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Oil prices, U.S. dollar fluctuations, and monetary policy in a small open oil exporting economy

We develop a New-Keynesian model of a small-open oil-exporting economy to quantify the dynamic effects of oil price and U.S. dollar fluctuations. Two alternative monetary policies are considered: Taylor-type and money supply rules. Oil, priced in the U.S. dollar, is the only commodity to export and the country borrows and mainly imports in terms of the euro. The country is, therefore, facing two exchange rates : The euro/U.S. dollar and U.S. dollar/Algerian dinar. Simulation results suggest that depreciations of the U.S. dollar have implied large country's terms of trade and current account deteriorations, because of external debt valuation, interest payments, and import prices. However, parallel increases in oil prices have offset these negative effects and led to large improvement of the country's net debt position and current account. Moreover, monetary authority may successfully manage the value of its currency and/or adjust the short-run nominal interest rate to isolate the Algerian economy from these external shocks.

Key words :

Oil-exporting economy model; Exchange rates; Oil prices; U.S. dollar fluctuations; Monetary policy.

Résumé

Nous développons un modèle nouveau keynésien d'une petite économie ouverte exportatrice du pétrole. Le modèle est utilisé afin de quantitativement mesurer les effets dynamiques des fluctuations des prix du pétrole et du dollar américain sur l'économie algérienne. Deux règles de politiques monétaires alternatives sont prises en compte: règle de type de Taylor et règle d'offre monétaire. Le pétrole, dont le prix est déterminé en dollar américain, est le seul produit d'exportation. De plus, la dette extérieure du pays et la majeure partie de ses importations sont contractées en euro. Par conséquent, le pays fait face à deux taux de change : taux de change euro versus dollar américain et taux de change dollar versus dinar algérien. Les résultats de simulation indiquent que la dépréciation du dollar vis-à-vis l'euro a entraîné une forte détérioration du terme d'échange et de la balance de paiement du pays, à cause des effets d'évaluation de la dette extérieure, paiements d'intérêt et les prix des importations. Cependant, l'augmentation parallèle des prix du pétrole a éliminée ces effets négatives, considérablement réduit la dette extérieure, et améliore la balance de paiement du pays. Ainsi, l'autorité monétaire serait capable de gérer de façon efficace la valeur de sa monnaie et/ou manipuler le taux de d'intérêt de court terme afin de mieux protéger l'économie algérienne de chocs externes.

Mots clés :

Modèle de l'économie du pétrole exporté ; Taux de change ; Prix du pétrole ; variation du dollar aux Etats-Unis ; Politique monétaire

مُلخّص

هذه الدراسة تقدِّم نموذجًا كينزيًا جديدًا لإقتصاد صغير منفتح ومصدِّر للنفط بهدف تقييم إنعكاسات تقلبات أسعار النفط وسعر صرف الدولار الأمريكي على الإقتصاد الجزائري. الدراسة تأخذ بعين الإعتبار سياستين نقديتين بديلتين : الأولى على نمط قاعدة تيلور والثانية قاعدة عرض النقود. الدراسة تفترض أنَّ النفط، الذي يُحدَّد ثمنه بالدولار الأمريكي، هو السلعة الوحيدة المصدَّرة إلى الخارج. في حين أنَّ الإقتراض الخارجي وتسعير مُعظم الواردات تَتِمان باليورو. يواجه البلد إذاً سعرين مختلفين للصرف : سعر صرف اليورو مقابل الدولار وسعر صرف الدولار مقابل الدينار الجزائري. النتائج الرئيسة تبيِّن أنَّ إنخفاض قيمة صرف الدولار أدَّت إلى تدهوُّر في معامل تبادل وميزان مدفوعات البلد. هذا التدهوُّر يرجع أساسا إلى تقويم الدين الخارجي وإرتفاع خدمات الدين وكلفة الواردات. من جهة أخرى، إرتفاع أسعار النفط ساهم بشكل كبير في محو الآثار السلبية لإنخفاض قيمة صرف الدولار. إضافة إلى ذلك، تبيِّن الدراسة أنَّه في وسع السلطة النقدية حماية الإقتصاد الجزائري من إنعكاسات التقلبات الخارجية وهذا بإستخدام أمثل للسياسة النقدية عن طريق تغيير سعر صرف الدينار أو التحكم في مُعدَّل فائدة المدى القصير.

الكلمات المفتاحية :

نموذج اقتصادي للبترول المُصَدر، سعر الصرف، سعر البترول، تقلب الدولار الأمريكي، السياسية النقدية

JEL CLASSIFICATION : E4 - E52 - F3 - F4

1 - INTRODUCTION

Since 2001, there have been rapid and significant appreciations of the major currencies relative to the U.S. dollar and currencies pegged to it. For example, since 2002, the U.S. dollar has depreciated by more than 50% relative to the euro, the currency of the Euro Area that has become one of the most important world currencies. Evidence, based on experiences of the exchange rates of several currencies, indicates that these depreciations are largely driven by forces of multilateral adjustments to the large U.S. current account and fiscal imbalances.[1] The U.S. economy occupies a predominant position in the world economy. Therefore, when it incurs an unsustainable current account deficit, all other major currencies will appreciate relative to the U.S. dollar to facilitate global adjustment to the U.S. imbalances. Blanchard, Giavazzi and Sa (2005) analyzes the main forces behind the large U.S. current account deficits and their impacts on the U.S. dollar.[2] Thus, the underlying forces behind these depreciations are not driven by real fundamentals, normally identified as shifts in the demand for and supply of countries' produced goods relative to those produced in the U.S. economy, but by exogenous factors.

On the other hand, world oil prices have largely increased since 2001. For example, oil prices have jumped from about $30 in 2001 to around $150 in the mid of 2008. These rapid oil price soaring is a result of persistent increases in world demand driven, in particular, by the integration of emerging countries into the world economy. Consequently, oil exporting countries have widely benefited from the oil price increases. They have received large revenues from their oil exporting and most of them have accumulated huge amounts of reserves that are denominated in the U.S. dollar.

Therefore, since 2001, oil exporting economies have been affected by two opposite, but correlated, world shocks: The increases in oil prices and the depreciations of the U.S. dollar. The purpose of this paper is to investigate the dynamic effects of these two shocks on oil-exporting economies, and to examine how monetary authorities may accommodate them to offset their negative economic impacts. The oil-exporting economies differ from other developing small-open economies in different aspects. They rely heavily on oil for their exports earnings, and are highly dependent on imported consumption, capital goods, and intermediate inputs for domestic production. They also have more volatile business cycles, and are more crisis prone than small-open developed countries. In light of these features, fluctuations in world oil prices, terms of trade and world interest rates have significant roles on their business cycle fluctuations.

In theory, if country's export earnings are denominated in the U.S. dollar and the country manages its domestic currency relative to the export currency, but borrows and imports in terms of other world currency, let's be the euro, an exogenous depreciation of the U.S. dollar against the import currency will directly affect the current account position through different channels.[3] First, the U.S. dollar depreciation creates valuation effects on the country's external debt : The value of its liabilities increases in terms of the U.S. dollar and domestic currency, even when the country does not borrow fresh funds. Second, increases in external debt lead to a higher country-specific risk premium, implying that the country is facing higher interest rates in the international financial markets and has to pay higher interest payments on its gross liabilities. This significantly increases the costs of its external borrowing. Third, an exogenous depreciation of the U.S. dollar deteriorates the terms of trade (defined as relative export prices to import prices), as export prices become lower in terms of import currency. Thus, if imports, priced in currency other than the U.S. dollar, slowly adjust to the shocks, the current account incurs a deficit, at least, in the short term.

To investigate the impacts of the recent U.S. dollar depreciation and oil price increases, we develop a quantitative dynamic-optimizing model of a small open oil-exporting economy with microeconomic foundations, price rigidities, and several domestic and world shocks. This model is a class of New-Keynesian dynamic and stochastic general equilibrium (DSGE) models that have become the main tool used in macroeconomics to answer different questions related to business cycle fluctuations in both closed and open economies. In addition, several central banks are using these structural DSGE models for monetary policy analysis.[4] These models are structural because their equilibrium conditions are derived from the agents' optimization problems, and their deep parameters do not depend on the behavior of the economic agents. Also, introducing price rigidities implies non-neutral monetary policy in the short term and allows the deviation from the law of one price in the import sector, leading to incomplete pass-through effects of exchange rate movements.

The model, in this paper, is based on recent studies that have developed models for small open developed and emerging economies (Bergin 2003, Devereux and Yetman 2003, Dib 2003 and 2008, Kollmann 2001, and others). We model the recent U.S. dollar depreciations as exogenous shocks to the bilateral euro/U.S dollar exchange rate. These shocks, besides oil-price shocks, are another important source of terms of trade fluctuations. Therefore, any exogenous U.S. dollar depreciation increases import prices, which in turn decreases the terms of trade, deteriorates the country's current account, and slows down the economic activity.

The model is calibrated to Algeria (an oil-exporting country). The main features of its economy are: (1) the country manages its domestic currency (the Algerian dinar) to the U.S. dollar; (2) oil accounts for more than 95% of its exports with prices denominated in the U.S. dollar and set in the world markets; (3) 65% of its imports are invoiced in the euro; (4) the country is a net debtor to the rest of the world, with at least 60% of its foreign debt issued in currencies other than the U.S. dollar;[5] and (5) its current accounts position highly depends on oil-price fluctuations.

