	0.67	0.7846	0.0139	0.7652	0.7346	0.7928
ψ_o	5	5.6835	0.9667	6.3242	4.4166	8.7259
ψ_{no}	5	4.3408	0.8590	5.8580	4.1968	7.3139
ϑ	6	3.4365	0.6977	4.0356	3.0584	4.9204
χ_I	0.7	0.5911	0.0282	0.6240	0.5347	0.7083
χ_{no}	0.3	0.4721	0.0165	0.4152	0.2254	0.6579
α_o	0.31	0.1909	0.0058	0.1568	0.1254	0.1908
β_o	0.24	0.0749	0.0249	0.0932	0.0339	0.1250
θ_o	0.45	0.4318	0.0313	0.4036	0.3454	0.4514
α_{no}	0.23	0.3755	0.0082	0.3848	0.3234	0.4541
β_{no}	0.52	0.3721	0.0201	0.3981	0.3355	0.4435
θ_{no}	0.25	0.1209	0.0162	0.1421	0.1139	0.1802
Mon policy coef						
μ_e	0.70	0.0246	0.0659	0.0352	0.0247	0.0433
μ_π	0.50	1.8579	0.1430	1.9179	1.7909	2.2799
$\mu_{\pi_{no}}$	0.60	-0.0516	0.0843	-0.0452	-0.0560	$-$ 0.0331
Log-marg data		-659.462				

The lower part of Table 3.a exhibits the monetary policy coefficients. Our baseline model suggests that the exchange rate does not play a major role in the monetary policy decisions. Indeed, we see that the posterior mean related to the parameter μ_e is significantly below prior mean, 0.035 and 0.70 respectively.

As in Dib (2008a and b), we assumed that the parameter representing the degree of monopoly power in the intermediate good market, ϑ, is equal to 6. In other words, at the steady state the price-markup is 20 percent. Our posterior mean is close to the prior value and its value is equal to 4.03.

The share of imported goods (0.625) in the final good is greater than the non-oil goods (0.415). Indeed, as low-diversified oil-exporting countries, Algeria remains heavily dependent on imported capital goods, intermediate inputs, and also agricultural products[10].

The shares of capital, labor and oil resource in the oil and non-oil sectors exhibited by posterior mean are very close to prior mean. As this latter has been estimated by using Algerian date for the period 1990 − 2009, the small gap between prior and posterior means shows the relevance of our baseline model to analyze the Algerian economy.

Table3.b: Estimation results

	Prior mean	Post mode	S.D	Post mean	[5%	95%]
AR coefficients						
ρ_{R^f}	0.65	0.6027	0.0102	0.5776	0.6747	0.7210
ρ_{a_o}	0.65	0.6911	0.0107	0.6968	0.6628	0.7093
$\rho_{a_{no}}$	0.65	0.6532	0.0070	0.6800	0.5488	0.6068
ρ_{π^f}	0.65	0.6752	0.0102	0.6416	0.6036	0.6662
$\rho_{p_o^f}$	0.65	0.6078	0.0145	0.6240	0.5816	0.6520
ρ_O	0.65	0.6435	0.0153	0.6700	0.6488	0.6937
ρ_ξ	0.65	0.6483	0.0131	0.6581	0.6177	0.7213
S.d of shocks						
σ_{R^f}	0.5	3.7110	0.4480	3.6271	2.9458	4.2551
σ_{a_o}	0.5	0.0914	0.7638	0.1657	0.0504	0.2914
$\sigma_{a_{no}}$	0.5	0.7341	0.0561	0.4275	0.1523	0.7712
σ_{π^f}	0.5	0.1670	0.3170	0.1767	0.0463	0.3304
$\sigma_{p_o^f}$	0.5	0.2905	0.0185	0.3034	0.2670	0.3330
σ_O	0.5	4.6053	1.4088	4.6950	2.5819	7.2561
σ_ξ	0.5	9.1231	0.4013	9.0888	7.9347	10.4582
σ_r	0.5	0.1015	0.0445	0.0445	0.0458	0.0693
Log marg data		-659.462				

Clearly, according to our baseline model, the Algerian central bank does not react to exchange rate disturbances. This very low coefficient does not imply that Algerian authorities do not monitor exchange rate in their economic policy strategy. In fact, in the aftermath of the dramatic dinar devaluation in 1994 -included in the stabilization program- Algeria has adopted a *de facto* crawling band exchange rate regime[11]. The

[10] According to the World Trade Organization trade profiles, in 2009, agricultural products and manufactures account for 17.8% and 79.7% of total imports respectively.

[11] Using the Reinhart and Rogoff's classification. According to the IMF, Algeria in classified in the category "other managed arrangement with no preannounced path for the exchange rate". See IMF

main aim with this intermediate regime is to maintain the real effective exchange rate close to its equilibrium and to limit exchange rate volatility. Since 2002 this strategy has been successful: not only the real effective exchange rate is very stable, but also the gap between the real and the nominal effective exchange rates is very small. The low inflationary environment has favored such result. The inconvertibility of the dinar for financial transactions and the small size of the heavily regulated foreign exchange market allow the central bank to not respond directly, by manipulating the interest rate, to exchange rate swings. We see that headline inflation accounts for an important weight in the monetary policy (μ_π is equal to 1.918) while the coefficient associated to core inflation ($\mu_{\pi_{no}}$) is extremely low (-0.045). These coefficients are in line with the practice followed by numerous central banks. They tend to target total inflation instead of core inflation.

The lower part of Table 3.b suggests that monetary policy in Algeria must face to a volatile environment. Interestingly, standard deviations show that international shocks -EUR/USD exchange rate, oil price, international interest rates and foreign inflation-are among the main disturbances that hit this economy. In addition, it appears from the higher part of Table 3.b that shocks are also persistent. One of the main lesson of this Table is that many shocks affecting Algeria come from economic variables that are not under the control of the authorities. Considering the major importance of these external shocks for the Algerian economy, the impulse response functions of our baseline model focus on them (see Figures A-1). Globally speaking, responses of domestic macroeconomic aggregates are consistent with the structural characteristics of the Algerian economy. In addition, as our variables return relatively rapidly to their steady state level after a shock, our model is stationary. Our analysis focuses on contemporaneous responses to shocks.

As expected, GDP, investment and non-oil production increase after a positive oil price shock. Such response is consistent with the sensitiveness of the economy to oil sector. The negative response of oil output may rest on different factors. For this reason, the response is difficult to interpret. On the one hand, it may rest on the willingness of the authorities to limit the oil supply in order to maximize the oil rent. On the other hand, as an OPEC member, Algeria can not freely modify its oil supply according to oil prices changes. As a consequence, at least in the short-run, oil output can be relatively inelastic to prices fluctuations. Oil price shock implies a positive wealth effect for consumers. Despite the fact that the oil used domestically is refined mostly in foreign countries and then imported, as the authorities subsidize domestic oil products, increase

Country Report n°11/39, February 2011.

in oil price has few effects on the purchasing power of consumer. As a result, the main consequence of the increase in oil price is positive owing to the place of the oil sector in the economy. Sticky prices, in part due to the presence of subsidize and administrated prices explain the immediate responses of inflation: while the reaction is weak for headline inflation, we see a negative response for core inflation. However, both measures of inflation tend to increase in the aftermath of the oil shock. The contemporaneous response of current account balance is negative but it improves significantly after two periods. This response rests on the strong elasticity of domestic demand to the economic activity. More precisely, the positive wealth effect triggers an increase in domestic spending, and so higher imports. Later, as the value of exports improved, a current account surplus appears. Neither inflation in the import sector nor the real exchange rate react to the oil price shock. Both prices stickiness and the state control explain this response in the import sector. If the real exchange rate reaction to the oil price shock contrasts with other studies on oil-exporting countries and primary commodity exporting -such studies show that the domestic currency tends to appreciate in real terms after a positive primary commodity prices shock- it is consistent with the real exchange rate stability target of the Algerian authorities.

