External Shocks and Monetary Policy in an Oil Exporting Economy

Jean-Pierre Allegret, Mohamed Tahar Benkhodja

External Shocks and Monetary Policy in an Oil Exporting Economy[♦]

Jean Pierre Allegret[♣] and Mohamed Tahar Benkhodja[♥]

Absract

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. We analyze the impulse response functions of our external shocks according to alternative monetary rules. The welfare cost associated with each monetary policy rule is considered. We find that, over the period 1990-2010, 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.

JEL Classification: E3, E5, F4.
Keywords: Monetary policy, external shocks, oil exporting economy, Algeria, DSGE model.

1 Introduction

During 2000s', oil exporting countries benefited from exceptional windfalls due to high oil prices. From January 2000 to December 2010, the IMF oil index risen from 47.23 to 169.33. If we consider its peak (in July 2008), the index was more than five times as high as just eight years ago. This boom in oil prices has renewed interests in academics and international institutions circles about its macroeconomic consequences in rich resources countries[1]. In this paper, we focus our attention on a specific oil exporter: Algeria. This country is among the top three oil producers in Africa. In addition, Algeria is heavily dependent from hydrocarbon sector insofar as revenues generated from it account for around 30% of the GDP and more than 95% of export earnings. Despite significant oil revenues, macroeconomic performances in Algeria have been far from impressive. Over the period 2000-2010, the average real GDP growth was 3.9%, consistently below growth

[♦]Insightful comments by the referees and the Editor of the review are gratefully acknowledged.
[♣]Corresponding author: EconomiX, UMR CNRS and Université Paris Ouest Nanterre La Défense. Email: jallegret@u-paris10.fr. Tel.: +33 (0) 1.40.97.59.07 Fax: +33 (0) 1.40.97.41.98 Professional address: Université Paris Ouest Nanterre La Défense Building G, Office 603b, 200 avenue de la République 92001 Nanterre Cedex France.
[♥] At the time the article was written, the author was a teaching assistant at the University of Lyon 2 and affiliate to GATE-LSE, Lyon. Email: mbenkhodja@gmail.com. Cell: +33(0) 7. 78.55.55.16
[1] See, for instance, Arezski *et al.* (2011) and Baunsgaard *et al.* (2012).

performances in MENA region (5.4%). If we consider only oil exporting countries from this region, the growth gap is even more important.

Two main strands of literature provide potential explanations for these poor macroeconomic performances. First, the natural resource curse hypothesis suggests that the abundance of natural resources may be detrimental to long term economic growth (Ploeg, 2011; Breisinger *et al.*, 2014). Interestingly, this literature shows that, besides structural factors such as an insufficient economic diversification, weak institutional quality exerts a powerful influence on the ability of countries to adopt productivity-enhancing reforms (Addison and Balliamoune-Lutz, 2006; Arezski and Nabli, 2012). A second strand of literature focuses on macroeconomic stabilization policy in the aftermath of oil price shocks by using dynamic general equilibrium models. An extensive literature has been dedicated to fiscal rules as public spending tend to go hand in hand with oil receipts, generating pro-cyclical policy (El Anshasy and Bradley, 2012; Baunsgaard *et al.*, 2012). Other studies analyze the macroeconomic implications of alternative monetary policy rules for a small open economy hit by external shocks (Medina and Soto, 2005; Devereux *et al.*, 2006).

Our paper is linked to this second strand of literature, and, more especially, on monetary policy. 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 propose 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 motivation is twofold. On the one hand, as oil exporting countries rely heavily on oil export earnings and their growth portrays a high a high dependence on imports -for consumption goods, intermediate inputs, and capital goods- they are particularly exposed to external shocks. As a result, these countries experience higher business cycles volatility relative to other emerging and developing economies (IMF, 2012). On the other hand, as stressed in many IMF Country Report issues, monetary policy instruments are imperfectly transmitted to the real economy through usual transmission channels, and the inflation-output trade-off is far from satisfactory. Indeedexcess liquidity -due to hydrocarbon revenues- is a structural feature of the banking sector, limiting the ability of the central bank to influence the economy through the intereste rate. In this context, determining the best monetary policy rule is particularly critical.