To build a DSGE model for this economy, we make several assumptions. First, oil is the only tradable goods with prices, denominated in the U.S. dollar, evolve exogenously in the world markets. Second, total imports are either invoiced in the U.S. dollar or in the euro (we assume that 35% of imports are invoiced in the U.S. dollar, while 65% are invoiced in the euro). Third, the country has access to the international financial market where it can buy or sell non-contingent one period euro-denominated bonds at prices that depend on the world interest rate and country-specific risk premium. Fourth, the monetary authority (a central bank) conducts its monetary policy following a standard Taylor-type rule and manages the exchange rate of the Algerian dinar relative to the U.S. dollar. Finally, the monetary authority intervenes to optimally reallocate the resources in the economy.

Since the country exports in the U.S. dollar and mainly imports in the euro, it faces two exchange rates: The U.S dollar/Algerian dinar and the euro/U.S. dollar exchange rates. The U.S dollar/Algerian dinar exchange rate endogenously evolves in the model and determined by the Algerian economic fundamental. The euro/U.S. dollar exchange rate, however, exogenously evolves following a first-order auto-regressive stochastic process. This assumption is motivated by the fact that Algeria is a small open economy that takes the value of the U.S. dollar against other major world currencies as given.

The model is simulated under two alternative monetary policy rules: A Taylor-type rule and money supply rule. The simulation results show that, overall, the responses of key macroeconomic variables to these shocks are very similar under both alternative monetary policies. Main finding is that the U.S. dollar depreciation and oil-price shocks are among the main sources of Algerian business cycles. Furthermore, as expected by the theory, the U.S. dollar depreciation shocks have deteriorated the country's terms of trade and current account, as they increase the external debt and reduce export earnings in terms of the euro. In contrast, parallel positive oil-price shocks and the increase in oil production have offset the major negative impacts of the U.S. dollar depreciations. The movements of the euro/U.S. dollar exchange rate also generate high volatility in the economy and their negative effects are persistent. Nevertheless, the monetary authority may use devaluationary and monetary policies to neutralize the effects of these shocks.

The remainder of the paper is organized as follows. Section 2 develops a theoretical model. Section 3 discusses coefficient parametrization. Section 4 analyzes the simulation results. Finally, section 5 concludes.

2 - THE MODEL

We consider a small open economy inhabited by six agents: households, a final good producer, an oil producing firm, a continuum of non-oil producers, a continuum of importers, and a monetary authority. The agents take the world nominal interest rate, oil price, and imported-goods prices as given. Households have access to incomplete international financial markets where they can buy or sell euro-denominated bonds. The oil producer produces crude oil for export, using capital and a natural-resource factor. Oil prices are denominated in the terms of the U.S. dollar in world markets.

Imported and non-oil goods prices are sticky. In non-oil sector, each producer produces a distinct non-tradable intermediate good using capital and labour. The importers, however, import a homogeneous good produced abroad to produce a differentiated intermediate goods for the domestic market. It is assumed that a fraction α of total imports are invoiced in the U.S. dollar (hereafter, USD), while a fraction (1-α) is invoiced in the euro (hereafter, EUR). The final good producer aggregates the domestic- and imported-intermediate goods to produce a final good that is divided between consumption, government spending, and investment.

We consider two alternative monetary policy rules: A Taylor-type rule and a money supply rule. Under Taylor-type rule, monetary authority conducts its monetary policy by managing the short-term nominal interest rate or the value of the Algerian dinar (hereafter, DZD) relative to the U.S. dollar. Under money supply rule, monetary authority exogenously adjusts the money growth rate. Since the country is exporting in the U.S. dollar, while borrowing and mainly importing in the euro, it is facing two exchange rates : The euro/U.S. dollar (hereafter, the EUR/USD exchange rate) and U.S. dollar/ Algerian dinar (hereafter, the USD/DZD exchange rate).

2.1 - Households

The representative household derives utility from consumption, C_t, real money balances, $m_t = M_t / P_t$ (M_t is holdings of nominal balances and P_t is the consumer price level), and leisure 1- h_t, where h_t is labour supply to non-oil intermediate-goods producers. Household's preferences are described by the following expected utility function :

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, m_t, h_t), \qquad (1)$$

Where 0< β< is the discount factor. The single-period utility function is specified as :

$$u(\bullet) = \log(C_t) + \omega \log(m_t) + \eta \log(1-h_t), \qquad (2)$$

Where ω>0 and η>0 denote the weight on real balances and leisure in the utility function, respectively. We introduce money in the utility function to derive a standard money demand function with the interest elasticity equal to unity. The total consumption depends on private consumption, c_t, and public consumption, g_t, as the following :

$$C_t = \left[a^{\frac{1}{\gamma}} c_t^{\frac{\gamma-1}{\gamma}} + (1-a)^{\frac{1}{\gamma}} g_t^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}, \qquad (3)$$

Where γ>0 is the constant elasticity of substitution between private and public consumption, and 0< a <1 is the share of private consumption in total consumption. For 0<γ<1, private and public consumption are complement, so a positive government spending shock increases private consumption.

The household's revenue flows come from many resources. First, the household enters period t with real money balances, m_{t-1}, real domestic-currency bonds, d_{t-1}, and real net foreign-currency bonds d^*_{t-1}, that are totally denominated in the euro[6]. During period t, households may sell or purchase foreign bonds, d^*_t, in international financial markets for the price that depends on a country-specific risk premium and the world interest rate.

Furthermore, the household receives rent payments, $p_{Lt} L_t$, from the oil firm for using the natural-resource factor, L_t, and earns real wages, w_t, from supplying labour services to the non-oil intermediate-goods producers. It also receives dividend payments from the monopolistically competitive producers and importers, $\Omega_{nt} = \int_0^1 \Omega_{nt}(j)dj$ and $\Omega_{ft} = \int_0^1 \Omega_{ft}(j)dj$, receives lump - sum transfer from monetary authority, T_t, and pays lump-sum taxes, Γ_t, to finance government spending. Finally, it accumulates k_{ot} and k_{nt} units of capital stocks, used in the oil and non-oil sectors, for real rental rates q_{ot} and q_{nt}, respectively.[7]

Household uses some of its funds to purchase, at the nominal price P_t, consumption and investment. Investment is divided between oil and non-oil sectors : i_{ot} and i_{nt}, respectively. The evolution of capital stocks in each sector is given by :

$$k_{jt+1} = (1-\delta)k_{jt} + i_{jt} - \Psi_j\left(k_{jt+1}, k_{jt}\right), \qquad (4)$$

For j = {o,n}, where 0<δ<1 is the common depreciation rate and $\Psi_j(\,) = 0.5\psi_j\left(k_{jt+1}/k_{jt} - 1\right)^2 k_{jt}$ is capital-adjustment cost functions that satisfy Ψ_j (0)=0, Ψ_j'>0 and Ψ_j''<0. The adjustment cost parameters, ψ_j, are positive. With this specification, both total and marginal costs of adjusting capital are zero in the steady-state equilibrium.

The single-period budget constraint of the representative household is given by :

$$c_t + i_{ot} + i_{nt} + m_t + \frac{d_t}{R_t} + \frac{s_t \xi_t d_t^*}{\kappa_t R_t^*} \leq \frac{d_{t-1}}{\pi_t} + \frac{s_t \xi_t d_{t-1}^*}{\pi_t^*} + \frac{m_{t-1}}{\pi_t}$$
$$+ q_{ot}k_{ot} + q_{nt}k_{nt} + w_t h_t + p_{Lt}L_t + \Omega_{nt} + \Omega_{ft} + (T_t - \Gamma_t)/P_t, \qquad (5)$$

where s_t is the U.S. dollar/Algerian dinar (USD/DZD) real exchange rate, which is the price of one U.S. dollar in the Algerian dinars ; while ξ_t is the euro/U.S. real dollar (EUR/USD) exchange rate, which is the real price of one euro in terms of the U.S. dollars;[8] R_t>1 and R_t^*>1 denote the gross nominal risk-free domestic and foreign interest rates, π_t^*>1 is the world

κ_t

premium.

The EUR/USD exchange rate, ξ_t, the world nominal interest rate, R_t^*, and the world inflation rate, π_t^*, are assumed to exogenously evolve according to the following stochastic processes :

$$\log(\xi_t) = (1-\rho_\xi)\log(\xi) + \rho_\xi \log(\xi_{t-1}) + \varepsilon_{\xi t}; \quad (6)$$

$$\log(R_t^*) = (1-\rho_R)\log(R^*) + \rho_R \log(R_{t-1}^*) + \varepsilon_{Rt}; \quad (7)$$

$$\log(\pi_t^*) = (1-\rho_\pi)\log(\pi^*) + \rho_\pi \log(\pi_{t-1}^*) + \varepsilon_{\pi t}, \quad (8)$$

Where $\xi = 1$, $R^* > 1$, and $\pi^* > 1$; the autocorrelation coefficients ρ_ξ, ρ_R, and ρ_π are ranging between -1 and 1, and $\varepsilon_{\xi t}$, ε_{Rt}, and $\varepsilon_{\pi t}$ are normally distributed with zero mean and standard deviations σ_ξ , σ_R, and σ_π,, respectively.