Exchange rate shock exerts a significant influence on domestic macroeconomic variables. As exports are denominated in dollar and imports mainly in euro, it is important to keep in mind that nominal exchange rate shock is equivalent to terms of trade shock. We see that GDP, investment and non-oil production react negatively to a depreciation of the dollar against the euro. As oil prices are denominated in dollar, the very high share of the oil sector in the Algerian GDP explains the negative response of the latter. The exchange rate shock is equivalent to a negative wealth effect. In turn, the decrease in oil revenue leads to a fall in investment and non-oil output. Indeed, non-hydrocarbon sector is affected by the exchange rate shock *via* the fiscal expenditure policy which is dependent from oil revenue. The hydrocarbon stabilization fund established in 2000 has a limited impact on the pro-cyclicity of the fiscal policy. In other words, the volatility of the non-oil sector is significantly linked to the volatility of the oil sector. As the main trade partners of Algeria belong to the Euro area, the exchange rate shock leads to an increase in imported inflation that, in turn, induces a positive response of both headline and core inflation. As expected, consumption decreases on the impact of the exchange rate shock according to a negative wealth effect. The current account balance strongly deteriorates. Indeed, in accordance with a J-curve effect, the immediate effect of the exchange rate shock is a decrease in the value of exports with the depreciation of dollar while the value of imports tends to increase with the euro appreciation. After several periods, trade volumes adjust to the shock and the current account improves. Inflation in the import sector does not respond to the exchange rate shock. The real exchange rate appreciates on the impact of the shock, but the response is short-lived.

Both the international interest rate and the foreign inflation shocks tend to exert a weaker influence on domestic variables. The weak influence of the international interest rate rests on the relatively low level of financial openness of Algeria. Whatever the indicator of financial openness -the *de jure* Chinn and Ito's index or the *de facto* Lane and Milesi-Ferretti's estimate- it appears that the Algerian economy is among the least open one. Recall that the dinar remains inconvertible for capital transactions. In 2008, according to the Chinn and Ito's index, Algeria has been ranked at the 113th position over 182 countries in terms of financial openness[12]. As suggested by the responses of domestic variables to the foreign inflation shock, the Algerian economy seems very few sensitive to external nominal foreign disturbances. The prevalence of real external shocks relative to nominal ones has important implications to assess the choice of the right monetary policy rule. Such a rule must favor both the stabilization of the inflation rate and the low volatility of production. In this perspective, a strict inflation targeting framework -in which the central bank targets only the deviation of the CPI inflation rate relative to its steady state equilibrium- may lead to excessive volatility of real macroeconomic variables (see the pioneer work by Svensson (2000)). Such a volatility when the economy is mainly hit by real shocks.

3.2.2 External shocks under alternative monetary policy rules

Figures A2 to A5 exhibit the responses of our domestic macroeconomic aggregates to four shocks: oil price, international interest rate, nominal exchange rate, and foreign inflation respectively. We show the results for the baseline model and the three monetary policy rules introduced in subsection 2.6: strict inflation targeting rule (IT rule), core inflation targeting rule (CIT rule) and exchange rate rule (ER rule). The importance of each monetary policy will be deduced from the gap of the responses of our selected variables shown in each figure. The aim is to determine the monetary policy rule that both minimizes the macroeconomic volatility and maintains the inflation rate at a low level once we take into account the main shocks that hit this country.

[12]The de facto measure gives a similar picture. In 2007, the volume-based measure of financial integration -that is the sum of the stock of foreign assets and liabilities divided by the GDP- was 104.1 per cent for Algeria against 182.1 percent for emerging countries. Authors' calculations using the updated and extended version of the External wealth of nations, Mark II database developed by Lane and Milesi-Ferretti (2007).

Effects of an oil price shock To analyze the effects of oil price shock, we distinguish the responses of real macroeconomic variables and inflation respectively under alternative monetary policy rules. Results on real variables show that, except for oil output, the alternative monetary policy rules provide better outcomes than the baseline model. This suggests that the current monetary policy followed by the central bank is not optimal to respond to oil price shocks. Both GDP, non-oil output, and consumption exhibit weaker contemporaneous responses under the core-inflation targeting rule. We find no significant differences for investment between the two inflation rules while the exchange rate rule does not allow a smooth response of this variable. Immediate responses are only one side to consider the monetary policy rule best adapted to shocks affecting the economy. The analysis of the adjustment is the other side. Adjustment refers to the speed at which a specific variable returns to its steady state level. Under the baseline model and the exchange rate rule, all real variables follow an unstable adjustment process. More precisely, our results shows that short-run fluctuations are sizeable under these two scenarios. Inflation targeting and core-inflation targeting rules do not exhibit significant different adjustment process.

Responses of headline inflation and core-inflation give more mixed results. On the impact of the shock, the weakest response for total inflation is obtained with the baseline model while the core-inflation targeting rule is the best one to limit the response of core-inflation. In both cases, the worst monetary policy is the exchange rate rule. The analysis of the adjustment process confirms the latter result. Thus the exchange rate rule tends to be accompanied by sizeable short-run fluctuations. At the opposite, core-inflation targeting offers the most stable adjustment for both headline and core inflation.

After the oil price shock, inflation in the import sector exhibits the strongest response under the inflation targeting rule. Such result confirms findings in the previous literature on strict inflation targeting. This monetary regime induces wide fluctuations of the macroeconomic variables. Interestingly, as suggested by the adjustment process, this monetary rule does not allow a rapid adjustment of inflation in the import sector. The inflation targeting rule exerts a weaker influence on the contemporaneous response of the real exchange rate. We find the opposite for the core-inflation rule. But we need to be cautious to interpret these results as all alternative rules and the baseline model show only very short-lived responses of the real exchange rate to the oil price shock.

To sum up, we see that the exchange rate rule is especially inefficient to respond to oil price shocks. Indeed, this rule implies a too reactive interest rate reaction to any exchange rate deviation from its equilibrium state. Such reaction leads to a high volatility of macroeconomic variables. Our results suggest at the same time that exchange rate rule is unable to stabilize inflation. From this perspective, if we consider the trade-off macroeconomic stabilization-low inflation environment, we find that the core-inflation targeting rule is superior to the inflation targeting rule. Our results are in line with the recent literature on monetary policy in small open economies (Parrado (2004); Medina and Soto (2005) and Dhawan and Jeske (2007)). In the case of Algeria, targeting core-inflation instead of headline inflation allows to avoid the potential monetary policy overreaction due to oil prices fluctuations. Recall that this shock is one of the main affecting Algerian economy (see Table 3.b).

Effects of EUR/USD exchange rate shock In the case of exchange rate shock, all contemporaneous responses but one (the real exchange rate) are weaker under the CIT rule. At the same time, this monetary policy rule allows the smoother adjustment after the shock. Interestingly, both the baseline model and the exchange rate rule lead to higher macroeconomic volatility. More precisely, Figure A.3 shows that real variables such as GDP, consumption, investment, oil and non-oil production, and the current account) have stronger short-run responses relatively to the core inflation targeting. This result suggests that the central bank overreacts if the exchange rate is targeted (as in the case of exchange rate rule) or if it targets both oil price and exchange rate (in the case of our baseline model). The exchange rate rule is especially effective to stabilize the real exchange rate in the aftermath of the shock. However, when assessing the pro and cons of alternative monetary rules, this effectiveness must not be overestimated, for two main reasons. Firstly, as exhibited in Figure A.3, the responses of the real exchange rate are short-lived whatever the monetary rule. Secondly, as we stressed above, the Algerian foreign exchange market is very thin. The central bank is the sole seller of foreign exchange. More precisely, the central bank accumulates foreign exchange reserves by beneficing from the revenues due to hydrocarbon exports. Foreign exchange reserves are the main instrument used by the authorities to monitor the dinar exchange rate. In other words, the nominal interest rate is not constrained by the exchange rate target.