The estimated model differs from the previous literature in many aspects. First, given that in several oil exporting countries, authorities aim 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, following Dib (2008b), two exchange rates are introduced: the U.S. dollar/Algerian dinar and the euro/U.S. dollar. The first exchange rate is the exports' currency and the second represents a part of the imports' currency. Third, as in Algeria, we assume that (i) oil resource is used in the production function of the oil firm; (ii) the refined oil is used as an input in non-oil production, and (iii) oil price is subsidized. In addition to these features, we assume that prices are sticky in the non-oil and import sectors. This allows monetary policy to play a role.

Three alternative monetary policy rules are analyzed: 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 oil exporting countries, the presence of the oil component in headline CPI inflation raises the question whether the relevant measure of inflation is the headline inflation or the core inflation. In the spirit of the seminal study by Poole (1970), the criterion to assess the best monetary rule is its ability to stabilize both output and inflation.

Our main findings are twofold. First, the estimate of the model shows that foreign shocks are the main disturbances hitting the Algerian economy. In addition, real shocks -e.g. oil price and real exchange rate shocks- tend to exert a stronger influence on domestic variables than nominal ones (international interest rates and international inflation). Second, the prevalence of real external shocks has important implications to assess the choice of the best monetary policy rule. Indeed, as suggested by the pioneer work by Svensson (2000), a strict inflation targeting -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, in particular when the economy is mainly affected by real shocks. We find that, over the period 1990Q1-2010Q4, core inflation monetary rule allows the best combination in terms of price stability and low volatility of production.

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. It presents the estimation results. Section 4 measures the welfare effect of the external shocks under alternative monetary policy rules. Section 5 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.

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:

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

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

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

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:

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

where ϕ denotes the parameter measuring the risk premium, e_t and ξ_t are two exchange rates[2]: the US dollar/ Algerian dinar (USD/DZD hereafter) and the euro/US dollar (EUR/USD hereafter) respectively and $\tilde{B}_t^f$ 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[3]. In our case, we assume that $B_t^f < 0$ to the extent that the Algerian economy is net borrower. This assumption rests on the fact that foreign liabilities exceed foreign assets excluding foreign exchange reserves. 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. 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-

---

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

[3] 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.

oil sectors for nominal rental $Q_{o,t}$ and $Q_{no,t}$ respectively. The evolution of capital stock in each sector is given by:

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

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 by:

$$\Psi_{j,t}(.) = \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right)^2 k_{j,t}, \text{for } j{=}o{,}no \quad (6)$$

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

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

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.

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. Despite the increase in domestic oil consumption since 2000, it accounts in average for 12.5 percent of the total oil production[4]. This simplifying assumption is thus consistent with the situation in Algeria.

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

[4] Source: BP Statistical Review of World Energy.

$$\max_{k_{o,t},h_{o,t},O_t} \left[e_t P^f_{o,t} Y_{o,t} - Q_{o,t} k_{o,t} - W_{o,t} h_{o,t} - P_{O,t} O_t \right], \quad (8)$$

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

To resolve (8), firms must consider their function of production given by the following Cobb-Douglas technology:

$$Y_{o,t} \leq A_{o,t} k^{\alpha_o}_{o,t} h^{\beta_o}_{o,t} O^{\theta_o}_t , \quad (9)$$

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.

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:

$$Y_{no,t}(i) \leq A_{no,t} k^{\alpha_{no}}_{no,t}(i) h^{\beta_{no}}_{no,t}(i) {Y^I_{o,t}}^{\theta_{no}}(i), \quad (10)$$

where $k_{no,t}(i), h_{no,t}(i)$ and $Y^I_{o,t}(i)$ are used by firms to produce the non-oil goods. $A_{no,t}$ is a technology shock specific to the non-oil sector.