The risk-premium term, κ_t, which reflects departures from the uncovered interest rate parity, is increasing in the foreign-debt-to-total-export ratio and evolves according to :

$$\kappa_t = \exp\left(-\varphi \frac{\xi_t \tilde{d}_t^*}{p_{ot}^* y_{ot}}\right), \quad (9)$$

Where φ is a parameter measuring the risk premium, $\tilde{d}_t^*$ <0$ is the average real stock of external debt, p_{ot}^*, is the oil price set in the U.S. dollar, and y_{ot} denotes oil output exported abroad. By following this functional form, the risk premium ensures that the model has a unique steady state.[9]

The household chooses $[c_t, m_t, h_t, k_{ot+1}, k_{nt+1}, d_t, d^*_t]$ to maximize the expectation of the discounted sum of its utility flows subject to the equations (4) and (5). The first-order conditions are :

$$\frac{aC_t}{c_t} = \lambda_t^r; \quad (10)$$

$$\frac{\varpi}{m_t} = \lambda_t - \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right); \quad (11)$$

$$\frac{\eta}{(1-h_t)} = \lambda_t w_t; \quad (12)$$

$$\beta\left[\frac{\lambda_{t+1}}{\lambda_t}\left(q_{nt+1} + 1 - \delta + \psi_n\left(\frac{k_{nt+2}}{k_{nt+1}} - 1\right)\frac{k_{nt+2}}{k_{nt+1}}\right)\right] = \psi_n\left(\frac{k_{nt+1}}{k_{nt}} - 1\right) + 1; \quad (13)$$

$$\beta\left[\frac{\lambda_{t+1}}{\lambda_t}\left(q_{ot+1} + 1 - \delta + \psi_o\left(\frac{k_{ot+2}}{k_{ot+1}} - 1\right)\frac{k_{ot+2}}{k_{ot+1}}\right)\right] = \psi_o\left(\frac{k_{ot+1}}{k_{ot+1}} - 1\right) + 1; \quad (14)$$

$$\frac{\lambda_t}{R_t} = \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right); \quad (15)$$

$$\frac{\lambda_t}{\kappa_t R_t^*} = \beta E_t\left(\frac{s_{t+1}\xi_{t+1}^{\varepsilon}\lambda_{t+1}}{s_t\xi_t^{\varepsilon}\pi_{t+1}^*}\right); \quad (16)$$

In addition to the budget constraint; λ_t is the Lagrangian multiplier of the budget constraint.

Equations (10) and (12) equate the marginal rate of substitution between consumption and labour to the real wage. Equation (11) stipulates that the marginal utility of real money balances is equal to the difference between the current and marginal utility of consumption and the expected future marginal utility of consumption adjusted for the expected inflation rate. Equations (13) and (14) correspond to the optimal distribution of capital between the two production sectors. Equations (15) and (16) imply the uncovered interest rate parity condition, so that

$$\frac{R_t}{\kappa_t R_t^*} = \frac{s_{t+1}\xi_{t+1}^{\varepsilon}\pi_{t+1}}{s_t\xi_t^{\varepsilon}\pi_{t+1}^*}.$$

2.2 - Firms

2.2.1 - Final-good producer

It is assumed that the perfectly competitive final-good producer uses domestic-intermediate goods, y_{nt}, and imported goods, y_{ft}, to produce a final good, z_t, according to the following CES technology :

$$z_t = \left[(1-b)^{\frac{1}{v}} y_{nt}^{\frac{v-1}{v}} + b^{\frac{1}{v}} y_{ft}^{\frac{v-1}{v}}\right]^{\frac{v}{v-1}}, \quad (17)$$

Where b>0 denotes the share of imports in the final good, and v>0 is the elasticity of substitution between domestic and imported goods. It also denotes the price elasticity of domestic and imported goods demand functions. Similarly, both inputs are produced using the CES technology:

$$y_{nt} = \left(\int_0^1 [y_{nt}(j)]^{\frac{\theta-1}{\theta}} dj,\right)^{\frac{\theta}{\theta-1}} \text{ and } y_{ft} = \left(\int_0^1 [y_{ft}(j)]^{\frac{\theta-1}{\theta}} dj,\right)^{\frac{\theta}{\theta-1}}, \quad (18)$$

Where ϵ >1 is the constant elasticity of substitution between intermediate goods in composite goods aggregation. The demand function for domestic- and imported-intermediate goods are :

$$y_{nt}(j) = \left(\frac{P_{nt}(j)}{P_{nt}}\right)^{-\theta} y_{nt} \text{ and } y_{ft}(j) = \left(\frac{P_{ft}(j)}{P_{ft}}\right)^{-\theta} y_{ft} \quad (19)$$

Domestic and import prices that are the producer- and importer-price index (PPI and IPI) satisfy

$$P_{nt} = \left(\int_0^1 [P_{nt}(j)]^{1-\theta} \right)^{\frac{1}{1-\theta}} dj \text{ and } P_{ft} = \left(\int_0^1 [P_{ft}(j)]^{1-\theta} \right)^{\frac{1}{1-\theta}} dj \quad (20)$$

Given the final-good price, P_t and given P_{nt} and P_{ft}, the aggregator chooses y_{nt} and y_{ft} to maximize its profit. The maximization problem is

$$\max_{\{y_{nt}, y_{ft}\}} P_t z_t - P_{nt} y_{nt} - P_{ft} y_{ft},$$

Subject to (17). Profit maximization implies the following demand functions for domestic- and imported-composite goods :

$$y_{nt} = (1-b)\left(\frac{P_{nt}}{P_t}\right)^{-\nu} z_t \text{ and } y_{ft} = b\left(\frac{P_{ft}}{P_t}\right)^{-\nu} z_t \quad (21)$$

Thus, as the relative prices of domestic and imported goods rise, demand for domestic and imported goods decreases.

The zero-profit condition implies that the final-good price level, which is the consumer-price index (CPI), is linked to domestic- and imported-goods prices through :

$$P_t = \left[(1-b)P_{nt}^{1-\nu} + bP_{ft}^{1-\nu}\right]^{1/(1-\nu)} \quad (22)$$

The final good is divided between private consumption, government spending, and investment, so that

$$z_t = c_t + g_t + i_{ot} + i_{nt} \quad (23)$$

2.2.2 - Oil producer

In the oil sector, there is one perfectly competitive firm that produces crude oil, y_{ot}, using capital, k_{ot}, and a natural-resource factor, L_t, for capital return, q_{ot}, and a price of natural-resources, p_{Lt}. Production in this sector is modelled to capture the importance of natural resources in oil production. Production function is given by the following Cobb-Dauglas technology :

$$y_{ot} \le k_{ot}^{\alpha_o} L_t^{1-\alpha_o}, \quad (24)$$

Where $\alpha_o \in (0,1)$ is the share of capital in oil output. L_t might be interpreted as an indicator of expansion in crude oil production due to new discovery.

Oil output is totally exported abroad for the real price $p_{ot}^* = P_{ot}^* / P_t^*$ that is determined in world markets and denominated in the U.S. dollar. Therefore, multiplying p_{ot}^* by the USD/DZD exchange rate, s_t, yields oil producer's real revenues (export earnings in terms of the Algerian dinar). Given p_{ot}^*, s_t, q_{ot}, and p_{Lt}, the oil producer chooses k_{ot} and L_t that maximize its real profit flows. Its maximization problem is $\max_{k_{ot}, L_t} \{s_t p_{ot}^* y_{ot} - q_{ot} k_{ot} - p_{Lt} L_t\}$, Subject to the production technology, equation (24)

Oil prices are given in the world markets and it is assumed that the supply of the natural resource factor is exogenous, so p^*_{ot} and L_t evolve according to the two following stochastic processes :

$$\log(p^*_{ot}) = (1-\rho_p)\log(p^*_o) + \rho_p \log(p^*_{ot-1}) + \varepsilon_{pt}, \quad (25)$$

$$\log(L_t) = (1-\rho_L)\log(L) + \rho_L \log(L_{t-1}) + \varepsilon_{Lt}, \quad (26)$$

Where $p^*_o > 0$ and L_t>0; ρ_p and ρ_L are the autoregressive coefficients ; and ε_{pt} and ε_{Lt} are uncorrelated and normally distributed innovations with zero mean and standard deviations σ_p and σ_L, respectively.

The first-order conditions derived from the oil producer's optimization problem are :

$$q_{ot} = \alpha_o s_t p^*_{ot} y_{ot} / k_{ot}; \quad (27)$$

$$p_{Lt} = (1-\alpha_o) s_t p^*_{ot} y_{ot} / L_t; \quad (28)$$

$$y_{ot} = k_{ot}^{\alpha_o} L_t^{1-\alpha_o} \quad (29)$$

These first-order conditions give the optimal choice of inputs that maximize the oil producer's instantaneous profits. The demand for k_{ot} and L_t are given by equations (27) and (28), respectively. These equations stipulate that the marginal cost of each input must be equal to its marginal productivity. Because the economy is small, the demand for domestic exports and their prices are completely determined in the world markets and domestic exports are only a negligible fraction in the rest of the world spending.

2.2.3 - Non-oil producers

In the non-oil sector, there is a continuum of monopolistically-competitive firms indexed by $j \in [0,1]$. Each firm *j* uses capital stock, k_{nt} (*j*), and hires, h_{nt} (*j*), units of labour from households to produce a differentiated intermediate goods, y_{nt} (*j*), according to the following constant-return-to-scale technology :

$$y_{nt} \leq A_t k_{nt}^{\alpha_n} h_t^{1-\alpha_n}, \quad (30)$$

Where $\alpha_n \in (0,1)$ is the share of capital in non-oil production and A_t is an exogenous technology shock common to all domestic producers. This shock follows the process

$$\log(A_t) = (1-\rho_A)\log(A) + \rho_A \log(A_{t-1}) + \varepsilon_{At}, \quad (31)$$

Where *A*>0, $\rho_A \in (-1,1)$ is an autoregressive coefficient, and ε_{At} is normally distributed with zero mean and standard deviation σ_A.