Effects of international interest rate and foreign inflations shocks The responses and adjustment of our variables of interest exhibit a very low reaction in the case of core inflation targeting. Indeed, in the case of international interest rate and foreign inflation shocks, figure (A-4 and A-5) show that the reaction of the most of selected variables (GDP, investment, non-oil and oil output and consumption, for example) is negligible in the case of CIT rule compared to the other two monetary policy rules, namely, IT and ER rules. This result is similar to the previous two shocks.

3.2.3 Business cycle properties

In this section, we compare the statistical properties of the model against those of the data. To do so, we estimate a Bayesian Vector Autoregression (BVAR) model using the same data set.

Volatility and correlation In what follows, we assess the performance of our DSGE model by considering the model implied volatilities (stabdard deviation) and correlation of some variables of interest in the data and from the model. Table 4 reports the results of the DSGE model and the BVAR model. The standard deviations are expressed in percentage terms.

Table 4: Volatility and correlation

Variables	Volatility		Correlation with GDP	
	VAR model	DSGE model	VAR model	DSGE model
Y	0.20	0.2570	–	–
c	0.569	0.4515	0.1283	0.7352
Y_o	0.303	0.2958	0.8129	0.8860
π	0.035	0.0435	−0.1602	−0.1831
P_o^f	0.758	0.1864	0.7585	0.0379
R^f	0.463	0.5479	−0.5418	−0.1530
s	0.332	0.4142	−0.8316	−0.7538

Columns 2 and 3 display standard deviations of seven selected variables (GDP, consumption, oil output, inflation, international oil price, international interest rate and real exchange rate). The main striking lesson from Table 4 is the consistency of our results. Indeed, variables with the higher volatility relative to the GDP (Y) are also the most volatile ones in the DSGE model. The only exception is the international oil price (P_o^f) for which we find a lower volatility in the DSGE model. In the two specifications, the domestic headline inflation (π) exhibit the lowest volatility. The fact that the international oil price and the headline inflation have a low volatility is common feature in New-Keynesian models with price and/or wage rigidities (Dib (2008b)).

Columns 4 and 5 report the cross-correlation for our key variables. The results show that the correlation is positive between GDP and consumption, oil price and oil output in both BVAR and Baseline models. The remaining variables, such as exchange rate, inflation, and international interest rate are negatively correlated with real GDP. Globally, the Baseline model succeeded well in reproducing the results obtained by the BVAR model.

Variance decomposition Our previous findings are confirmed by the variance decomposition: Algeria is especially sensitive to real shocks. Thus, technology shocks in both oil and non-oil sectors are the predominant source of macroeconomic fluctuations. This is common feature in New-Keynesian models, in which the main source of business cycle fluctuation is technology shocks. For instance, oil production shocks account for 56.21 percent of the variation in the GDP and 31.54 percent of the variation in the consumption. Non-oil production shocks explain 10.86 percent and 11.66 of the variance of GDP and consumption respectively.

Table 5: variance decomposition.

	ε_{R^f}	$\varepsilon_{p_o^f}$	ε_{π}^f	ε_{ξ}	ε_{a_o}	$\varepsilon_{a_{no}}$	ε_o	ε_R
Y_t	4.65	6.41	0.14	1.33	56.21	10.86	19.30	1.11
c_t	1.71	42.62	0.40	2.83	31.54	11.66	6.09	3.14
i_t	1.79	36.36	0.57	2.18	18.95	29.91	5.78	4.46
$Y_{o,t}$	5.96	9.04	0.06	2.51	76.34	4.70	0.91	0.48
$Y_{no,t}$	3.32	4.39	0.09	1.30	28.02	52.11	10.07	0.71
π_t	2.12	9.21	0.77	0.80	40.34	34.11	6.59	6.06
$\pi_{no,t}$	2.39	6.37	0.15	0.91	43.65	38.03	7.35	1.16
$q_{o,t}$	0.43	14.55	0.13	0.88	72.98	8.41	1.63	0.99
$q_{no,t}$	0.52	15.07	0.19	0.86	9.96	69.96	1.92	1.51

Interestingly, prices and monetary shocks tend to exert a weaker influence on macroeconomic variables. For instance, international interest rate and foreign inflation shocks explain only a small share of the variance decomposition of our domestic variables. The low financial openness of Algeria explains this result. Similarly, the low degree of financial development explains the weak influence of domestic interest rate shocks, except for total inflation. More precisely, the main instrument used by the Algerian central bank is not the interest rate -despite the introduction of open market operations in 1996- but the control of banking liquidity. To this end, the central bank continues to use indirect instruments such as reserve requirements and credit auctions.

4 Welfare effects

In this section we calculate the welfare cost of external shocks under alternative monetary policy rules. We compute the welfare cost using the unconditional expectation of the utility function. After estimating the model, we simulate it by using the posteriors of the parameters. Then, we varying parameters in the monetary policy rule, while keeping all other as in the benchmark model to examine the changes in welfare under each monetary policy rule. For doing so, we use a second order approximation of the utility function around the deterministic steady state[13]. Formally, the welfare criterion is derived from the following single-period utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \; U\left(c_t, h_t\right), \tag{51}$$

the second order approximation result is given by:

$$\begin{aligned} \mu(.) \quad \simeq \quad & \overline{\mu} + \overline{c}^{1-\gamma} E(\widehat{c}_t) - \overline{h}^{1+\sigma} E\left(\widehat{h}_t\right) - \\ & \frac{\gamma}{2}\overline{c}^{1-\gamma} E\left(var\left(\widehat{c}_t\right) + \left[E\left(\widehat{c}_t\right)^2\right]\right) - \frac{\sigma}{2}\overline{h}^{1+\sigma} E\left(var\left(\widehat{h}_t\right) + \left[E\left(\widehat{h}_t\right)^2\right]\right) \end{aligned} \tag{52}$$

where bars denote steady-state values and hats represent percentage deviations from the steady-state.

The welfare cost associated with each scenario is measured by the compensating variation which allows us to measure the percentage change in consumption in the deterministic steady state. Our main findings are summarized in Table 6:

Table 6: Welfare results (in % of the steady state of consumption)

	Oil price	EUR/USD	IIR	World inflation	All shocks
Monetary policy rules					
ER rule	3.4000	0.6042	0.2883	0.8869	4.7510
IT rule	1.4187	0.6110	0.4855	0.2183	4.6051
CIT rule	4.6850	0.6754	0.3459	0.1233	4.0779

Table reports that the welfare increases after external shocks for all monetary policy rules. Nevertheless, welfare gains are different depending on the monetary policy rule adopted. The results are listed for three scenarios: i) the baseline model under ER rule; ii) the baseline model under IT rule, and; iii) the baseline model under CIT rule. In each case, we simulate the model with all shocks, and then only one shock.

