

## OIL DEPENDENCE AND BUSINESS CYCLES IN ALGERIA: NEW KEYNESIAN DSGE FRAMEWORK ANALYSIS

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### ABSTRACT

This study aims to investigate the macroeconomic effect of oil price shock in Algeria at different levels of oil dependency. To do this, an extensive version of small open DSGE model developed by Medina and Soto (2005) has been used. This version of DSGE model is attentive to the fact that the Algerian economic structure is characterized by oil dependency. After we calibrate model parameters, this paper presents simulation results for positive oil price shock to illustrate how the structure of the model and its theoretical underpinnings shape the transmission of the shock to real variables of the domestic economy. In particular, the paper shows 3D impulse responses for oil price shock and characterizes their impact on real GDP, CPI inflation, external position and real effective exchange rate. The results show that the effect of the real oil price shock on the main macroeconomic variables varies according to the level of oil dependency. High oil dependence makes the economy more vulnerable to oil price fluctuations compared to low oil dependence. Therefore, structural transformation is unavoidable necessity for Algerian economy.

**KEY WORDS:** Business Cycles Fluctuation, oil-exporting economy, DSGE Model, oil dependence, Algeria.

**JEL CLASSIFICATION :** E30, E31, E32, F41 Q35.

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## تبعية النفطية و الدورات الاقتصادية في الجزائر:

### تحليل ضمن اطار نيوكنزي DSGE

#### ملخص

تهدف هذه الورقة الى دراسة الاثر الاقتصادي الكلي للصدمة في أسعار النفط في الجزائر عند مستويات مختلفة من التبعية النفطية. للقيام بذلك تم الاستعانة بنسخة موسعة من نموذج DSGE لاقتصاد صغير مفتوح المطور من طرف Medina and Soto (2005). تهتم هذه النسخة من نموذج DSGE بحقيقة أن هيكل الاقتصاد الجزائري يتميز بالتبعية النفطية. بعد معايرة معلمات النموذج، تظهر الورقة الاستجابات الدافعة ثلاثية الأبعاد لصدمة أسعار النفط وتميز تأثيرها على الناتج المحلي الإجمالي الحقيقي، وتضخم مؤشر أسعار المستهلكين، والمركز الخارجي، وسعر الصرف الفعلي الحقيقي. بينت النتائج في مجملها أن تأثير صدمة أسعار النفط الحقيقية على متغيرات الاقتصاد الكلي الرئيسية يختلف باختلاف مستوى التبعية النفطية، الاعتماد الكبير على النفط يجعل الاقتصاد أكثر عرضة لتقلبات أسعار النفط مقارنة بالاعتماد المنخفض على النفط. لذلك فإن التحول الهيكلي ضرورة حتمية للاقتصاد الجزائري.

#### كلمات مفتاحية

تقلبات الدورات الاقتصادية، الاقتصادات المصدرة للنفط، نموذج DSGE، التبعية النفطية، الجزائر.

تصنيف جال: E30, E31, E32, F41 Q35.

## **DEPENDANCE PETROLIERE ET CYCLES ECONOMIQUES EN ALGERIE : CADRE D'ANALYSE NOUVELLE KEYNESIENNE DSGE**

### **RÉSUMÉ**

Le but de ce papier est d'étudier l'effet macroéconomique du choc pétrolier en Algérie à différents niveaux de dépendance au pétrole. Pour ce faire, une version extensive du petit modèle DSGE ouvert développé par Medina et Soto (2005) a été utilisée. Cette version du modèle DSGE est attentive au fait que la structure économique algérienne est caractérisée par la dépendance au pétrole. Après avoir calibré les paramètres du modèle, cet article présente des résultats de simulation un choc positif sur les prix du pétrole afin d'illustrer comment la structure du modèle et ses fondements théoriques façonnent la transmission du choc aux variables réelles de l'économie nationale. En particulier, le papier montre les réponses impulsionnelles en 3D pour le choc des prix du pétrole et caractérise leur impact sur le PIB réel, l'inflation, la position extérieure et le taux de change effectif réel. Les résultats montrent que l'effet du choc des prix réels du pétrole sur les principales variables macroéconomiques varie en fonction du niveau de dépendance au pétrole. Une forte dépendance au pétrole rend l'économie plus vulnérable aux fluctuations des prix du pétrole qu'une faible dépendance au pétrole. Par conséquent, la transformation structurelle est une nécessité incontournable pour l'économie algérienne.

### **LES MOTS CLÉS**

Fluctuation des cycles économiques, économie exportatrice de pétrole, modèle DSGE, dépendance au pétrole, Algérie

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## INTRODUCTION

Commodity dependence, could be defined as the state characterizing countries that derive at least 60 per cent of their merchandise export earnings from the commodity sector, has been shown to be associated with several challenges include macroeconomic instability. (UNCTAD 2021).

The large fluctuations in oil prices that have appeared recently have brought to mind once again the importance of studying the macroeconomic effects of oil price shocks. Significant oil prices fluctuation influences real economic variables, especially in the countries with large dependency on oil exports. Mustapha and Masih (2016).