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, $Y^I_{o,t}$, used as an input in the production of non-oil goods. To maximize its profit, the producer i chooses $\{K_{no,t}(i), h_{no,t}(i) \text{ and } Y^I_{o,t}(i)\}$ and sets its price, $\tilde{P}_{no,t}(i)$ *à la* Calvo (1983).

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).

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, $Y_{I,t}$:

$$z_t = \left[\chi_{no}^{\frac{1}{\tau}} Y_{no}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}} Y_I^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}}, \tag{11}$$

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 $\chi_{no} + \chi_I = 1$.

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:

$$\frac{(1+R_{t+1})}{(1+\overline{R})} = \left(\frac{P_{no,t}}{P_{no,t-1}} \frac{1}{\overline{\pi}_{no}} \right)^{\mu_{\pi_{no}}} \left(\frac{P_t}{P_{t-1}} \frac{1}{\overline{\pi}} \right)^{\mu_{\pi}} \left(\frac{\Delta e_t}{\Delta \overline{e}} \right)^{\mu_e} \exp(\varepsilon_R), \tag{12}$$

where $\bar{R}, \bar{\pi}_{no}, \bar{\pi},$ and $\Delta\bar{e}$ 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[5], the oil domestically used (refined oil), $Y^{I}_{o,t}$, 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, $P^{f}_{o,t}$, denominated in the foreign currency.

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 *etal.* (2008) and Benkhodja (2014), 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:

$$P_{o,t} = (1-\upsilon)P_{o,t-1} + \upsilon e_t \xi_t P^{f}_{o,t}, \tag{13}$$

[5]As in Algeria, or, for instance, in Iran.

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:

$$\varpi \sum_{j=o,T,nT} W_{j,t}h_{j,t} + s_t p^f_{o,t} Y_{o,t} = \left(s_t \Xi_t p^f_{o,t} - p_{o,t}\right) Y^I_{o,t} + w_{o,t}h_{o,t} + q_{o,t}k_{o,t}, \tag{14}$$

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 $\left(w_{o,t}h_{o,t} + q_{o,t}k_{o,t}\right)$ in the oil sector and the amount of oil's subsidies $\left(s_t \Xi_t p^f_{o,t} - p_{o,t}\right) Y^I_{o,t}$.

3 Model estimation

In this section, we estimate the model by using the Bayesian method. In a first step, we present the methodology, data, and prior distributions. In a second step, we analyze the responses of the GDP, headline inflation, core inflation, and real exchange rate to external shocks[6]. In a last step, we show the responses of these domestic variables under alternative policy rules.

3.1 Calibration, data and priors

The model is estimated by using the Bayesian method. There are 30 parameters to be estimated gathered in Θ[7] The rest of the parameters are calibrated, as commonly done in the DSGE

---

[6] Results concerning the estimates of the baseline model are available in the working paper version of this article. See http://economix.fr/pdf/dt/2011/WP_EcoX_2011-39.pdf.

[7] Θ ={ ϕ_{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},

literature. Table 1 reports the calibration values[8].

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 *etal.*(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 0.0.25. 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 (2012), 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 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

---

$\rho_{a_{no}}$, 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, σ_ξ }

[8] See Appendix for Tables and Figures.

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, 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.

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 Responses of domestic variables to external shocks

Table 3 suggests that monetary policy in Algeria faces a volatile environment. 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, shocks are particularly persistent.Variance decomposition exhibits a particularly strong sensitivity of the economy to real shocks, including oil prices shocks and exchange rate ones (Table 4). So, in the rest of this paper, we consider the responses of domestic variables to these two external disturbances[9].

As expected, GDP increases after a positive oil price shock. Such response is consistent with the sensitiveness of the economy to oil sector. Sticky prices, in part due to the presence of subsidize and administrated prices explain the immediate responses of inflation: while the reaction is weak

[9] For an analysis of the other external shocks, see the working paper version of this paper.