Our results show that an increase in oil price leads to a high welfare compared to the other external shocks, namely, EUR/USD, international interest rate, and world inflation shocks. This is due to the fact that consumption of the Algerian households is highly dependent on oil revenues. However, the welfare gain associated with CIT rule is much greater than in the case of the other two monetary policy rules. Indeed, after an

[13] For similar method see Schmitt-Grohé and Uribe (2007)

oil price shock, the CIT rule causes welfare to increase by 4.6850 percent compared to 3.4000 and 1.4187 percent respectively in the case of ER and IT rules. This is the case when the economy experiences an EUR/USD shock.

Overall, we can conclude that in the case of CIT rule, the welfare gain is quite large relatively to ER and IT rules, except in the case of international interest rate and the world inflation shocks. These shocks have a low impact on the Algerian economy as shown in the variance decomposition and IRFs. This leads us to conclude that the choice of core inflation rule is better than headline inflation targeting and exchange rate rules.

5 Conclusion

In this paper, we estimated a multisector DSGE model for an oil exporting economy based on the features of the Algerian economy. To our knowledge, it's one of the first papers using DSGE model dedicated to this country. Building a three sectors model, we attempted to compare the response of some selected variables to external shocks and to evaluate three alternative monetary policy rules for Algerian economy. We try to shed some light to the following question: given the vulnerability of an oil exporting economy to external shocks, what is the appropriate monetary policy rule for Algerian economy? In a first step, we analyzed our results from our baseline model by focusing on posterior means and impulse response functions. In a second step, we compared different monetary rules. The welfare cost associated with each monetary policy rule has been considered. Our main findings show that, over the period 1990Q1-2010Q4, core inflation target is the best monetary rule to stabilize both output and inflation. This rule also appears to be the best way to improve social welfare. In other words, the current monetary policy -corresponding to our baseline model- followed by the Algerian central bank is not well-suited to face to oil shocks. These results are two main policy implications. Firstly, they suggest that Algeria should modify its monetary policy in order to adopt a core inflation targeting framework. This implies to fulfill some preconditions such as the central bank independence. Secondly, Algerian authorities must strengthen the influence of interest rate as a transmission channel of the monetary policy. To this end, they must promote banking lending to the private sector and the development of the capital market. On these two points, Algeria lags relative to other upper middle income countries, especially in MENA region, preventing the use of the interest rate as the main instrument of the monetary policy.

The main drawback of this paper is the absence of fiscal policy in our model. Indeed, as in some primary commodity countries, such as Chile, Algeria has established in 2000 an hydrocarbon stabilization fund (*Fonds de régulation des recettes).* One of the targets of this fund is to reduce the sensitivity of the fiscal policy to hydrocarbon revenues fluctuations. Indeed, public spending tend to go hand in hand with oil receipts, generating an unstable fiscal policy stance. The integration of fiscal policy, and its interaction with monetary policy, in our model is the main avenue for future research.

References

[1] Almeida, V. (2009). Bayesian Estimation of a DSGE Model for the Portuguese Economy. Working Papers w200914, Banco de Portugal.

[2] Benkhodja, M.T (2011). Monetary Policy and the Dutch Disease in a Small Open Oil Exporting Economy. Working Paper GATE-CNRS.

[3] Bernanke, B., M. Gertler, and M. Watson (1997). Systematic Monetary Policy and the Effects of Oil Price Shocks. Brookings Papers on Economic Activity, 1: 91-142.

[4] Bouakez, H., N. Rebei and D. Vencatachellum (2008). Optimal Pass-Through of Oil Prices in an Economy with Nominal Rigidities. Working Paper 08/31, CIRPEE.

[5] Calvo, G. (1983). Staggered Prices in a Utility-Maximizing Framework. Journal of Monetary Economics, 12(3): 383-398.

[6] Devereux, M., P. R. Lane, and J. Xu (2006). Exchange Rate and Monetary Policy in Emerging Market Economies. The Economic Journal, 116: 478–506.

[7] Del Negro, M. and F. Schorfheide (2008). Forming Priors for DSGE Models (and How It Affects the Assessment of Nominal Rigidities). Journal of Monetary Economics, vol. 55(7): 1191-1208.

[8] Del Negro, M. and F. Schorfheide (2010). Bayesian Macroeconometrics. Handbook of Bayesian Econometrics. Forthcoming.

[9] Dhawan, R. and K. Jeske (2007). Taylor Rules with Headline Inflation: a Bad Idea. Federal Reserve Bank of Atlanta, Working Paper Series, 2007-14, July.

[10] Dib, A. (2008a). Welfare Effects of Commodity Price and Exchange Rate Volatilities in a Multi-Sector Small Open Economy Model. Bank of Canada Working Paper 2008-8.

[11] Dib, A. (2008b). Dynamic Effects of the U.S. Dollar Fluctuations in a Small Open Oil Exporting Economy: The Case of Algeria. Manuscript.

[12] Fernández-Villaverde, J. (2010). The Econometrics of DSGE Models. Journal of the Spanish Economic Association, SERIEs (2010) 1:3–49.

[13] Hamilton, J.D. (1983). Oil and the Macroeconomy Since World War II. Journal of Political Economy, 91(2): 228-248.

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

[15] Ireland. P. (2003). Endogenous Money or Sticky Prices?" Journal of Monetary Economics 50: 1623–48.

[16] Leduc, S. and K. Sill (2004). A Quantitative Analysis of Oil-Price Shocks, Systematic Monetary Policy, and Economic Downturns. Journal of Monetary Economics 51: 781-808.

[17] Medina, J.P. and C. Soto (2005). Oil Shocks and Monetary Policy in an Estimated DSGE Model for a Small Open Economy. Central Bank of Chile Working Paper n°353.

[18] Parrado R. (2004). Inflation Targeting and Exchange Rate Rules in an Open Economy. IMF Working Paper, WP/04/21, February.

[19] Rabanal, P. and J.F. Rubio-Ramirez (2005). Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach. Journal of Monetary Economics, 52(6): 1151-1166.

[20] Schmitt-Grohé, S. and M. Uribe (2003). Closing Small Open Economy Models. Journal of International Economics, 61: 163-185.

[21] Schmitt Grohé, S. and M. Uribe (2007). Optimal, Simple, and Implementable Monetary and Fiscal Rules. Journal of Monetary Economics, 54: 1702–25.

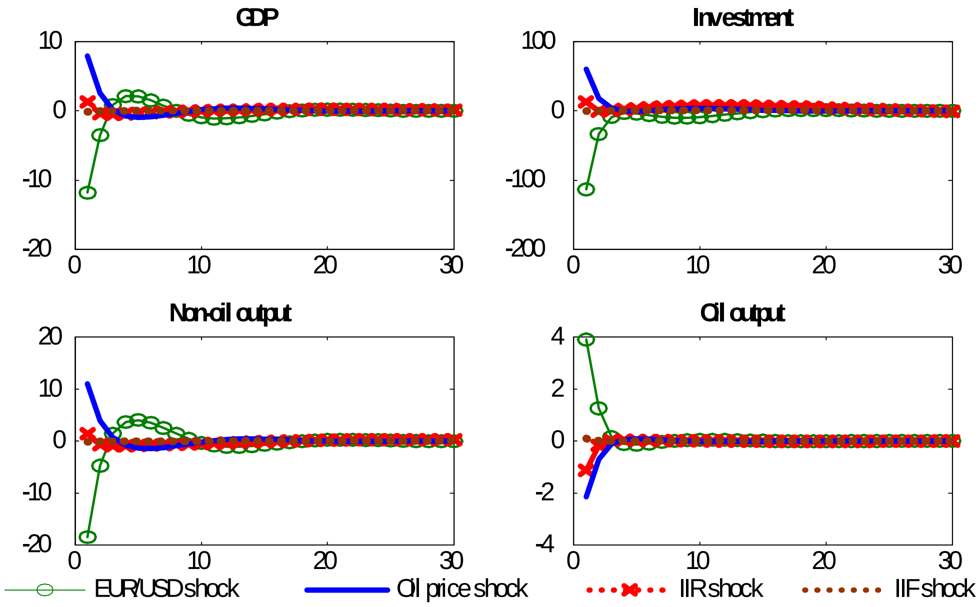
[22] Svensson, L.E.O. (2000). Open Economy Inflation Targeting. Journal of International Economics,50(1): 155–83.