Algeria is highly specialized in hydrocarbons. The sector accounts for about half of total output, three-quarters of fiscal revenues, and 98 percent of according to IMF estimates. Furthermore, the manufacturing sector represents a relatively small percentage of total output, even for an oil-concentrated economy. Given this pattern of specialization, it is not surprising that aggregate growth in Algeria is driven in large part by hydrocarbon prices.

Algeria is currently facing substantial challenges due to the sharp fall in the international price of oil in 2014 and 2015, which has strained public finances. The fall in the value of hydrocarbons exports has also led to rapid deterioration in the current account balances, which stood at a deficit of 16.5% of GDP in 2015 and a similar figure in 2016, according to IMF estimates. However, tight control over spending has seen the fiscal deficit decline to less than a projected 5% in 2017 and under 1% by 2019. Still, the deficit put additional pressure on foreign currency reserves. In such conditions, understanding the mechanism of transmission of oil prices shock is the one of the key factors that allow the economic policy to weaken negative impact of this shock on macroeconomic variables.

In this research we will compare, at different levels of oil dependence, the impact of oil price fluctuations on the following macroeconomic variables: the gross domestic product (GDP),

consumer price index (CPI) inflation, real effective exchange rate and external position. We will answer the following question:

How would be the macroeconomics effect of positive oil price shock on the Algerian economy, in term of stability, at a lower level of oil dependence?

Inspired by Medina and Soto (2005), we describe in this paper an open-economy DSGE model with calibration approach. The calibration is based on Algeria as a small open oil-exporting economy severely hit by oil price shock due to the high dependence on oil sector performance. The choice of the **Medina and Soto (2005)** model is premised on the need to approximate Algerian economic environment with models that address business cycles fluctuations.

Moreover, DSGE models have a number of advantages, a number of studies show that DSGE models have higher performance than non-structural VAR or even Bayesian VAR (now BVAR) models. (Smets and Wouters (2004), Del Negro and Schorfheide (2004), Dib and Gammoudi and Moran (2008), Kilponen and Ripatti (2006)).

Despite the advantages that the new Keynesian DSGE framework proves, very few papers used these models in the study of economic cycles and analysis macroeconomic policy in Algeria. (Dib and Mazouz (2005), Allegret and Benkhodja (2015), Dib and Mazouz (2005), Chaouche and Toumache (2017), Oughlissi (2017), Chaouche and Toumache (2017)).

As far as we know, none of these previous studies has investigated the relationship between oil dependence and the business cycle in Algeria. Therefore, the contribution of this paper is to test whether low oil dependence matters for isolating macroeconomic variables after the oil shock. Specifically, the paper examines through 3D impulse response functions, whether the lower level of oil dependence has different effects, in terms of macroeconomic stability, compared to current level of oil dependence.

The remainder of the paper is organized as follows. Section 2 spells out a small-open-economy DSGE model that explains some features of Algerian macroeconomics data as an oil exporting country. In Section

3, we discuss the procedure of parameters calibration. Section 4 discusses the simulation results and finally we bring to a close in Section 6 with concluding remarks.

## 1- THE NK-DSGE MODEL

The model in this paper, as previously mentioned, builds extensively on the work of Medina and Soto (2005) that lays out the structure of a basic small open economy New Keynesian DSGE model. This basic model has been extended as in Algozhina (2015) and Allegret & Benkhodja (2015) Benkhodja (2018) to account for the specific features associated with oil production, accumulation and use of oil revenues in the economy of Algeria.

The oil exporting economy consists of a representative household, firms producing final goods, a firm producing oil and authority that sets monetary policy in the country. The household uses a variety of final goods, offers its labor on the market. There are many firms in the country that they produce diversified products under monopolistic competition and nominal price rigidity. The representative household owns non-oil firms and receives profit from them. All firms use oil in their production and purchase it at a price prevailing on the world oil market. Oil sector determines the volume of oil production to maximize its profits. Capital-intensive oil production has only capital input affected by a real FDI shock, we assume that government, which is the owner of the oil firm, and all oil production is exported.

### 1.1- Household

The domestic economy is inhabited by a continuum of households.

Habits are formed at the level of the aggregate consumption good. Utility is derived from the habit-adjusted composite consumption good  $\tilde{C}_t$ .

$$\tilde{C}_t = C_t - hC_{t-1}$$

where  $C_t$  is the composite consumption index and  $h$  is the habit persistence parameter.

The objective of the consumer is to maximize the expected value of the discounted sum of period utility function:

$$\sum_{t=0}^{\infty} \beta^t \left\{ \exp g_t \left[ \frac{\tilde{C}_t^{1-1/\sigma}}{1-1/\sigma} - \frac{L_t^{1+\sigma_L}}{1+\sigma_L} \right] \right\} \quad (1)$$

Under the sequence of budget constraints:

$$\tilde{C}_t + \frac{B_t}{R_t P_t} \leq \frac{B_{t-1}}{P_t} + \frac{W_t}{P_t} L_t + \frac{T_t}{P_t} \quad (2)$$

Where  $\tilde{C}_t$  is aggregate consumption;  $L_t$  is employment; and  $g_t$  is domestic demand shock;  $B_t$  is bonds;  $R_t$  is nominal interest rate;  $W_t$  is nominal wage; and  $T_t$  is net lump-sum transfers from the government. Parameters  $\beta$ ,  $\sigma$  and  $\sigma_L$  are respectively the discount factor, the intertemporal substitution of consumption and the inverse elasticity of labor supply with respect to real wages.