As in Dib (2008), each producer *j* sells its output at price $\tilde{p}_{nt}(j)$ in a monopolistically competitive market. Following Calvo (1983), the producer cannot change its prices unless it receives a random signal. The probability that such a signal appears is constant and given by $(1-\phi)$. Therefore, on average the price remain unchanged for $1/(1-\phi)$ periods. Following Yun (1996), if the producer is not allowed to optimize its price, it fully indexes them to the steady-state CPI inflation rate.

When the producer is allowed to change its price, it chooses $k_{nt}(j)$ and $h_t(j)$, and sets the price $\tilde{p}_{nt}(j)$ that maximizes the expected discounted flows of its profits. This maximization problem is :

$$\max_{\{k_{nt}(j), h_t(j), \tilde{P}_{nt}(j)\}} E_0\left[\sum_{l=0}^{\infty}(\beta\phi)^l \lambda_{t+l}\Omega_{nt+l}(j)\right],$$

Subject to (30) and the following demand function :

$$y_{nt+l}(j) = \left(\frac{\pi^l \tilde{p}_{nt}(j)}{p_{nt+l}}\right)^{-\theta} y_{nt+l}, \quad (32)$$

where the profit function is

$$\Omega_{nt+l}(j) = \pi^l \tilde{P}_{nt}(j) y_{nt+l}(j)/P_{t+l} - q_{nt+l}k_{nt+l}(j) - w_{nt+l}h_{t+l}(j) \quad (33)$$

The producer's discount factor is given by the stochastic process $\beta^l \lambda_{t+l}$, where λ_{t+l} denotes the marginal utility of consumption at period *t + l.*

The first-order conditions of this maximization problem are :

$$q_{nt} = \frac{\alpha_n y_{nt}(j)\zeta_t}{k_{nt}(j)}; \quad (34)$$

$$w_t = \frac{(1-\alpha_n) y_{nt}(j)\zeta_t}{h_t(j)}; \quad (35)$$

$$\tilde{p}_{nt} = \frac{\theta}{\theta-1}\frac{\sum_{l=0}^{\infty}(\beta\phi)^l \lambda_{t+l} y_{nt+l}(j)\zeta_{t+l}}{\sum_{l=0}^{\infty}(\beta\phi)^l \lambda_{t+l} y_{nt+l}(j)\pi^l \pi_{t+l}^{-1}}, \quad (36)$$

Where $\tilde{p}_{nt} = \tilde{P}_{nt}/P_t$ is the relative non-traded goods price and ζ_t is the real marginal cost that is common to all firms in the non-oil sector. The relative non – traded – intermediate - goods price, $p_{nt} = P_{nt}/P_t$, evolves according to :

$$p_{nt}^{1-\theta} = \phi(p_{nt-1}/\pi_t)^{1-\theta} + (1-\phi)\tilde{p}_{nt}^{1-\theta} \quad (37)$$

The equations (34) and (35) state that the marginal costs of inputs must be

The

equation (36) relates the optimal price to the expected future prices of the final good and to expected future real marginal costs. This condition together with (37) allows us to derive a New-Keynesian Phillips curve that relates the current and expected domestic-output inflation to the marginal costs.

2.2.4 - Importers

In this sector, there is a continuum of monopolistically competitive importers indexed by $j \in [0,1]$ that import a homogeneous good produced abroad. A fraction α of total imports is invoiced in the U.S. dollar, while the remaining imports, a fraction (1-α), are invoiced in the euro. Total imports are used to produce a differentiated good $y_{ft}(j)$ that is used to produce the final good z_t.

As in the non-oil sector, importers can only change their prices when they receive a random signal. The constant probability of receiving such a signal is $(1-\phi)$. Also, if an importer is not allowed to optimize its prices, it fully indexes them to the steady-state CPI inflation rate. The presence of price rigidity implies that the response of the imported goods price to exogenous shocks is gradual. Thus, there is incomplete pass-through of exchange rate changes to the levels of prices in the economy. Devereux and Yetman (2003) found that there is incomplete exchange rate pass-through in the emerging economies including Algeria.

If importer *j* is allowed to change its price, it sets the price $\widetilde{P}_{ft}(j)$ that maximizes its weighted expected profits, given the aggregate price of imported goods, P_{ft}, the USD/DZD real euro/dinar exchange rate, s_t, and the EUR/USD real exchange rate, ξ_t. The maximization problem is :

$$\max_{\widetilde{P}_{ft}(j)} E_0\left[\sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l}\Omega_{ft+l}(j),\right]$$

subject to demand function

$$y_{ft+l}(j) = \left(\frac{\pi^l \widetilde{P}_{ft}(j)}{P_{ft+l}}\right)^{-\theta} y_{ft+l}, \qquad (38)$$

Where the profit function is

$$\Omega_{ft+l}(j) = \left\{\pi^l \widetilde{P}_{ft}(j) - s_{t+l}\left[\alpha + (1-\alpha)\xi_{t+l}\right]\right\} y_{ft+l}(j). \qquad (39)$$

The importer's discount factor is also given by the stochastic process $\beta^l \lambda_{t+l}$. At period *t* the importer's real marginal cost is $s_{t+l}\left[\alpha + (1-\alpha)\xi_{t+l}\right]$. Therefore, exogenous variations in the EUR/ USD real exchange rate have direct impacts on the real marginal costs of importing from the Euro Area.

The first-order condition of this optimization problem is :

$$\widetilde{p}_{ft} = \frac{\theta}{\theta-1}\frac{\sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} y_{ft+l}(j) s_{t+l}\left[\alpha + (1-\alpha)\xi_{t+l}\right]}{\sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} y_{ft+l}(j)\pi^l \pi_{t+l}^{-1}}, \qquad (40)$$

Where $\tilde{p}_{ft} = \tilde{P}_{ft} / P_t$ is the relative non-tradable goods price and $s_{t+l}\left[\alpha + (1-\alpha)\xi_{t+l}^{\varepsilon}\right]$ is the real marginal cost that is common to all importers. The relative import-intermediate-goods price, $p_{ft} = P_{ft} / P_t$, evolves according to

$$p_{ft}^{1-\theta} = \phi(p_{ft-1} / \pi_t)^{1-\theta} + (1-\phi)\tilde{p}_{ft}^{1-\theta} . \qquad (41)$$

The equation (40) governs the optimal setting of the new import price over time. In the absence of price rigidity ($\phi = 0$), imported-goods prices are flexible, and the law of one price holds. This equation together with (41) allows us to derive the New Keynesian Phillips curve that relates the current and expected import-inflation rates to the real exchange rates.

2.3 - Monetary authority

We compare the role of monetary authority under two alternative monetary policies: A standard Taylor-type rule and a money supply rule. Under the Taylor-type rule, monetary authority endogenously adjusts the short-term nominal interest rate in response to inflation variations; while, under the money supply rule, monetary policy exogenously manipulates money growth rate to directly affect the money supply. Note that, under Taylor-type policy rule, money supply endogenously evolves to equal money supply.

According to Taylor-type rule, monetary authority endogenously adjusts the short-term nominal interest rate, R_t, to response to variations of the CPI inflation rate, π_t, and the USD/DZD exchange rate, s_t, according to :

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\rho_\pi} \left(\frac{s_t}{\chi_t}\right)^{\frac{\rho_s}{1-\rho_s}} \exp(\varepsilon_{rt}) , \qquad (42)$$

Where χ_t is a devaluation shock, ρ_r is a smoothing-term parameter, ρ_π, and ρ_s are policy coefficients measuring central bank's responses to deviations of π_t and s_t from their steady-state levels. The serially uncorrelated monetary policy shock, ε_{rt}, is normally distributed with zero mean and standard deviation σ_r.

It is assumed that the devaluation shock, χ_t, follows an autoregressive process :

$$\log(\chi_t) = (1-\rho_\chi)\log(\chi) + \rho_\chi \log(\chi_{t-1}) + \varepsilon_{\chi t} , \qquad (43)$$

Where χ= s > 0 is the steady-state value of the USD/DZD exchange rate, $\rho_\chi \in (-1,1)$ and $\varepsilon_{\chi t}$ is normally distributed with zero mean and standard deviation σ_χ.

The coefficient ρ_s is restricted to be between 0 and 1. If $\rho_s = 1$, the monetary authority strictly pegs the domestic currency to the US dollar. If $\rho_s = 0$, the monetary policy approximates a pure floating exchange rate, while larger values of ρ_s approximate a managed float regime. Given that

Algeria manages the value of its currency relative to the U.S. dollar, it is natural to assume that the central bank uses a devaluation policy to keep the value of the Algerian dinar stable against the U.S. dollar. Thus, an exogenous increase in the exchange rate target, χ_t, induces a decrease in the short-term nominal interest rate.