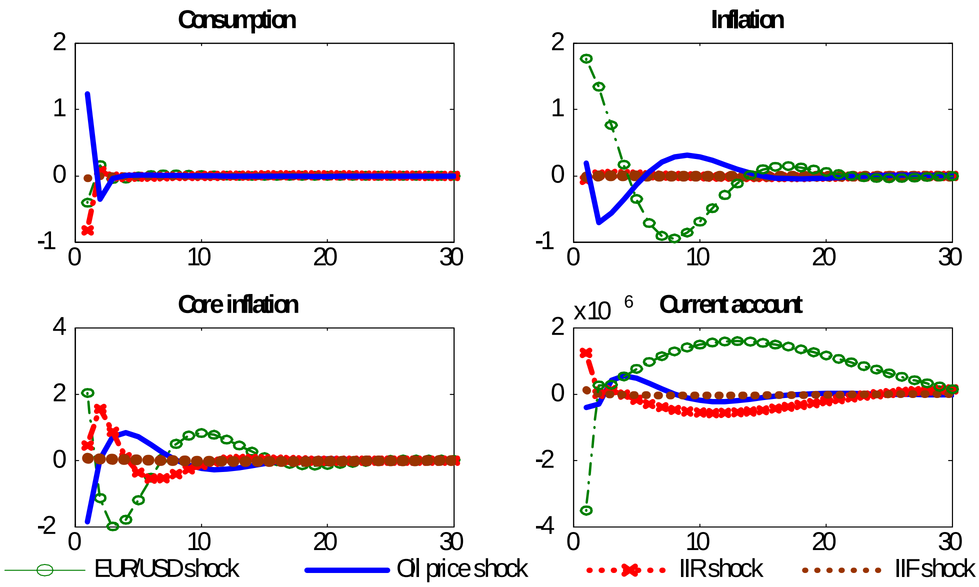
[23] Sungbae, A. and F. Schorfheide (2007). Bayesian Analysis of DSGE Models. Econometric Reviews, 26(2-4): 113-172.

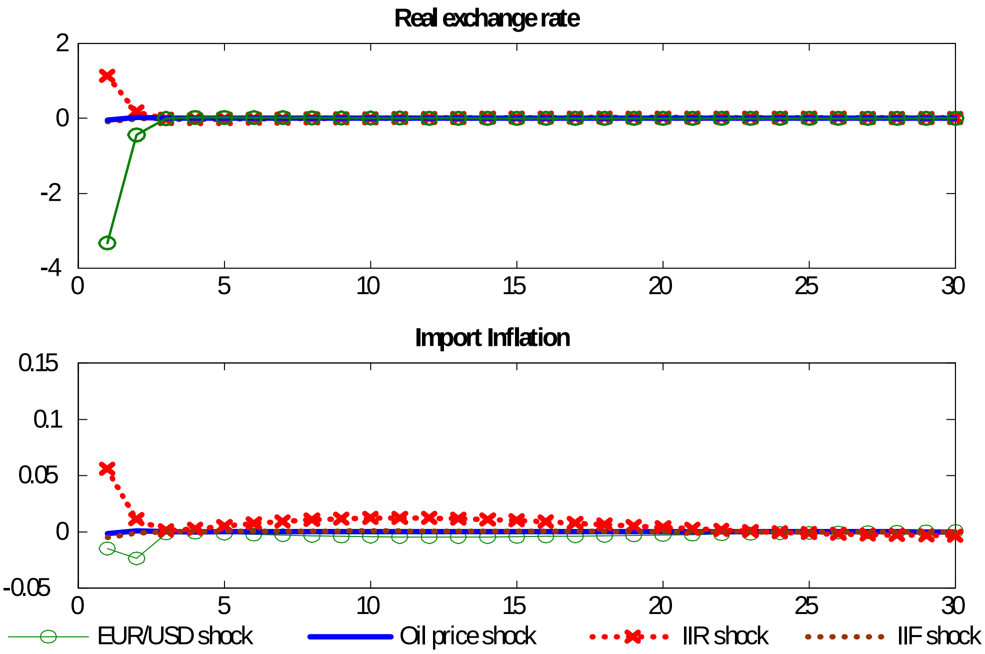
[24] Yun, T. (1996). Nominal Price Rigidity, Money Supply Endogeneity, and the Business Cycles. Journal of Monetary Economics 37:345-370.

A Impulse response functions

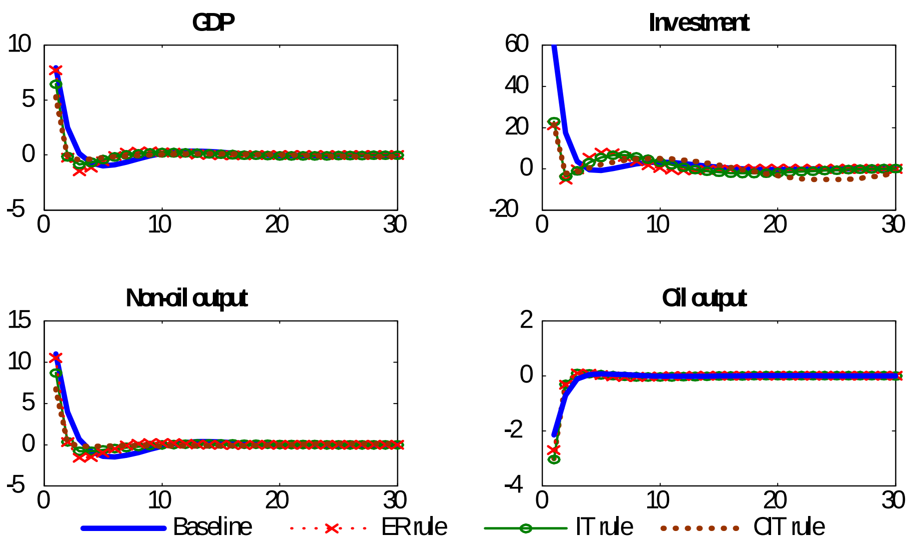
A.1 Responses to multiple shocks (Baseline model):