Aggregate consumption is a composite of fuel (Oil) consumption  $C_{o,t}$  and of non-fuel consumption (core consumption)  $C_{q,t}$ :

$$C_t = \left[ (1 - \gamma_c) \frac{1}{\eta_o} (C_{q,t})^{\frac{\eta_o-1}{\eta_o}} + \gamma_c \frac{1}{\eta_o} (C_{o,t})^{\frac{\eta_o-1}{\eta_o}} \right]^{\frac{\eta_o}{\eta_o-1}} \quad (3)$$

Core consumption is a composite of domestic (H) and Foreign (F) goods:

$$C_{q,t} = \left[ (1 - \alpha_c) \frac{1}{\eta_c} (C_{H,t})^{\frac{\eta_c-1}{\eta_c}} + \alpha_c \frac{1}{\eta_c} (C_{F,t})^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c-1}} \quad (4)$$

Where  $\eta_o$ ,  $\eta_c$  are, respectively, the elasticity of substitution between Oil and core consumption, and the intertemporal elasticity of substitution between Home and Foreign goods. Parameter  $\gamma_c$ ,  $\alpha_c$  are, respectively, the fraction of oil in the total consumption basket and the share of foreign (imported) goods in the core consumption basket, it can be also referred to natural index of openness.

The demand functions for Oil and core consumption are given by:

$$C_{q,t} = (1 - \gamma_c) \left( \frac{P_{q,t}}{P_t} \right)^{-\eta_o} C_t, \quad C_{o,t} = \gamma_c \left( \frac{P_{o,t}}{P_t} \right)^{-\eta_o} C_t \quad (5)$$

The demand functions for Home and Foreign goods are given by:

$$C_{H,t} = (1 - \alpha_c) \left( \frac{P_{H,t}}{P_t} \right)^{-\eta_c} C_{q,t} \quad , \quad C_{F,t} = \alpha_c \left( \frac{P_{F,t}}{P_t} \right)^{-\eta_c} C_{q,t} \quad (6)$$

The consumption-based price index (CPI),  $P_t$ , and the core consumption price index  $P_{q,t}$ , which excludes the price of Oil, are given by:

$$P_t = [(1 - \gamma_c) P_{q,t}^{1-\eta_o} + \gamma_c P_{o,t}^{1-\eta_o}]^{\frac{1}{1-\eta_o}} \quad , \quad P_{q,t} = [(1 - \alpha_c) P_{H,t}^{1-\eta_c} + \alpha_c P_{F,t}^{1-\eta_c}]^{\frac{1}{1-\eta_c}} \quad (7)$$

Where  $P_{H,t}$  and  $P_{F,t}$  are, respectively, the price of domestic and imported consumption basket.

The household maximizes equation (1) with respect to consumption, domestic bond holdings, and labor supply subject to (2). The first order conditions for this optimization problem are given by:

$$\tilde{C}_t^{1/\sigma} L_t^{\sigma L} = \frac{W_t}{P_t} \quad (8)$$

$$\beta E_t \left( \frac{\exp g_{t+1}}{\exp g_t} \right) \left( \frac{\tilde{C}_{t+1}}{\tilde{C}_t} \right)^{-\frac{1}{\sigma}} \left( \frac{P_t}{P_{t+1}} \right) R_t = 1 \quad (9)$$

Where equation (6) is the first order conditions linked to labor supply decisions, and (7) is the first order condition associated with home bond holdings.

### 1.2- Domestic Firms (non-oil sector)

Non-oil sector, indexed by H, is represented by the continuum of firms  $j \in (0,1)$ , each using labor  $L_t$ , and oil  $O_t$  to produce its output based on Cobb-Douglas technology:

$$Y_{H,t}(j) = A_t L_t(j)^\alpha O_t(j)^{(1-\alpha)} \quad (10)$$

Where parameter  $\alpha$  is The share of labor in non-oil sector output and  $A_t$  is the non-oil sector technology shock following AR(1) process:

$$\log A_t = \rho_a \log A_{t-1} + \varepsilon_{a,t} \quad , \quad \varepsilon_{a,t} \sim (0, \sigma_a) \quad (11)$$

Where  $\rho_a \in (0,1)$  is the autocorrelation coefficient showing the persistence of non-oil production technology and  $\varepsilon_{a,t}$  is random variable with mean zero and finite standard deviation  $\sigma_a$ .