The alternative monetary policy rule (Money supply rule) implies that the central bank exogenously adjusts the money supply according to the following rule :

$$\log(\mu_t) = (1-\rho_\mu)\log(\mu) + \rho_\mu \log(\mu_{t-1}) + \varepsilon_{\mu t}, \qquad (44)$$

Where $\mu > 1$ is the steady-state value of the money growth rate, $\rho_\mu \in (-1,1)$ and $\varepsilon_{\mu t}$ is normally distributed with zero mean and standard deviation σ_μ. The money growth rate is given by :

$$\mu_t = \frac{M_t}{M_{t-1}} = \frac{\pi_t m_t}{m_{t-1}}, \qquad (45)$$

Where M_t is per capita money stock at period *t*, while m_t is real money balances.[10]

Under both policy rules, money supply evolves according to $M_t - M_{t-1} = T_t$, where T_t is nominal lump-sum transfers to households. We also assume that the government consumes a fraction *g* of the final good and runs a balanced-budget deficit financed with lump-sum taxes : $P_t g_t = \Gamma_t$, where g_t follows the following autoregressive process :

$$\log(g_t) = (1-\rho_g)\log(g) + \rho_g \log(g_{t-1}) + \varepsilon_{gt}, \qquad (46)$$

Where $g > 0$ is the steady-state value of government spending, $\rho_g \in (-1,1)$ and ε_{gt} is normally distributed with zero mean and standard deviation σ_g.

2.4 - New-Keynesian Phillips curves and the current account

Equations (36) and (40) involve infinite summations. By log-linearizing these equations together with (37) and (41) around the steady-state values of the variables, we obtain two New-Keynesian Phillips curves that relate the current and expected inflation to real marginal costs. The New-Keynesian Phillips curve that relates the current and expected producer-price-index (PPI) inflation, $\pi_{xt} = P_{xt} / P_{xt-1}$, to the real marginal costs in the non-oil sector, ζ_t, is given by

$$\hat{\pi}_{xt} = \beta E_t[\hat{\pi}_{xt+1}] + \frac{(1-\phi)(1-\beta\phi)}{\phi}\hat{\zeta}_t. \qquad (47)$$

The hat above a variable refers to the deviation of the log of the variable from its steady-state value. Similarly, the New-Keynesian Phillips curve relates the current and expected importer-price-index (IPI) inflation, $\pi_{ft} = P_{ft} / P_{ft-1}$, to the exchange rate movements in s_t and ξ_t, is

$$\hat{\pi}_{ft} = \beta E_t\left[\hat{\pi}_{ft+1}\right] + \frac{(1-\phi)(1-\beta\phi)}{\phi}\left[\hat{s}_t + (1-\alpha)\hat{\xi}_t\right] \qquad (48)$$

On the other hand, substituting the resource constraints, money transfer, and firms' profit equations into the household budget constraint allows us to derive an equation that describes the evolution of the current account, which measures, over a period, the change in the value of a country's claims on the rest of the world-the change in its net debt position. The current account is the main channel through which foreign shocks affect small open economies. The current account of this oil-exporting country, in real terms and expressed in euro, is

$$ca_t = d_t^* - d_{t-1}^* = \left(1 - \frac{1}{\kappa_t R_t^*}\right)d_t^* + \frac{p_{ot}^* y_{ot}}{\xi_t} - \left(1 - \alpha + \frac{\alpha}{\xi_t}\right)y_{ft} \qquad (49)$$

This equation states that the current account, in terms of the euro, depends on interest payments, $\left(1-(\kappa_t R_t^*)^{-1}\right)d_t^*$, export earnings, $p_{ot}^* y_{ot} / \xi_t$, and total imports, $\left(1-\alpha+\alpha/\xi_t\right)y_{ft}$. In each period, the country uses a fraction $\left(1-(\kappa_t R_t^*)^{-1}\right)$ of its newly external contracted debt to pay back interests on its previous debt. The interest payments positively depend on d_t^* and $(\kappa_t R_t^*)^{-1}$, the price of foreign bonds that negatively depends on the world interest rate and the risk-premium terms. Thus, increases in the external debt, world interest rate and/or risk premium lead to an increase in the external debt burden (the interest payment on the external debt), implying deterioration of the current account. Tille (2003) analyzes the impact of exchange rate movements on the U.S. current account.

On the other hand, the fluctuations in export earnings have a direct impact on the current account. The sources of these fluctuations are driven either by variations in the terms of trade (the relative prices of exports to imports) given by p_{ot}^* / ξ_t or by changes in exports y_{ot}. An appreciation in the EUR/USD exchange rate (a decrease in ξ_t) and/or an increase in the oil price, p_{ot}^*, imply an increase in the terms of trade, which leads to an improvement in the current account. Finally, fluctuations in total value of imports, due to movements in ξ_t and/or changes in y_{ft}, have a direct influence on the current account movements.

2.5 - Equilibrium and solution

In the equilibrium, all domestic-intermediate producers and importers are identical, so that $y_{xt} = y_{xt}(j)$, $y_{ft} = y_{ft}(j)$, $k_{xt} = k_{xt}(j)$, $h_t = h_t(j)$, $p_{xt} = p_{xt}(j)$, $p_{ft} = p_{ft}(j)$, $\Omega_{xt} = \Omega_{xt}(j)$, and $\Omega_{ft} = \Omega_{ft}(j)$, for all $j \in [0,1]$ and $t \geq 0$. Furthermore, the market-clearing conditions $M_t = M_{t-1} + T_t$, $\tilde{d}_t^* = d_t^*$, and the trans-versality conditions regarding household accumulation of money and bonds must hold for all $t \geq 0$.

Let $p_{xt} = P_{xt} / P_t$ and $p_{xt} = P_{xt} / P_t$ denote the relative prices of domestic and imported goods, respectively. The equilibrium system is then composed of an allocation and a sequence of prices and co-state variables that satisfy the first-order conditions of the households and the oil and non-oil producers, the aggregate resource constraints, the monetary policy rule, the two New-Keynesian Phillips curves, the current account equation, and the stochastic processes of the shocks.[11]

The model is too complex to permit an analytical solution. We, therefore, resolve it numerically by log-linearizing the equilibrium conditions around the deterministic steady state to obtain a system of linear difference equations. Then, the solution was found using Blanchard and Kahn's (1980) procedure. [12] The state-space solution is of the form :

$$\hat{S}_{t+1} = \Phi_1 \hat{S}_t + \Phi_2 \varepsilon_t; \qquad (50)$$

$$\hat{D}_t = \Phi_3 \hat{S}_t, \qquad (51)$$

Where S_t is a vector of state variables that includes predetermined and exogenous variables; D_t is the vector of control variables; and the vector ε_t contains exogenous innovations to the stochastic processes.[13] The elements of the matrices Φ_1, Φ_2, and Φ_3, depend on the structural parameters of the model that describe household's preferences, technologies, monetary policy, and stochastic processes. The state-space solution in (50)-(51) is used to simulate the model.

3 - PARAMITRIZATION

The numerical simulations entail assigning numerical values to the model's structural parameters. For this, we use a combination of calibration and ordinary-least-squared (OLS) estimations. Some parameters are resorted to calibrated values based on previous studies, while others are set to match the model's steady-state ratios to those observed in the data.[14] The parameters of the Taylor-type policy rule and the exogenous stochastic processes (autoregressive coefficients and standard deviations of the shocks) are estimated using some annual Algerian, Euro Area, and U.S. data.[15]

First, we summarize the parameter values set by the calibration, see Table 1. The discount factor β is set equal to 0.97, implying an annual steady-state real interest rate on external debt of 3.1%, matching the observed average in the data for the period 1992-2005. The parameter η, denoting the weight put on leisure in the utility function, is set at 0.68, so that the representative household spends roughly one third of its time in market activities. The elasticities of substitution between private and public consumption, γ, is set equal to 0.5. Thus, we assume some complementarity between the two consumption goods. The share of private consumption in total consumption, *a*, is set equal to 0.65, matching the observed ratio in the data for the period 1992-2005. The parameter *v* which is determining the steady-state money velocity is set equal to 0.029, implying a steady-state ratio of real balances to GDP equals to 0.31, matching the observed ratio of money stock (M1) to GDP.

The shares of capital and the depreciation rates in the oil and non-oil sectors, α_o, α_x, δ_o, and δ_x, are assigned values of 0.4, 0.25, 0.1, and 0.08, respectively. These values are commonly used in open economy literature. The parameter θ that measures monopoly power in domestic- and imported-intermediate-goods markets is set equal to 6, implying a steady-state markup of price over marginal costs equal to 20%. The parameter ϕ determining the degree of nominal price rigidity in domestic and import sectors, is set at 0.5. Thus, on average the domestic and imported goods prices remain unchanged for two years. The parameter *v* measuring the elasticity of substitution between domestic and imported goods in the final output, is set equal to 0.6. Thus, domestically produced goods are only slightly substitutable for imported goods. This reflects the nature of Algerian imports that consist mainly of investment goods and food. It is widely believed that it is less costly to adjust the stock of capital in the oil sector than in the non-oil sector, so we set the capital adjustment cost parameters ψ_o and ψ_x equal to 4 and 5, respectively. These values are chosen so that investment volatility matches the one observed in the data. The share of imports invoiced in the U.S. dollar, α, is set at 0.35, matching the one observed in the data.[16] The fraction of imported goods in the final goods, *b*, is set at 0.22, so that the steady-state ratio of import-to-GDP matches its historical average of Algeria for the period 1992-2005.