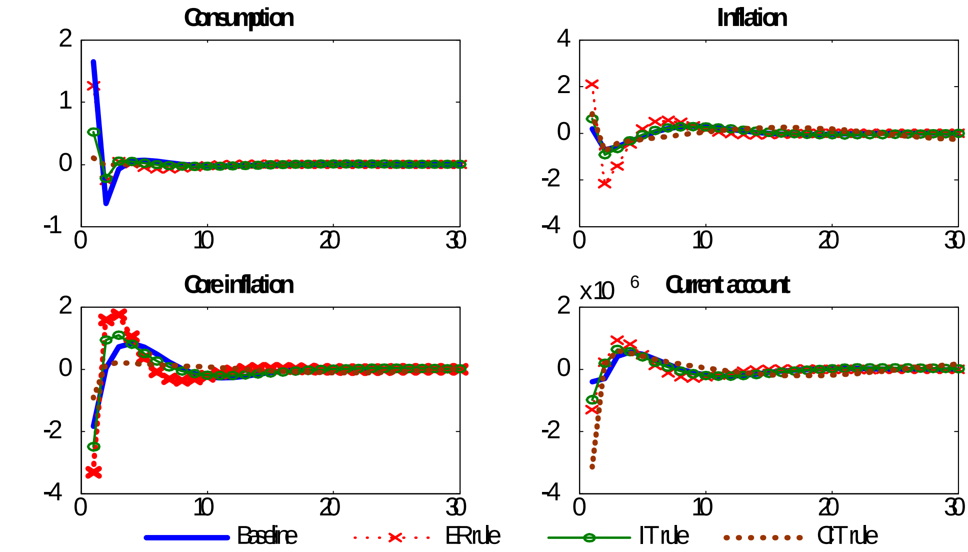


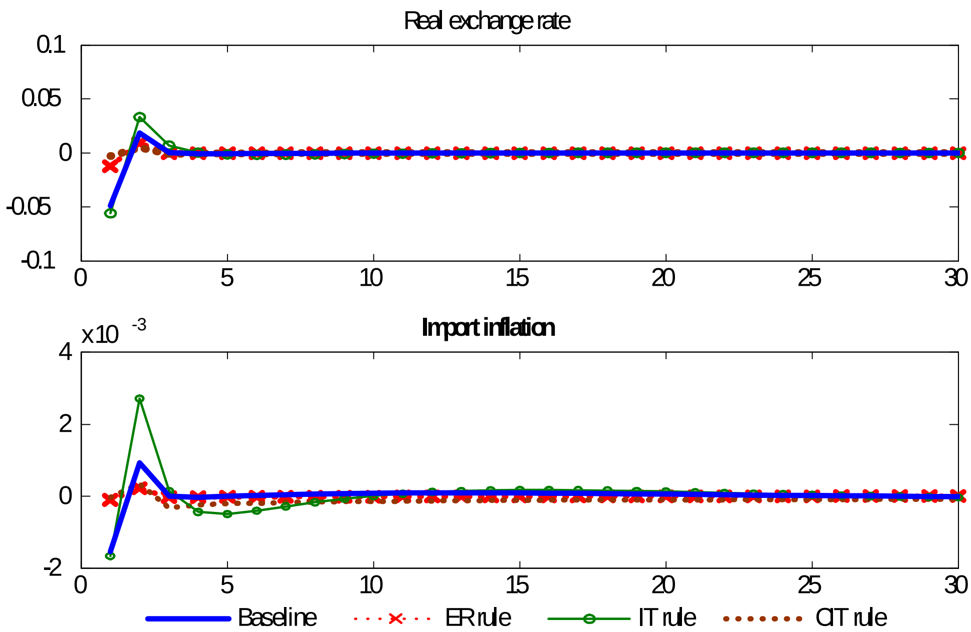




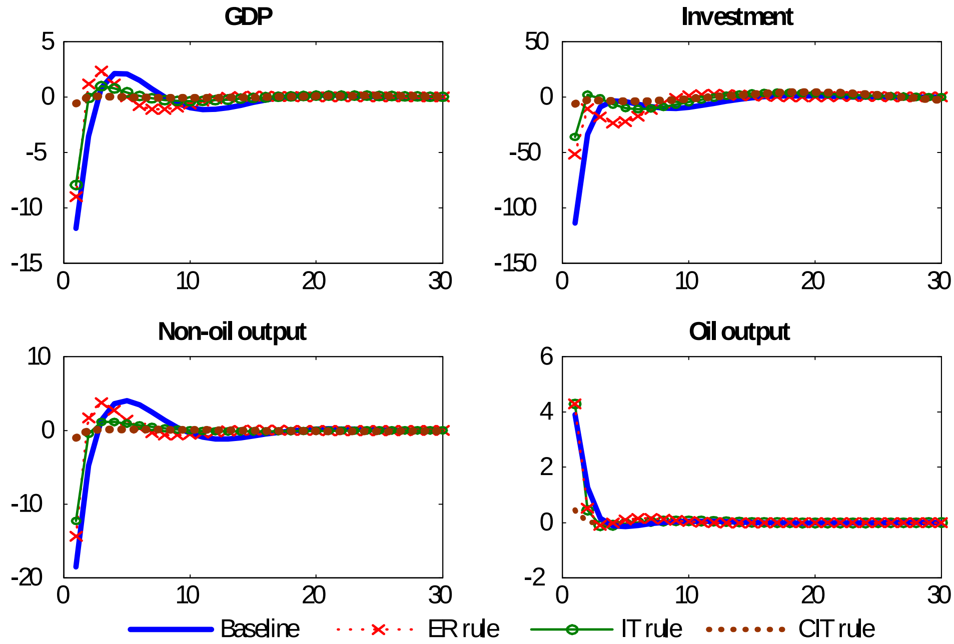
A.2 The effect of 1% positive oil price shock:

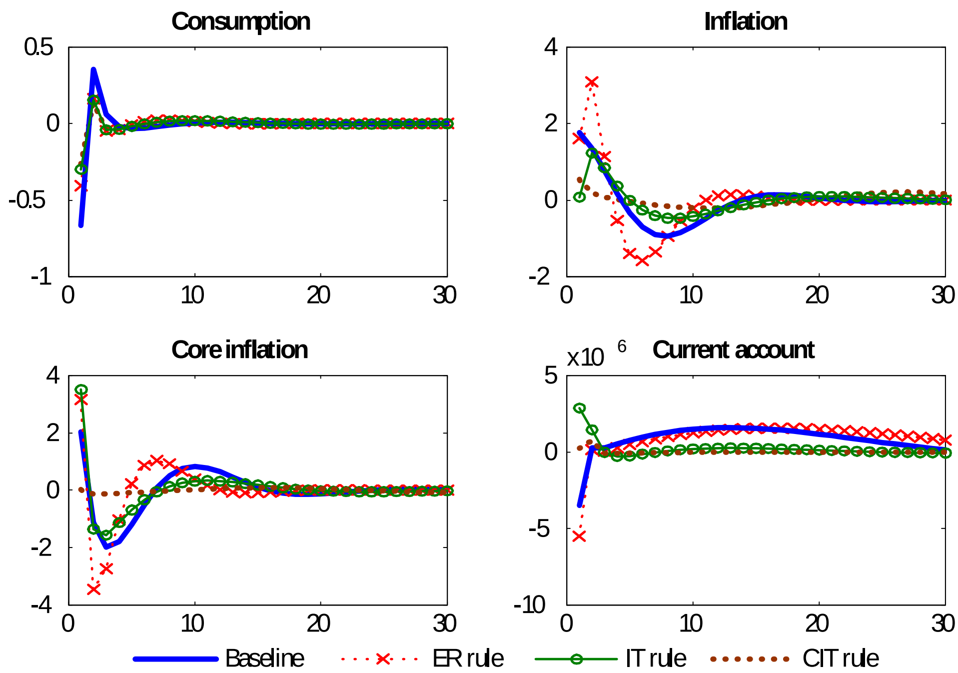


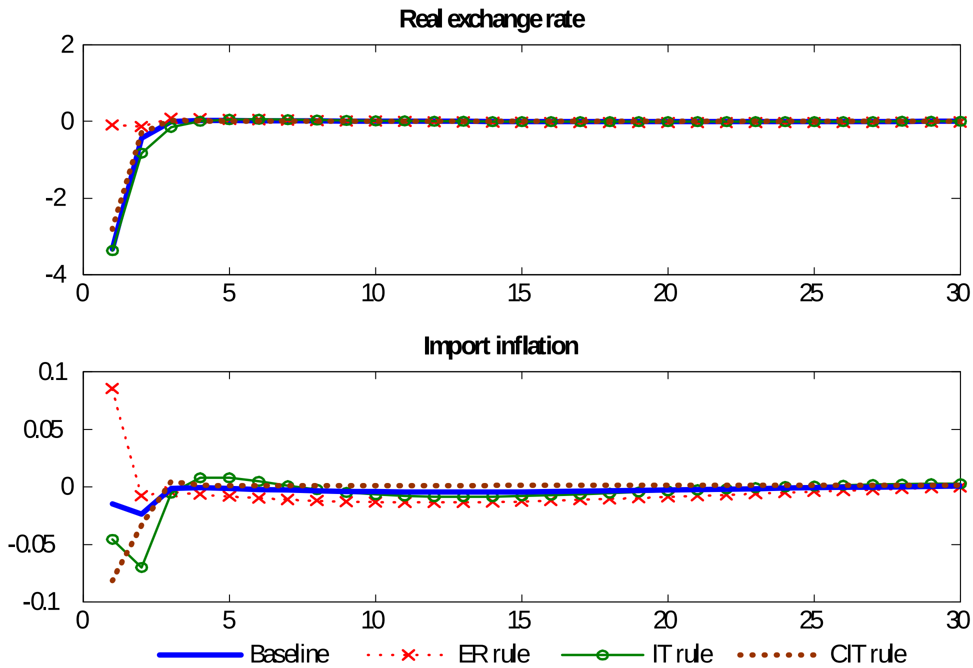




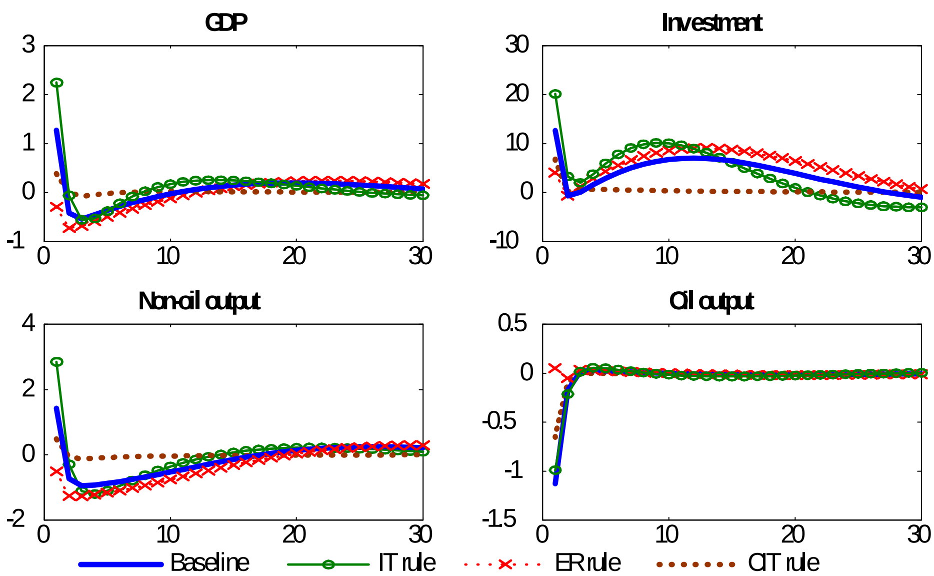
A.3 The effect of 1% positive EUR/USD shock:

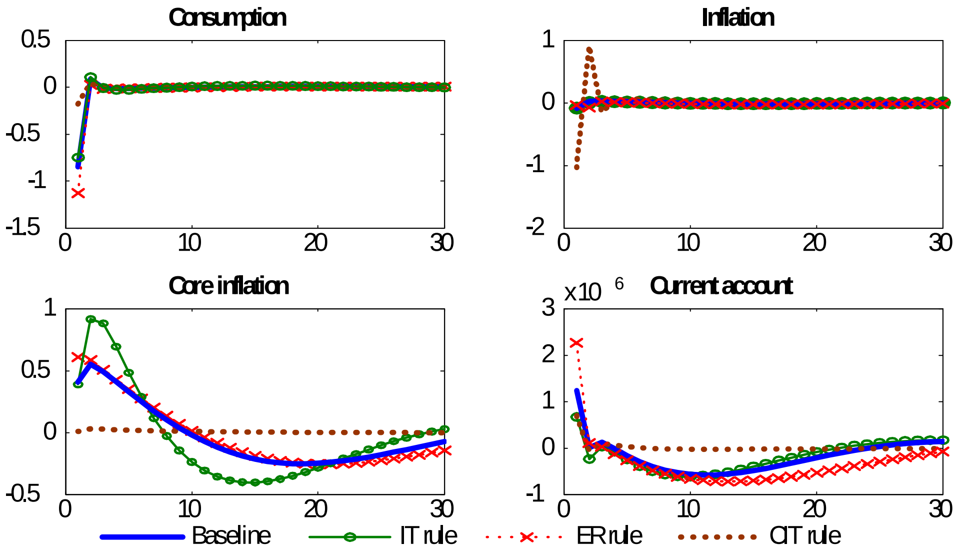

GDP
Investment
Non-oil output
Oil output
Baseline
ER rule
IT rule
CIT rule

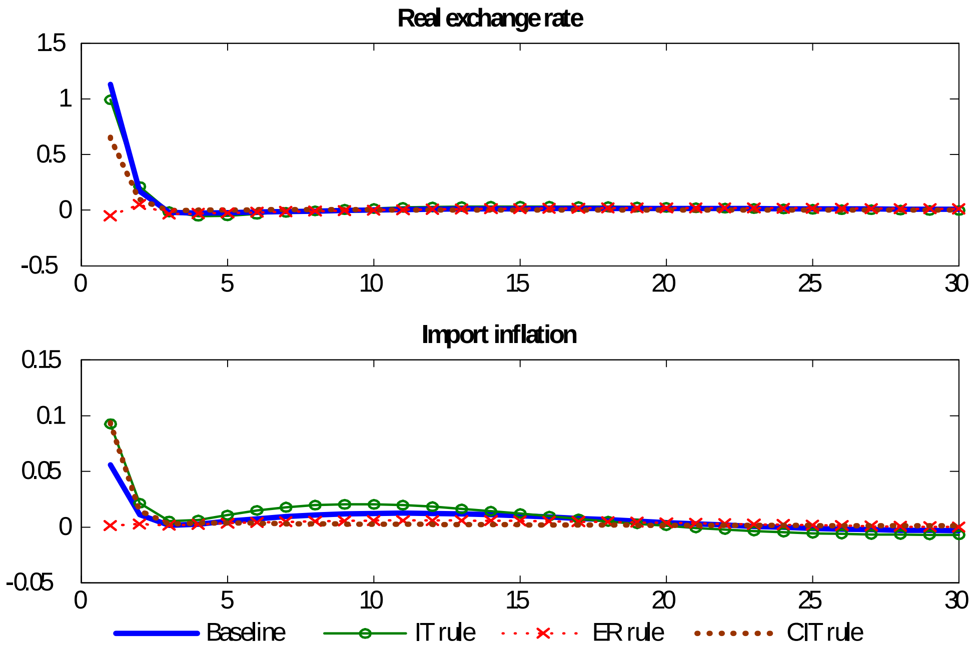

Consumption
Inflation
Core inflation
x10 6
Current account
Baseline
ER rule
IT rule
CIT rule