To maximize its profit, the producer  $j$  chooses  $L_t(j)$  and  $O_t(j)$  and sets its price, à la Calvo (1983). Following to Calvo (1983) rule, in each period, a typical firm sets a new price with probability  $1 - \phi_c$ , independently of the time that has passed since the firm last changed its price, and keeps its current price with probability  $\phi_c$ . Those firms that are to change their price do so by choosing the price  $\bar{P}_{H,t}(j)$  so as to maximize the present discounted value of the flow of profits according to the following problem:

$$\max_{\bar{P}_{H,t}} \sum_{k=0}^{\infty} (\theta \phi_c)^k E_t \{ Q_{t,t+k} [Y_{H,t+k} (\bar{P}_{H,t} - MC_{t+k})] \} \quad (12)$$

Subject to:

$$Y_{H,t+k}(j) = \left( \frac{\bar{P}_{H,t}}{\bar{P}_{H,t+k}} \right)^{-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*) \quad (13)$$

Where  $C_{H,t+k}^*$  denotes the foreign demand for home goods. Note that in equation (11), it is implicitly assumed that the home consumption good is an aggregated bundle of a continuum of varieties. This means that  $C_{H,t} = \left[ \int_0^1 C_{H,t}(j)^{1-\frac{1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}$  such that in equilibrium we must have:

$$Y_{H,t} = \left[ \int_0^1 Y_{H,t}(j)^{1-\frac{1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} = C_{H,t} + C_{H,t}^* \quad (14)$$

In (10)  $MC_{t+k}$  refer to the period  $t + k$  nominal marginal cost and is given by:

$$MC_t = \frac{1}{\alpha^\alpha (1 - \alpha)^{1-\alpha}} \frac{W_t^\alpha (P_t^\alpha)^{1-\alpha}}{A_t} \quad (15)$$

The first order condition for a typical firm implies:

$$\bar{P}_{H,t}(j) = \bar{P}_{H,t} = \frac{\varepsilon}{(\varepsilon - 1)} \frac{\sum_{k=0}^{\infty} (\phi_c \beta)^k E_t \left[ \frac{C_{t+k}^{-1/\sigma}}{P_{t+k}} P_{H,t+k}^{\phi_c} Y_{H,t+k} MC_{t+k} \right]}{\sum_{k=0}^{\infty} (\phi_c \beta)^k E_t \left[ \frac{C_{t+k}^{-1/\sigma}}{P_{t+k}} P_{H,t+k}^{\phi_c} Y_{H,t+k} \right]} \quad (16)$$

Since all the firms that can reoptimize in a given period face the same decision problem, they will choose a common new price  $\bar{P}_{H,t}$ . The CES aggregate for the price level  $P_{H,t}$  can then be rewritten as:

$$P_{H,t} = [\phi_c P_{H,t-1}^{1-\varepsilon} + (1 - \phi_c) \bar{P}_{H,t}^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \quad (17)$$

### 1.3- Oil Sector

Oil sector, indexed by O, is represented by oil firms that works in competitive market. Same to Aliya Algoosina (2016) each firm using capita  $K_{o,t}$  to produce its output assuming that oil production is a capital-intensive sector:

$$Y_{o,t} = A_{o,t} K_{o,t}^{\gamma_o} \quad (18)$$

Where:  $\gamma_o \in [0,1]$ ,  $A_{o,t}$  are, respectively, the share of capita in oil sector output and technology shock following AR(1) process:

$$\log A_{o,t} = \rho_{a,o} \log A_{o,t-1} + \varepsilon_{ao,t}, \quad \varepsilon_{ao,t} \sim (0, \sigma_{ao}) \quad (19)$$

Where  $\rho_{a,o}$  is the autocorrelation coefficient showing the persistence of oil production technology and  $\varepsilon_{ao,t}$  is random walk variable.

The capital in oil firms is accumulated by FDI which follows an exogenous AR (1) process:

$$k_{o,t} = (1 - \delta)k_{o,t-1} + FDI_t \quad (20)$$

And :

$$FDI_t = \rho_{FDI} FDI_{t-1} + \varepsilon_{FDI,t}, \quad \varepsilon_{FDI,t} = \sim (0, \sigma_{ao}) \quad (21)$$

Where  $\rho_{FDI}$  is the autocorrelation coefficient showing the persistence of oil firm capital and  $\varepsilon_{FDI,t}$  is random walk variable.

### 1.4- Foreign Economy

For the sake of simplicity, we assume as Medina and Soto (2005) a symmetric structure for the foreign sector. Thus, the foreign demand for home non-oil goods can be defined as:

$$C_{H,t}^* = (1 - \alpha^*) \left( \frac{P_{H,t}^*}{P} \right)^{-\eta^*} C_t^* \quad (22)$$

Where  $C_{H,t}^*$  is the total demand from the rest of the world.