The steady-state of gross inflation and nominal rates, π, π_t^*, R, and R_t^*, are set equal to 1.101,1.023,1.13.47, and 1.0403, respectively. These values are the annual observed averages in the data of the Algerian and Euro Area economies for the period 1992-2005. 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.

Monetary policy coefficients, except ρ_s, are estimated using the instrumental variable estimation procedure and annual Algerian data on the nominal risk-free interest rate and the CPI inflation for the period of 1992-2005. The estimated values of ρ_r, ρ_π, and σ_r are 0.86, 0.17, and 0.015, respectively. They are all statistically significant at the 5% level and economically meaningful. On the other hand, the parameter ρ_s, which measures the responses of monetary authority to exchange rate variations, is set equals to 0.05. Thus, we assume that monetary policy actively manages the domestic currency relative to the U.S. dollar and uses devaluationary policy to affect the real economy. For the alternative money supply rule, the autoregressive coefficient, ρ_μ, is set at 0.68, based on the OLS estimation of the money growth stochastic process given by the equation (44)

Table 2 reports the results of different OLS estimations of the exogenous stochastic processes. The individual parameters are all statistically significant at the 5% level. The stochastic processes are highly persistent, with AR(1) parameters above 0.54. The standard deviations of the innovations to the processes vary widely in magnitude, ranging from 0.0044 in the case of the world inflation rate to 0.19 in the case of the oil price. The oil-price shocks are persistent and largely volatile, with an autoregressive coefficient of 0.64 and standard deviation of 0.19 that is larger than the standard deviation of any other forcing process in the model. The large persistence and high volatility of the oil-price shocks suggest the importance of these shocks for the Algerian business cycles. The EUR/USD exchange rate and devaluation shocks are also highly persistent and volatile, with autoregressive coefficients, ρ_{ξ} and $\rho_{\gimel}$, estimated at 0.78 and 0.81, respectively. These shocks are also highly volatile with standard deviations σ_{ξ} =0.082 and $\sigma_{\gimel}$ =0.097. Hence, these two shocks may play a significant role in the short-term fluctuations of the Algerian economy.

The data used are from many sources. The Algerian data are mainly from the IMF financial statistics report (2006), while those of the U.S. and Euro Area are from St. Louis Federal Reserve Bank (USA) and the OCDE, respectively. The series of Algerian GDP, imports, exports, foreign debt, money, and the current account are real expressed in per capita terms (dividing by the Algerian population). We are only interested in the cyclical fluctuations of the Algerian economy, so we extract the cyclical components of each series by linearly detrended the non-stationary series. Table 3 reports the steady-state ratios of key macroeconomic variables to GDP. These ratios match those observed in the Algerian data for the period 1992-2005.

4 - SIMULATION ANALYSIS

To evaluate the performance of the model, we calculate and analyze the unconditional second moments and autocorrelations of some key variables of the model under the two alternative monetary policies: Taylor-type rule versus money supply rule. We also simulate the dynamic response of the Algerian economy to exogenous shocks. Our analysis, however, particularly focuses on real effects of shocks to the EUR/USD exchange rate, oil prices, devaluation, and monetary policy. We also display and discuss pass-through of exchange rate effects to import and final good (CPI) prices following EUR/USD exchange rate and oil price shocks.

4.1 - Volatility and autocorrelations

Table 4 summarizes some standard deviations (unconditional second moments), expressed in terms of percentage, and the autocorrelation coefficients (unconditional autocorrelations) computed in the data and generated by the model, under the Taylor-type rule.[17] These statistics are reported for some key macroeconomic variables: the USD/DZD real exchange rate, CPI inflation, investment, GDP, non-oil output, oil output, total exports, and total imports. To compute the model's predictions, we use stochastic simulations with shocks generated using the standard deviations from Table 2 and imposing independence across the different types of shocks. The calculated statistics, both for the model and the data, are for linearly detrended series, except for the inflation rate.

In the data, the USD/DZD real exchange rate, investment, and GDP are highly volatile, having a standard deviations above 12%, while domestic non-oil production, inflation, and exports are relatively volatile (but still highly volatile if compared to what observed in the developed or other emerging economies. For example, Algerian GDP and inflation are three to five times more volatile than those in Canada). The model highly overpredicts the volatility of inflation and GDP, as their standard deviations exceed those in the data, while it successfully predicts those of investment, non-oil output, and exports. The model, however, slightly underpredicts standard deviations of the real exchange rate. Overall, the model succeeds in reproducing the unconditional second moments of the key variables in the model.

Similarly, in the data, all variables exhibit high persistence, as their AR(1) coefficients are all above 0.61, except the world inflation rate. The model is relatively successful in reproducing the unconditional autocorrelations, even though the autocorrelation coefficients generated by the model are mostly smaller than those observed in the data.

4.2 - Dynamic responses to exogenous shocks

This section evaluates and compares, under the two alternative monetary policies, the model's performance using impulse responses to a 1% transitory shock to the EUR/USD exchange rate, oil prices, devaluation policy, and monetary policy. The first two shocks are shocks to the terms of trade, while the two others are monetary policy shocks. We perform the impulse responses of nominal interest rate, CPI inflation, the USD/DZD real exchange rate, the currant account, foreign debt, total import, non-oil output, consumption and the country-specific risk premium. Each response is expressed as the percentage deviation of a variable from its steady-state level.

4.2.1 - Responses to EUR/USD exchange rate shocks

Figure 1 plots the impulse responses to a 1% positive EUR/USD exchange rate shock: An exogenous depreciation of the U.S. dollar relative to the euro (a temporary increase in $\varepsilon_{\xi t}$). This shock reflects the fluctuations of the U.S. dollar value in international financial markets. As most of oil-exporting economies, Algeria is a small open economy. It takes the U.S. dollar value in terms of other major world currencies as given and beyond its control. Therefore, by performing this analysis, we try to quantitatively assess the economic effects of the recent depreciation of the U.S. dollar on oil-exporting economies, in particular Algeria.

Firstly, we note that an exogenous depreciation of the U.S. dollar relative to the euro, an increase in ξ_t, significantly appreciates the Algerian dinar relative to the U.S. dollar by about 0.4% upon impact. It also leads to an instantaneous, but not persistent, jump of CPI inflation above its steady-state value by about 0.2%. The increase in CPI inflation is mainly driven by the increase in import prices, even though these prices slowly adjust because of import price stickiness. Under Taylor-type rule, monetary authority reacts to these shocks by slightly raising the short-term interest rate, since it has committed to respond to inflation variations, but no action is taken under money growth rule. Therefore, the central bank allows the adjustment of its currency to partially offset the negative effects of the exogenous depreciation of the U.S. dollar.[18] The appreciation of the domestic currency helps in reducing the price of imported goods in terms of the Algerian dinar.

Furthermore, an increase in ξ_t^{ε} deteriorates the country's terms of trade, as it reduces export prices, denominated in the U.S. dollar, relative to import prices that are set in the euro. As expected, such a shock instantaneously deteriorates the country's current account, which leads to a persistent increase in foreign debt. The instantaneous fall in the current account is about 0.14% upon impact, while the country's external debt significantly and persistently increases, by more than 2% at the fifth year after the shock. This is the result of the decline of export earnings in terms of the euro and increases in marginal costs of importing. Consequently, imported goods become more expensive, so their demand significantly and persistently decline after the shock. The fall in imports is about 0.8% at the forth period after the shock. The exogenous depreciation of the U.S. dollar also leads to an increase in the valuation of the external debt, which is denominated in the euro, in terms of the U.S. dollar. Thus, if oil prices or exports remain unchanged, the domestic country must borrow further from abroad, by selling more foreign bonds, to finance its external debt services and its import purchase. Consequently, the country-specific risk premium persistently rises above its long-term level. With higher risk premium, the country allocates a larger portion of its newly borrowed funds to repay the interest payments on its external debt.

Similarly, the decline in the export revenues in terms of the euro and the appreciation of the domestic currency against the U.S. dollar shift domestic demand of foreign goods, from those invoiced in the euro to those priced in the U.S. dollar. Nevertheless, this shift has small impact and cannot permanently increase the total imports, given that 65% of total imports are priced in the euro. We note that the current account, foreign debt, and the country-specific risk premium similarly respond to the EUR/USD exchange rate, under both monetary policy shocks.

Nevertheless, production in the non-oil sector slightly jumps upon impact and persists for many periods after the shock, while consumption gradually, but persistently, declines below its steady state level. Production in the non-oil sector rises, due to the expenditure-switching effect. Households increase their demand of domestic goods relative to imported goods, because domestic goods are relatively cheaper than the imported ones in the aftermath of the shock. Therefore, even though the negative effects of the EUR/USD exchange rate on the country's current account, the shock still improves production in the non-oil sector. The responses of non-oil output, consumption and total imports are qualitatively similar under both alternative monetary policies.

4.2.2 - Responses to oil price shocks

Now, we investigate macroeconomic effects of oil price shocks, p_{ot}^*. Figure 2 plots the impulse responses to a 1% positive oil-price shock (an increase in the oil price by 1%). Fluctuations in oil prices in the world markets are the main source of business cycles of oil-exporting countries. An increase in oil prices raises the oil-exporting country's revenues in terms of the U.S. dollar.

As shown in Figure 2, a positive oil-price shock implies an instantaneous appreciation of the Algerian dinar, because the domestic country's reserves in the U.S. dollar increase. As export revenues jump up and the domestic currency appreciates, the country's current account entails an instantaneous surplus. In addition, the country optimally uses a portion of the surplus to pay back some of its foreign debt. This leads to a gradual decline in the foreign debt position and to a lower country-specific risk premium. What, in turn, reduces the marginal borrowing cost that the county is facing in international financial markets.