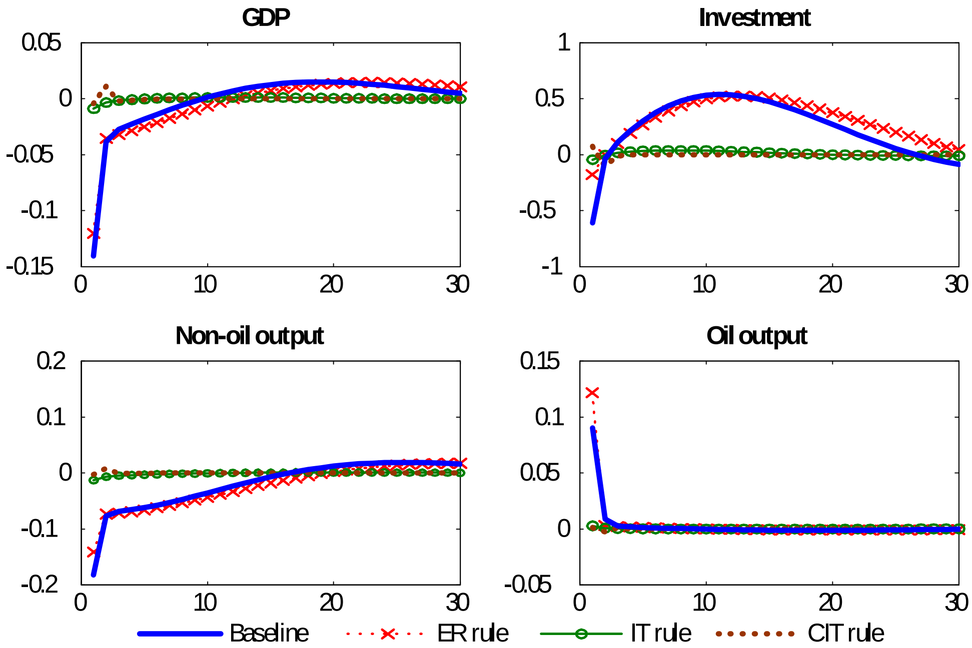
A.4 The effect of 1% positive international interest rate shock:

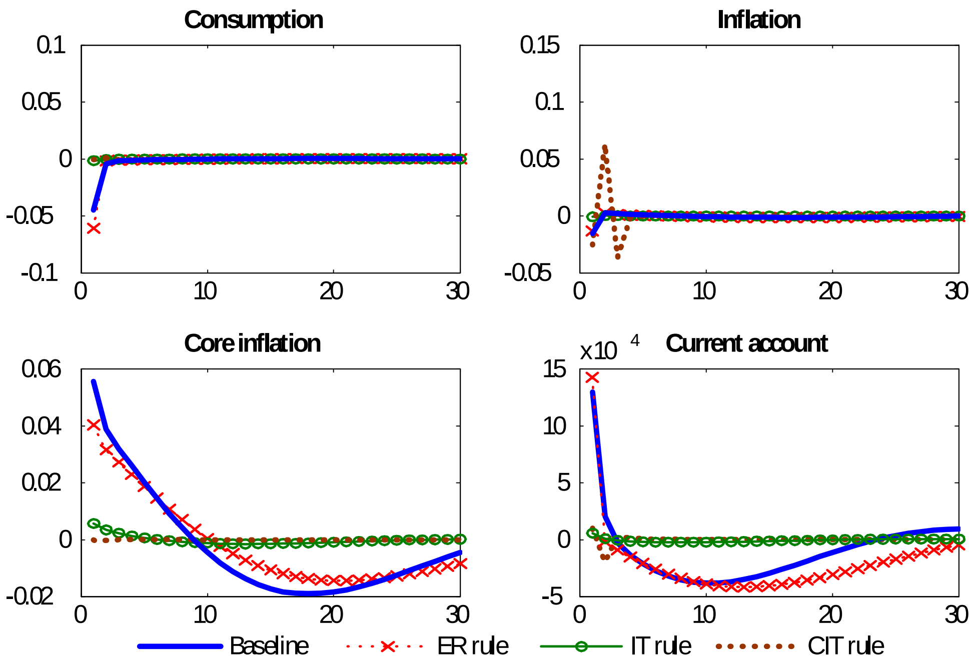


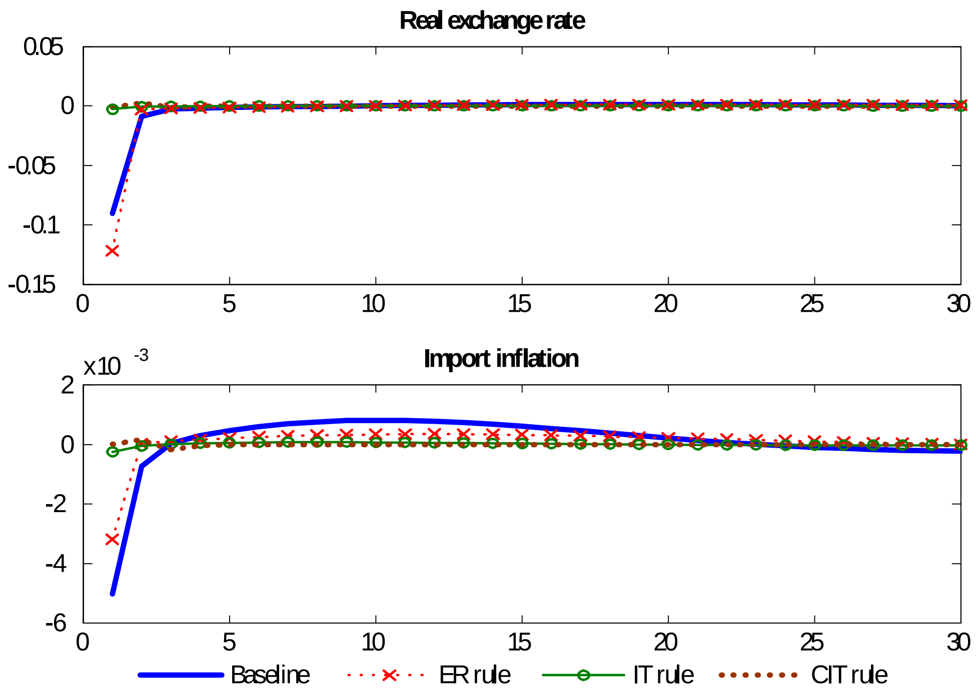




A.5 The effect of 1% positive foreign inflation shock:


GDP
Investment
Non-oil output
Oil output
Baseline
ER rule
IT rule
CIT rule


Consumption
Inflation
Core inflation
x10 4
Current account
Baseline
ER rule
IT rule
CIT rule



B Data description

In this paper we used Algerian data obtained from IMF-IFS and ONS (National Office of Statistics). The common period covered by all series is 1990:Q1-2010:Q4.

Oil production is measured by crude petroleum production, IMF-IFS database.

Domestic inflation is measured by the percentage change in the consumer price index. The CPI is obtained from IMF-IFS database and ONS.

Domestic interest rate is the nominal discount rate of the bank of Algeria, IMF-IFS database.

USD/DZD real exchange rate is constructed by multiplying the bilateral nominal exchange rate, defined as the price of one U.S dollar in terms of Algerian dinar, by the ratio of the U.S consumer price index (CPI) to the Algerian CPI, IMF-IFS database.

Domestic Output is the Gross Domestic Product. In the IMF-IFS database, the GDP serie is published in annual frequency. We transformed it into quarterly frequency. The GDP is also seasonally adjusted by using X-11 procedure.

Consumption is measured by the household expenditure. As in the case of real GDP, the consumption serie was transformed into quarterly data, IMF-IFS database.

International oil price is the world nominal oil price, it comes from IMF primary commodity prices database.