$(1 - \alpha^*)$  corresponds to the share of domestic non-oil goods in the consumption basket of foreign agents and  $\eta^*$  is the price elasticity of

foreign demand. By assuming that domestic firms cannot price differentiate across markets and markets are complete, the law of one price holds for home goods sold abroad  $P_{H,t} = \epsilon_t P_{H,t}^*$  and  $C_t^* = Y_t^*$  the equation (18) can be written as:

$$C_{H,t}^* = (1 - \alpha^*) \left( \frac{1}{RER_t} \frac{P_{H,t}^*}{P_t^*} \right)^{-\eta^*} Y_t^* \quad (23)$$

Where  $RER_t$  is the real exchange rate is defined as the relative price of the foreign consumption basket,  $P_{F,t}$  relative to the price of the domestic consumption basket:

$$RER_t = \frac{\epsilon_t P_t^*}{P_t} = \frac{P_{F,t}}{P_t} \quad (24)$$

Additionally, one of the assumptions made in the open economy models, as suggested by Medina and Soto (2005) is the assumption of complete securities markets which it mean that economic agents have access to the complete set of internationally traded securities, therefor, there is international risk sharing. Based on this assumption we can link domestic consumption with that of the rest of the world as follows:

$$\beta E_t \left( \frac{\exp g_{t+1}}{\exp g_t} \right) \left( \frac{\tilde{C}_{t+1}}{\tilde{C}_t} \right)^{\frac{1}{\sigma}} \frac{P_t}{P_{t+1}} R_t = \beta E_t \left( \frac{\tilde{C}_{t+1}^*}{\tilde{C}_t^*} \right)^{\frac{1}{\sigma}} \frac{P_t}{P_{t+1}} \frac{\epsilon_t}{\epsilon_{t+1}} R_t = 1 \quad (25)$$

This equation indicate that the marginal utility of household's consumption (domestically and externally) should be equal.

Equation (25) can be rewrite in term of real exchange rate  $RER_t$  as:

$$\left( \frac{\tilde{C}_{t+1}}{\tilde{C}_{t+1}^*} \right)^{\frac{1}{\sigma}} RER_t \exp g_{t+1} = \left( \frac{\tilde{C}_t}{\tilde{C}_t^*} \right)^{\frac{1}{\sigma}} RER_t \exp g_t \quad (26)$$

Using equation (7) the definition of  $P_t$  and re-arranging gives as the inflation of the consumption basket, under the assumption of perfect pass through from the exchange rate to imported good prices sold locally:

$$1 = (1 - \alpha_c) \left( \frac{P_{H,t}}{P_t} \right)^{1-\eta_c} + \alpha_c RER_t^{1-\eta_c} \quad (27)$$

In addition, as in Benkhodja, et al (2018) we have two real prices of oil (domestic and foreign) the domestic real price of oil is given by the following expression:

$$\frac{P_{o,t}}{P_t} = (1 - \omega) \frac{P_{o,t-1}}{\pi_t} + \omega RER \frac{P_{o,t}^*}{P_{F,t}^*} \quad (28)$$

Where  $\omega \in [0,1]$  is the oil price rule parameter, indicates the degree of domestic oil price subsidy from the government.  $P_{o,t}^*$  is the price of oil in international market in terms of foreign currency and the ratio  $\frac{P_{o,t}^*}{P_{F,t}^*}$  is assumed to follow AR(1) process:

$$\log \frac{P_{o,t}^*}{P_{F,t}^*} = \rho_{rpo^*} \log \frac{P_{o,t-1}^*}{P_{F,t-1}^*} + \varepsilon_{rpo^*,t}, \quad \varepsilon_{rpo^*,t} \sim (0, \sigma_{rpo^*}) \quad (29)$$

### 1.5- Equilibrium

Goods market clearing in this economy requires that the sum of non-oil output and oil exporting revenues is equal to the sum of total consumption and net export as follow:

$$Y_{GDP,t} = C_t + CA_t \quad (30)$$

$$Y_{GDP,t} = Y_{H,t} + \frac{\epsilon_t P_{o,t}^*}{P_t} Y_{o,t} \quad (31)$$

The log-linear form of equation (31) is given by the following equational form:

$$\hat{y}_{GDP,t} = YH_Y \hat{y}_{H,t} + (1 - YH_Y) \hat{y}_{o,t}$$

Where:  $(1 - YH_Y)$  is the shear of oil exports to total GDP. This is the main parameter in this study as it is used as an indicator of oil dependence.

Goods market clearing in the non-oil sector requires that domestic non-oil output is equal to the sum of domestic consumption and foreign consumption of domestically produced non-oil goods or exports:

$$Y_{H,t} = C_{H,t} + C_{H,t}^* \quad (29)$$

The expression of the aggregate accumulation of international bonds:

$$\frac{\epsilon_t B_t^*}{(1 + i_t^*)P_t} = \frac{\epsilon_t B_{t-1}^*}{P_t} + \frac{P_{X,t} X_t}{P_t} - \frac{P_{M,t} M_t}{P_t}$$

From the rest of aggregate equilibrium conditions, current account can be obtained as:

$$CA_t = \frac{P_{X,t} X_t}{P_t} - \frac{P_{M,t} M_t}{P_t} \quad (32)$$

Where real exports value  $P_{X,t} X_t$  is defined as:

$$\frac{P_{X,t} X_t}{P_t} = \frac{\epsilon_t P_{H,t}^*}{P_t} C_{H,t}^* + \frac{\epsilon_t P_{O,t}^*}{P_t} Y_{O,t} \quad (33)$$