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. We find that the real exchange rate does not respond to oil shock. This finding contrasts with other studies on oil-exporting countries -in which the domestic currency tends to appreciate in real terms after a positive oil price shock- but it is consistent with the priority attached by the monetary authorities to the stability of the real exchange rate.

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 reacts negatively to a depreciation of the dollar against the euro. 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. The real exchange rate appreciates on the impact of the shock, but the response is short-lived.

3.2.1 External shocks under alternative monetary policy rules

Figures 1 and 2 in Appendix 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.

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 show that 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. More specifically, we see that GDP exhibits the weakest contemporaneous response under the core-inflation targeting rule. 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, the GDP follows 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.

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.

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 2 shows that GDP exhibits 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, the responses of the real exchange rate are short-lived whatever the monetary rule. Secondly, 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.

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.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.

Table 5 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 exchange rate shock. 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 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.

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. Addison, T. and M. Baliamoune-Lutz (2006), Economic Reform When Institutional Quality is Weak: The Case of the Maghreb. *Journal of Policy Modeling* 28: 1029–1043.
2. Arezki R., T., Gylfason, and A., Sy (editors) (2011), *Beyond The Curse, Policies to Harness The Power of Natural Resources*, International Monetary Fund, Washington D.C.
3. Arezki, R. and M.K. Nabli (2012), Natural Resources, Volatility, and Inclusive Growth: Perspectives from the Middle East and North Africa. *IMF Working Paper*, WP/12/111, April.
4. Baunsgaard, T., M. Villafuerte, M. Poplawski-Ribeiro, and C. Richmond (2012), Fiscal Frameworks for Resource Rich Developing Countries, *IMF Staff Discussion Note*, SDN/12/04.
5. Benkhodja, M.T (2014). Monetary Policy and the Dutch Disease Effects in a Small Open Oil Exporting Economy. *International Economics* 138: 78-102.
6. 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.
7. Breisinger, C., X. Diao, and M. Wiebelt (2014), Can Oil-Led Growth and Structural Change Go Hand in Hand in Ghana? *Journal of Policy Modeling* 36: 507-523.
8. Calvo, G. (1983). Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics* 12: 383-398.
9. Devereux, M., P. R. Lane, and J. Xu (2006). Exchange Rate and Monetary Policy in Emerging Market Economies. *The Economic Journal* 116: 478–506.
10. 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.
11. 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.
12. Dib, A. (2008b). Dynamic Effects of the U.S. Dollar Fluctuations in a Small Open Oil Exporting Economy: The Case of Algeria. Manuscript.
13. El Anshasy, A.A., and M.D. Bradley (2012), Oil Prices and the Fiscal Policy Response in Oil-Exporting Countries. *Journal of Policy Modeling* 34: 605-620.

IMF (2012), Commodity Price Swings and Commodity Exporters, in *World Economic Outlook*, April, 125-169.

14. 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.
15. Parrado R. (2004). Inflation Targeting and Exchange Rate Rules in an Open Economy. IMF Working Paper, WP/04/21, February.
16. Ploeg, F. van der (2011), Natural Resources: Curse or Blessing? *Journal of Economic Literature* 49: 366-420.
17. Poole, W. (1970), Optimal Choice of Monetary Policy Instruments in a Simple Stochastic Macro Model. *The Quarterly Journal of Economics* 84: 197-216.
18. Rabanal, P. and J.F. Rubio-Ramirez (2005). Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach. *Journal of Monetary Economics* 52: 1151-1166.
19. Svensson, L.E.O. (2000). Open Economy Inflation Targeting. *Journal of International Economics* 50: 155–83.