The oil-exporting country is richer (wealth effect) after a positive oil-price shock, so households enjoy higher consumption, increase their investment, and reduce their labour supply. Imported goods are relatively cheaper after the appreciation of the domestic currency. Therefore, the domestic country's demand of foreign goods increases faster and production in the non-oil sector persistently declines one period after the shock, reflecting that domestic agents substitute the domestic goods by the imported goods, even though consumption and investment increase (expenditure-switching effect).

On the other hand, the appreciation of the domestic currency cannot fully offset the effects of the increases in domestically-produced and imported goods price on CPI inflation. The impacts of the exchange rate appreciation partially pass through to import and domestic prices, because of price stickiness in the two sectors. Under Taylor-type monetary policy, the central bank accommodates this shock by slightly decreasing the short-term nominal interest rate and allowing. The nominal interest rate slightly falls for longer periods.

The role of the two alternative monetary policies is remarkably different. The responses of imports, non-oil and consumption are relatively larger in the short terms when adopting the Taylor rule. Nevertheless, in response to oil price shocks, inflation increases under the Taylor-type rule, while it decreases under the money supply rule. This opposite responses may be explained by the fact that, under the Taylor rule, monetary authority intervenes to reduce the magnitude of the appreciation of the domestic currency relative to the U.S. dollar. Since the USD/DZD exchange rate is the real marginal cost of importing, smaller the appreciation implies higher increases in import prices. Furthermore, there are additional pressures on inflation implies by the larger increase in consumption under Taylor rule. Under money supply rule, the central bank does not intervene to limit the appreciation of the Algerian dinar. Further appreciation of the exchange rate means lower real marginal costs of importing, so import prices slightly increase in the short terms.

4.2.3 - Responses to monetary policy shocks

We now return to investigate whether the monetary authority is able to reduce the impacts of the EUR/USD and oil price shocks using either devaluation or monetary policy shocks. In theory, with price stickiness, the monetary policy is not neutral in the short terms. Monetary authority may react to neutralize the short term effects of exogenous shocks, by optimally reallocates the resources in the economy.

Figure 3 plots the impulse responses to a 1% positive monetary policy shock under both alternative monetary policy rules (an increase in ε_{rt} under the Taylor-type rule or $\varepsilon_{\mu t}$ under the money supply rule). Each one is a tightening monetary policy shock that decreases domestic aggregate demand. Following a positive increase in the nominal interest rate, output, consumption, foreign debt, and the risk-premium terms jump below their steady-state equilibrium values. The negative responses of output, consumption, and inflation (under Taylor rule) last for two or three periods after the shock.

On the other hand, the domestic currency appreciates after a monetary policy shock, because of the improvement in the current account. Imports negatively and significantly respond to monetary policy shocks, despite the appreciation of the domestic currency. Overall, under both alternative policies, a tightening monetary policy shock leads to a current account surplus, due to the instantaneous decrease in domestic demand and the decline in the foreign debt.

Figure 4 displays the impulse responses to devaluation shocks (an increase in $\varepsilon_{\chi t}$, under the Taylor-type rule. It is an expansionary monetary shock that increases domestic aggregate demand. This shock devaluates (decreases) the value of the Algerian dinar relative to the U.S. dollar. This shock significantly depreciates the real exchange rate of the Algerian dinar upon impact: The depreciation of the Algerian dinar is bout 0.4% on impact. Furthermore, foreign debt, the country-specific risk premium, and imports gradually increase for few periods after the shocks. Consequently, the current account shows a deficit in the short term before returning to its long-run level. As an expansionary monetary policy shock, an exogenous devaluation has positive effects on non-oil output, consumption, inflation, and the nominal interest rate.

Thus, the simulation results indicate that monetary authority might insolate the economic activity from the EUR/USD exchange rate and oil price shocks by adjusting the value of the domestic currency (devaluationary policy) and managing the nominal interest rate (monetary policy). Furthermore, the country can reduce the effects of the EUR/USD shocks by simply diversifies the provenance of its imports and external borrowing.

4.3 - Pass-through of exchange rate effects

Figure 5 summarizes the model's predictions concerning the effects of the shocks to the EUR/USD exchange rate and oil prices on the nominal exchange rate, consumer-price index (CPI), and import-prices index (IPI). Panel A shows that, in response to the EUR/USD exchange shock, the nominal USD/DZD exchange rate slightly appreciates in the short terms before depreciating in the long terms. Import prices, however, gradually increases in response to this shock, due to the presence of import-price rigidity. In the long-term, import prices converge to 4.3 following a 1% EUR/USD exchange rate shock. In contrast, the increases in the CPI are gradual and modest.

Panel B plots the responses of the nominal USD/DZD exchange rate, CPI, and IPI to a 1% shock to oil prices. Following this shock, the nominal exchange rate appreciates in the short terms before depreciating in the medium and long terms. The CPI shortly jumps to its long terms levels. The IPI, however, display a gradual and slow decline after the shock. The increases in import and consumer prices, after both shocks, are gradual because, in this model, we deviate from the law of one price by imposing price rigidity in the import sector.

5 - CONCLUSION

This paper develops a New-Keynesian DSGE model of a small open oil-exporting economy. The model is based on microfoundations and includes domestic- and imported goods price rigidities and capital adjustment costs. Two alternative monetary policies are considered: Taylor-type and money supply rules. The oil-exporting country is assumed to export exclusively oil at prices set in the U.S. dollar in world markets, while it borrows funds and mainly imports in terms of the euro. The economy is, therefore, facing two types of exchange rates: EUR/USD and USD/DZD exchange rates. The country also manages its currency with respect to the U.S. dollar and conducts its monetary policy following a Taylor-type rule. The model is calibrated to the Algerian economy to investigate the dynamic effects of the recent U.S. dollar depreciation relative to most world currencies and to assess macroeconomic impacts of oil price increases.

The simulation results show that the exogenous EUR/USD exchange rate shock, leading to a U.S. dollar depreciation, negatively affects the oil exporting economy. It deteriorates the country's terms of trade and the current account, and increases the external debt burden, as the foreign debt valuation and country-specific risk premium rise. The depreciation of the U.S. dollar relative to the euro increases the cost of imports, so the domestic agents substitute domestically produced goods for imported goods. Hence, imports jump down after the shock, while domestic non-oil production increases.

On the other hand, positive oil-price shocks offset the major negative effects of the EUR/USD exchange rate shock, by increasing the terms of trade and export earnings. The impacts of the U.S. depreciation are largely offset by parallel increases in oil prices and by world interest rate declines that have been appearing since 2001. It is also possible for this oil-exporting country to reduce negative effects of U.S. depreciation by issuing U.S. dollar denominated foreign bonds and diversifying the provenance of its imports. Furthermore, the monetary authority might intervene to reduce the negative effects of these shocks on the economic activity by either adjusting the short-term nominal interest rate and/or devaluating the domestic currency.

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Table 1 : Calibration of the model's parameters

Parameters	Definition	Values
β	Discount factor	0.97
a	Share of imports invoiced in the US dollar	0.35
ρ_r	Smoothing coefficient in the monetary policy	0.86
ρ_π	Inflation coefficient in the monetary policy	0.17
ρ_s	Exchange rate coefficient in the monetary policy	0.05
σ_r	Standard deviation of monetary policy shocks	0.015
ν	Elasticity of substitution between home and imported	0.6
γ	goods	0.5
a	Elasticity of substitution between private and public	0.65
ϕ	consumption	0.5
θ	Share of private consumption in total consumption	6
ψ_o	Price rigidity parameter	4
ψ_n	Elasticity of substitution between intermediate goods	5
α_o	Capital adjustment cost parameter, oil sector	0.4
α_n	Capital adjustment cost parameter, non-oil sector	0.25
b	Share of capital in the oil sector	0.22
δ_o	Share of capital in the non-oil sector	0.08
δ_n	Share of imports in GDP	0.1
φ	Capital depreciation rate in the oil sector	0.015
η	Capital depreciation rate in the non-oil sector	0.68
ω	Country-specific risk premium parameter	0.029
	Weight of leisure in utility	
	Weight of money in utility	

Note : Monetary policy coefficients, except ρ_s, are estimated using IV and annual data: 1992-2005.

Table 2 : Calibration of the stochastic processes parameters

Shocks	Autocorrelations		Standards deviations	
EUR/USD exchange rate (ξ_t)	ρ_ξ	0.78	σ_ξ	0.082
Oil price (p_t^*)	ρ_p	0.64	σ_p	0.19
Devaluation (χ_t)	ρ_χ	0.81	σ_χ	0.097
Natural resources (L_t)	ρ_L	0.70	σ_L	0.11
Non-oil technology (A_t)	ρ_A	0.75	σ_A	0.04
Government spending (g_t)	ρ_g	0.54	σ_g	0.023
Money growth (μ_t)	ρ_μ	0.68	σ_μ	0.033
World interest (R_t^*)	ρ_R	0.58	σ_R	0.011
World inflation (π_t^*)	ρ_π	0.64	σ_π	0.0044

Note : Autocorrelations and standard deviations of the stochastic processes : OLS estimations using annual data for the period 1992-2005.