Real imports  $\frac{P_{M,t} M_t}{P_t}$  value is given by:

$$\frac{P_{M,t} M_t}{P_t} = RER_t C_{H,t}^* + \frac{\epsilon_t P_{O,t}^*}{P_t} O_t$$

### 1.6- Monetary Policy

Since monetary aggregates are absent in this model, we assume that the central bank adjusts short-term nominal interest rate in response to fluctuation in core inflation  $\left(\frac{P_{q,t}}{P_{q,t-1}}\right)$  and the CPI inflation  $\left(\frac{P_t}{P_{t-1}}\right)$ . Therefor, the monetary policy rule in this economy can be written as the following Taylor-type relationship:

$$\frac{1 + i_t}{1 + i} = \left(\frac{1 + i_{t-1}}{1 + i}\right)^{\rho i} \left(\frac{P_{q,t}}{P_{q,t-1}}\right)^{(1-\rho i)\varphi_{\pi q}} \left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho i)\varphi_{\pi c}} \quad (35)$$

Where  $i$  denote the steady state values of the corresponding variable,  $\varphi_{\pi q}$  and  $\varphi_{\pi c}$  are weights put by monetary authority, respectively, on Core inflation and CPI inflation. The lagged interest rate serves for interest rate smoothing while  $\rho i$  denotes the extent of persistence of interest rate.

## 2- MODEL CALIBRATION

To simulate the model and analyze the dynamics of key macroeconomic variables in response to oil price shock, the model parameters are calibrated to reflect properties of the Algerian economy as representative oil-exporting economy. Based on calibration process, some parameters are borrowed from previous studies on Algerian economy, particularly, Allegret and Benkhodja (2011), Benkhodja et al (2018) and from previous studies of similar structure economies, while other parameters are set to match the model's steady-state ratios to those observed in Algerian economy data.

As shown in Appendix (1), the discount factor  $\beta$  is set at 0.99, implying an annual steady-state real interest rate 4%. The inverse of intertemporal substitution between consumption  $\sigma$  and the inverse of the labor supply elasticity  $\sigma_L$  are set, respectively, to 2 and 1. We assume that  $\alpha_c$  the share of foreign (imported) goods in the consumption basket and the share of oil in the total consumption basket  $\gamma_c$  are equal to 0.7 and 0.023 respectively. We calibrate the elasticity of substitution among home and foreign goods  $\eta_c$  and among oil and non-oil goods (core consumption)  $\eta_o$  to 0.8 and 0.45, respectively. The parameters  $\eta^*$  determine the price elasticity of foreign demand is set equal to 0.8. The Calvo parameters of price rigidities  $\theta_p$ , wage rigidities  $\theta_w$  and degree of indexation of wages and home goods prices to past inflation  $\chi_w$  and  $\chi_p$  are set at 0.75. The parameters  $\alpha$  the share of labor in non-oil sector production function and  $\gamma_0$  the share of capital in production function of oil sector are suggested to be equal 0.75 and 0.35 respectively. Other parameter in oil sector is depreciation rate of capital  $\delta$  that we calibrate to 0.025. We set the parameters of the elasticity of substitution among different labor varieties  $\varepsilon_w$  and among different goods  $\varepsilon_p$  to 11. The habit formation  $h$  is set to 0.5. The last two structural parameters persistence in foreign direct investment  $\rho_{fdi}$  and oil price parameters  $\omega$  are set at 0.8,0.3 respectively.

The parameters of monetary policy (Taylor rule) are the feedback Taylor rule CPI inflation  $\varphi_{\pi c}$  and the feedback Taylor rule core inflation  $\varphi_{\pi q}$  we calibrate them to 1.8 and 0.5 respectively.

The Steady state ratios parameters are the share of net export in real GDP; NXY and the share of the domestic output in total GDP; YH\_Y , which is our parameter of interest. Based on averages of Algerian annual data<sup>1</sup> over 2000 -2019. we calibrate these two parameters to 0.3 and 0.6 respectively, means that the share of the oil output in total GDP (level of oil dependency) is 0.3.

For the stochastic proses of oil price, the autocorrelation coefficient of real oil prices  $\rho_{rpo^*}$  is set at 0.65 and its standard deviation  $\sigma_{rpo^*}$  at 0.33.

### 3- SIMULATION RESULTS

In order to understand the transmission mechanisms of stochastic oil price shock over key macroeconomic variables and to what extent the oil dependence degree affects those mechanisms, we simulate the calibrated model under different levels of oil dependence, this will allow knowing whether lower oil dependence matters for macroeconomic stabilization.

The results has been discussed using the 3D impulse response function that depicts the dynamic response of macroeconomic variables when the economy hit by the shock. where the vertical z axis represents the deviation of variables from deterministic steady state, the y axis represents the oil dependence levels and the x axis is the time horizon expressed in quarters.