Appendix

Table 1: Calibration and 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-sumtaxparameter	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
Oilpriceruleparameter	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

Table 2: Prior distribution of the estimated parameters

				Priors	
Coefficient	Description	Domain	Density	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	$\Re$	Normal	5	2.00
ψ_{no}	Cap-adjust-non-oil	$\Re$	Normal	5	2.00
ϑ	Inter-goodselasticity	$\Re^+$	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

Table 2 (continued)

$\mu_{\pi_{no}}$	Coreinfpol-rule	$\Re$	Normal	0.70	0.30
μ_{π}	Inflation pol-rule	$\Re$	Normal	0.50	0.30
μ_{e}	Exch-rate pol-rule	$\Re$	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 oilprice	$[0\,1]$	Beta	0.65	0.20
ρ_{O}	AR oilresource	$[0\,1]$	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	$\Re^+$	InvGamma	0.5	inf
σ_{a_o}	s.doil produc	$\Re^+$	InvGamma	0.5	inf
$\sigma_{a_{no}}$	s.dnon-oil produc	$\Re^+$	InvGamma	0.5	inf
σ_{π^f}	s.d world inflation	$\Re^+$	InvGamma	0.5	inf
$\sigma_{p_o^f}$	s.doilprice	$\Re^+$	InvGamma	0.5	inf
σ_{O}	s.doilresource	$\Re^+$	InvGamma	0.5	inf
σ_{ξ}	s.d EURO/USD	$\Re^+$	InvGamma	0.5	inf

Table 3: 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

Table 3 (continued)

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			

Table 4: 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

Table 5: Welfare results (in % of the steady state of consumption)

	Oilprice	EUR/USD	All shocks*
Monetarypolicyrules			
ER rule	3.4000	0.6042	4.7510
IT rule	1.4187	0.6110	4.6051
CIT rule	4.6850	0.6754	4.0779

* Including international interest rates and world inflation shocks.

Impulse response functions

Figure 1: The effect of 1% positive oil price shock

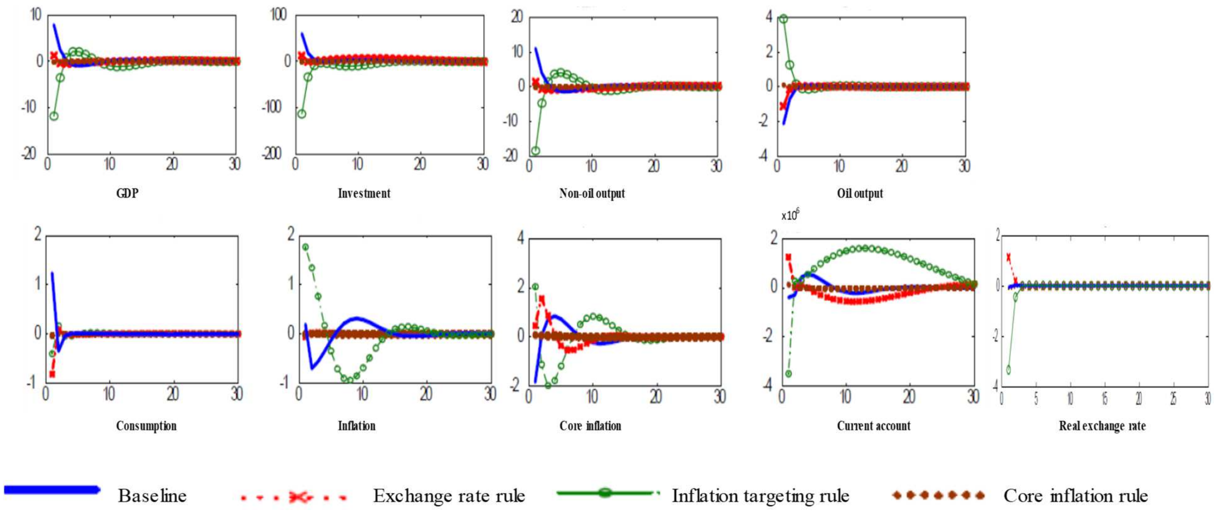

Figure 2:The effect of 1% positive EUR/USD shock