In order to see the potential effect of an increase of oil price, when oil dependence level change. Figures (1) and (2) shows the responses of four key macroeconomic variables to an unanticipated increase of the real price of oil of one standard deviation under different value of

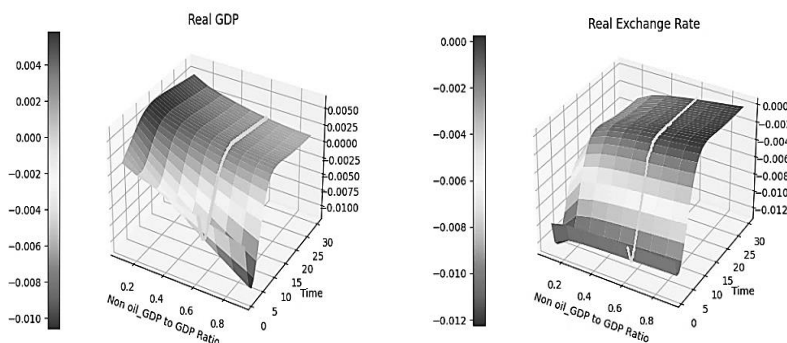
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<sup>1</sup> The data are available from the webpages of the ONS and IFS. They include real GDP, net exports, oil output.

non-oil GDP to GDP ratio as oil dependence indicator, its take value from 0.1 to 0.9 including the baseline model value 0.7.

We assume in our model that the Algerian economy is a refined-oil importer and a small part of households' expenditure is devoted to consuming oil products. As a consequence, positive oil price shock implies negative responses of consumption. the shock also increases cost of firms producing home goods, and their prices relative to the prices of foreign goods increases.

**Figure 1:** Responses of real GDP and real exchange rate to an oil price shock



Note: Yellow represents the line formed by the baseline result.

Source: realized by author.

Moreover, an increase in oil price pushes up oil exports causing an appreciation of the real exchange rate. Therefore, foreign goods become cheaper in international markets. Households will substitute home goods with imported goods which makes an additional expenditure-switching mechanism that lowers even further the non-oil GDP and GDP. This mechanism take place only in the early six (6) quarters post-oil price shock in our base line result.

As oil prices increase ,oil exploration becomes more attractive, which leads to increased resource-seeking FDI flows. As a consequence, oil sector output goes up, which in turn, pushes up the total GDP to increase after it was decreasing and appreciate the external position of the economy after it was deteriorating. We can

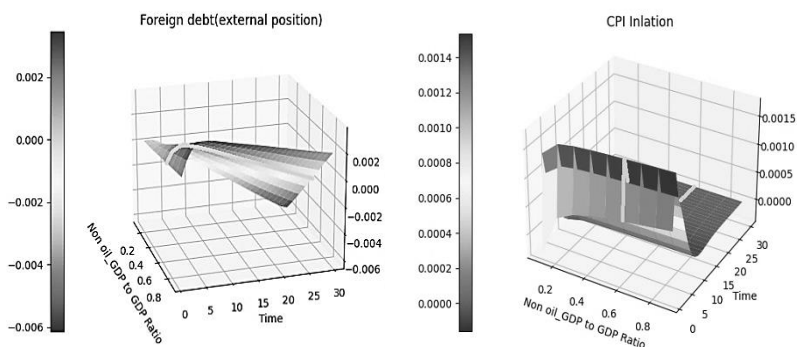


observe the effect of this transformation after the sixth (6) quarters post-oil price shock.

A positive oil price shock, as mentioned earlier, increases the cost of production in the non-oil sector resulting in higher core and CPI inflation. It takes nearly two years for this effect before the rate of inflation returns to steady state level.

**Figure 2:** Responses of foreign debt and CPI inflation to an oil price shock

*Source: realized by author.*

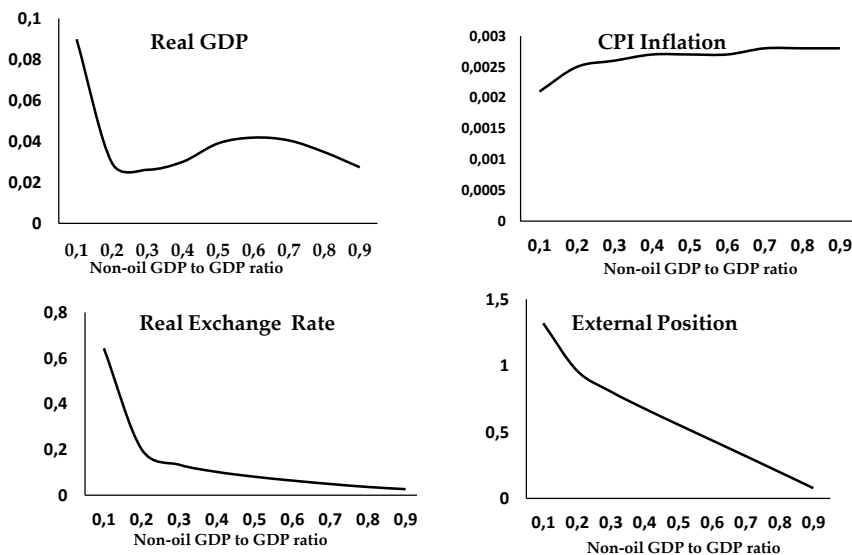


Note: Yellow represents the line formed by the baseline result.

*Source: realized by author.*

From the oil dependence perspective, we can clearly observe from figures (1-2) above that high oil dependence make the economy more -vulnerable to oil price fluctuations, specifically for real exchange rate and external position. For example, if we take the two extreme values of non-oil GDP to GDP ratio (0.1, and 0.9) we note that when non-oil GDP to GDP ratio is close to 0.1, which means there is high oil dependence, the deviation of macroeconomic variables from its long-run level return slowly to their steady-state, but when non-oil GDP to GDP ratio is close to 0.9 which means there is low oil dependence, the deviation of variables returns rapidly to their steady-state level. As a result, when oil dependence level is high the macroeconomic effects of oil price shock are more persistent.

**Figure 3:** The standard deviation of simulated variables at different levels of oil dependency



Source: realized by author

To confirm these results, we calculate the standard deviation of the simulated variables at different levels of oil dependency to determine the size of fluctuations generated by the oil price shock. Figure 3 clearly shows the strong inverse relationship between the size of fluctuations generated by the oil shock and the level of oil dependency for the exchange rate and the external position variables.

However, there is a weak positive relationship between the size of inflation fluctuations generated by the oil shock and the level of oil dependency. the same thing for real GDP specially when non-oil GDP to GDP ratio is between 0.3 and 0.6.

In fact, this result was expected due to the implicit assumption in our model that the Algerian economy is an importer of refined oil, which means that even at low levels of dependence on oil, fluctuations in oil prices will transmitted to some economic variables through refined oil imports.

## CONCLUSION

Inspired by Medina and Soto (2005) small open new Keynesian DSGE model, we present in this paper extended version for an oil exporting country. Along with the non-oil sector, the model includes the oil sector, which plays an important role in the economy. The model is calibrated to the Algerian economy to investigate the dynamic effects of real oil price shock at deferent level of oil dependence. Using the 3D impulse response analysis, we examine the dynamic properties of the model to check its stability and to identify the variables that display interesting dynamics.

As the main result, under the baseline model a positive real oil price shock, total GDP decrease for six quarters post-shock before it become positive then returned to the steady-state. The real exchange rate and external position appreciates a bit more and inflation rises.

Moreover, simulation the model under different levels of oil dependence shows that high oil dependence makes the economy more vulnerable to oil price fluctuations.

Our empirical findings have important policy implications, which is the need to diversify the economy, specifically, export sectors. Therefore, structural transformation is a clear necessity for Algeria.

Finally, the results presented in the paper open several areas for future work, some of which remain empirically challenging, like better inclusion of the fiscal policy in the model as Oil-dependent economies are vulnerable to macroeconomic fiscal instability stemming from high oil price volatility in the short - run and the exhaustibility of oil in the long – run.

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## Appendix

**Tabel 1:** Parameters Calibration

Parameters Description	Values
Subject discount factor	$\beta = 0.99$
The elasticity of intertemporal substitution of consumption	$\sigma = 2$
The inverse of the labor supply elasticity	$\sigma_L = 1$
The habit formation	$h = 0.5$
The share of imported goods in the non-oil consumption basket	$\alpha_c = 0.7$
Depreciation rate of capital	$\delta = 0.025$
The elasticity of substitution among home and foreign goods	$\eta_c = 0.8$
The elasticity of substitution between oil and non-oil or core consumption	$\eta_o = 0.47$
The share of oil in the total consumption basket	$\gamma_c = 0.023$
The Calvo parameter of price rigidities	$\theta_p = 0.75$
The share of labor in production function of non-oil sector	$\alpha = 0.75$
The share of capital in production function of oil sector	$\gamma_0 = 0.35$
The degree of indexation to past inflation of Home goods prices	$\chi_p = 0.75$

The elasticity of substitution among different goods varieties.	$\varepsilon_p = 0.11$
The elasticity of substitution among labor and oil as inputs in non-oil production	$\omega_o = 0.1$
The Calvo's parameter of wage rigidities	$\theta_w = 0.75$
The degree of indexation of wages to past inflation	$\chi_w = 0.75$
The elasticity of substitution among different labor varieties.	$\varepsilon_w = 11$
The price elasticity of foreign demand	$\eta^* = 0.8$
The Oil price parameters	$\omega = 0.3$
Persistence in foreign direct investment	$\rho_{fdi} = 0.8$
<i>monetary policy parameters</i>	
Autocorrelation of monetary policy	$\rho_m = 0.65$
Feedback Taylor rule headline inflation	$\varphi_{\pi c} = 1.8$
Feedback Taylor rule core inflation	$\varphi_{\pi q} = 0.5$
<i>Steady state ratios</i>	
The share of the domestic output in total GDP	YH_Y=0.7
The share of net export in real GDP	NXY=0.15
<i>AR parameters and S.D of real oil price shock</i>	
Autocorrelation real oil price shock	$\rho_{rpo^*} = 0.65$
SD of real oil price shock	$\sigma_{rpo^*} = 0.3$

Source: realized by author