Table 3 : The model's steady-state ratios to GDP

External Debt	-0.294	Consumption	0.652
Total exports	0.243	Investment	0.188
Total imports	0.231	Government spending	0.160
Non-oil output	0.757	Money stock	0.310

Table 4 : Volatility and autocorrelations: Annual data (1992-2005) and the model (under Taylor-type rule)

Variables	Volatility		Autocorrelations	
	Data	Model	Data	Model
Real exchange rate	13.2	8.60	0.81	0.61
CPI inflation	5.6	9.23	0.63	0.49
Investment	20.1	19.3	0.75	0.58
GDP	12.2	13.0	0.63	0.57
Non-oil output	9.1	7.93	0.74	0.72
Oil output	10.3	10.5	0.61	0.77
Total exports	21.0	25.3	0.56	0.65
Total imports	15.3	20.2	0.67	0.73

Note : The unconditional moments are calculated using OLS.

GRAPHIQUE

Figure 1 : Effects of a shock to EUR/USD exchange rate ()

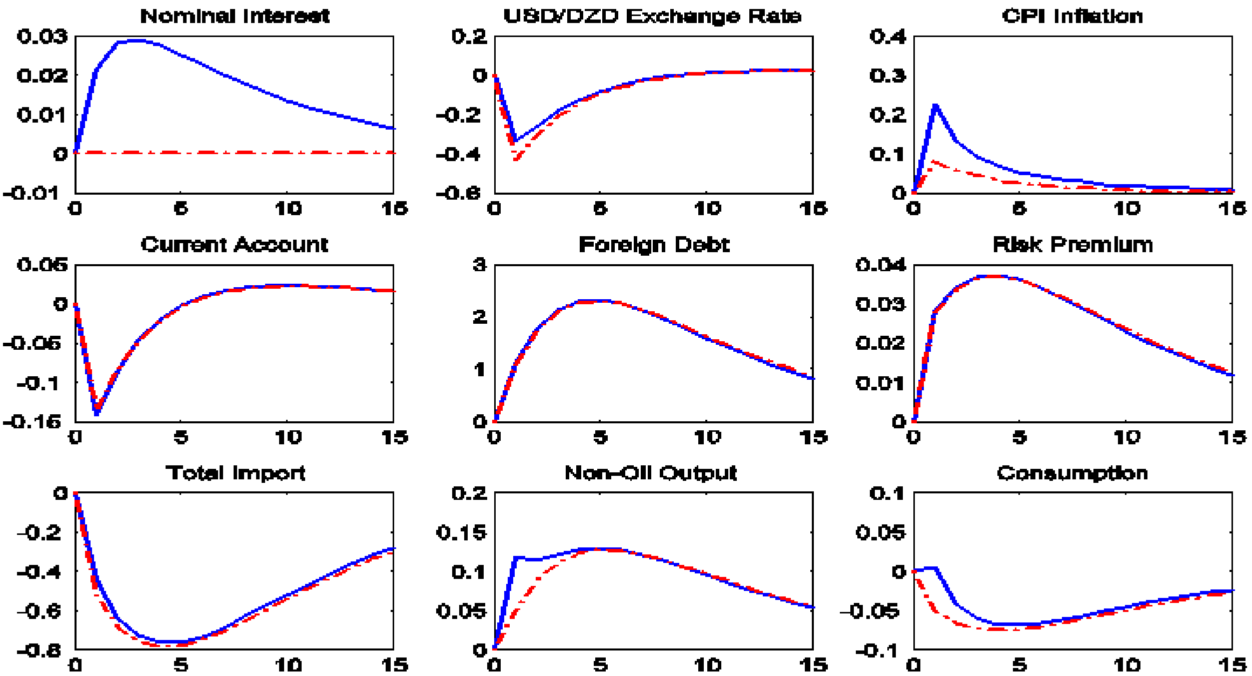


Figure 2 : Effects of a shock to oil prices ()

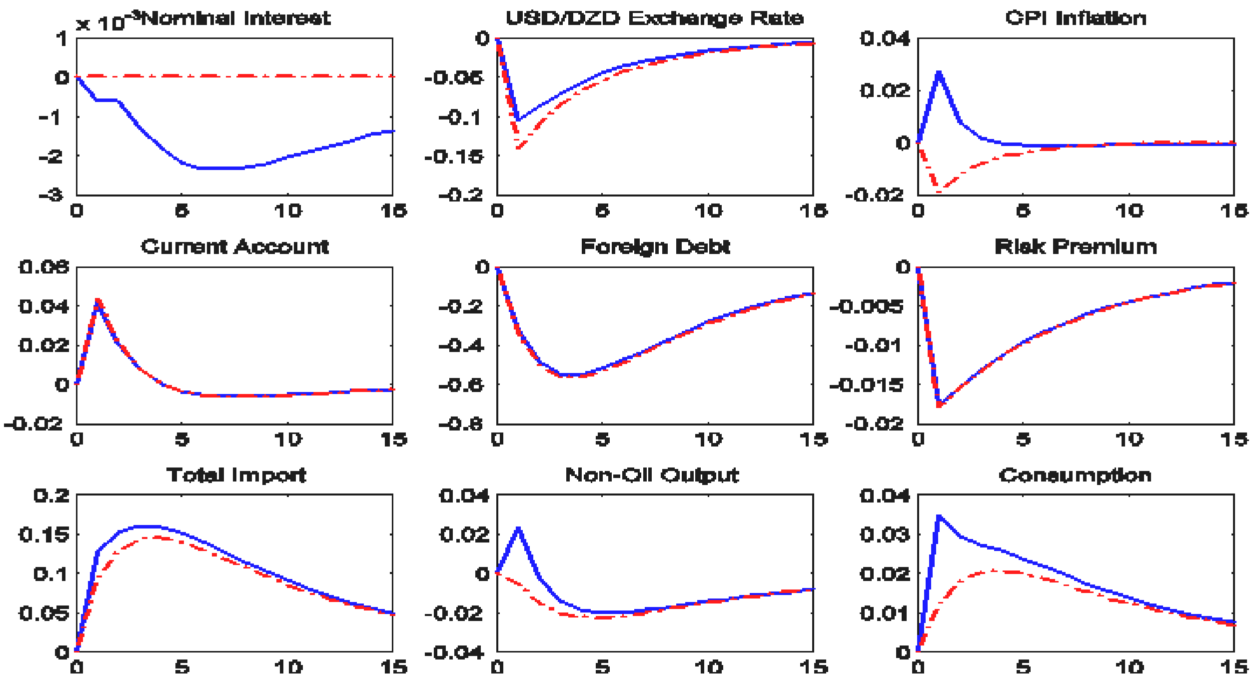


Figure 3 : Effects of monetary policy shocks ()

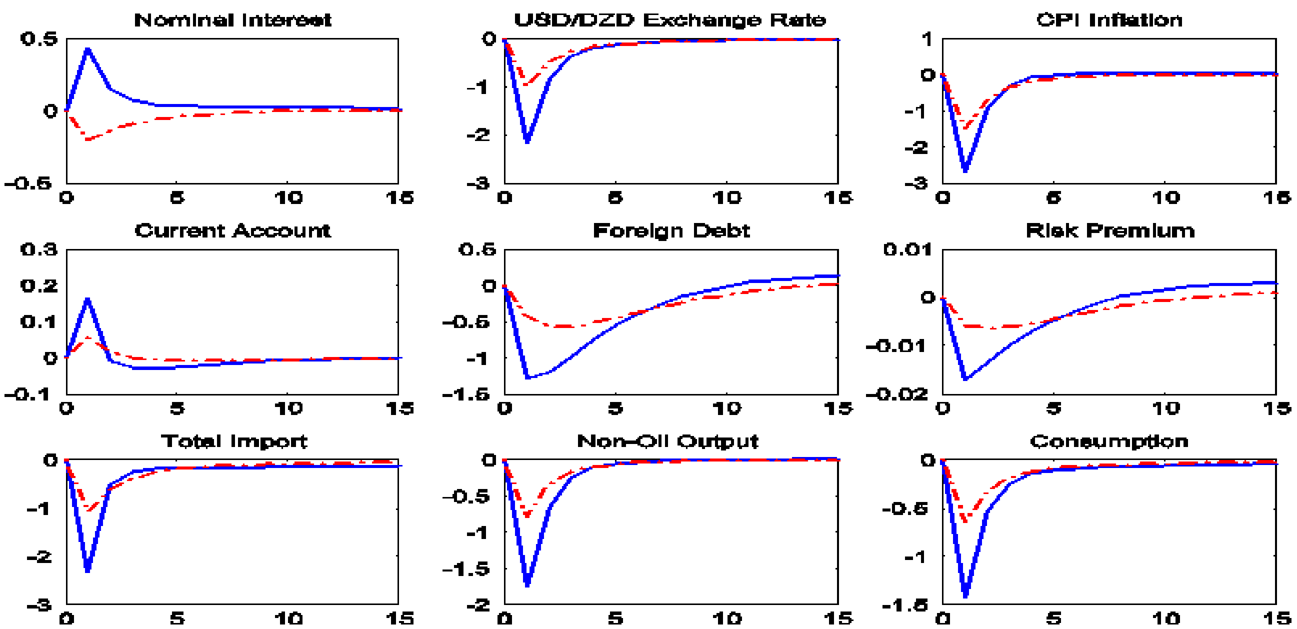


Figure 4 : Effects of a devaluation shock ()

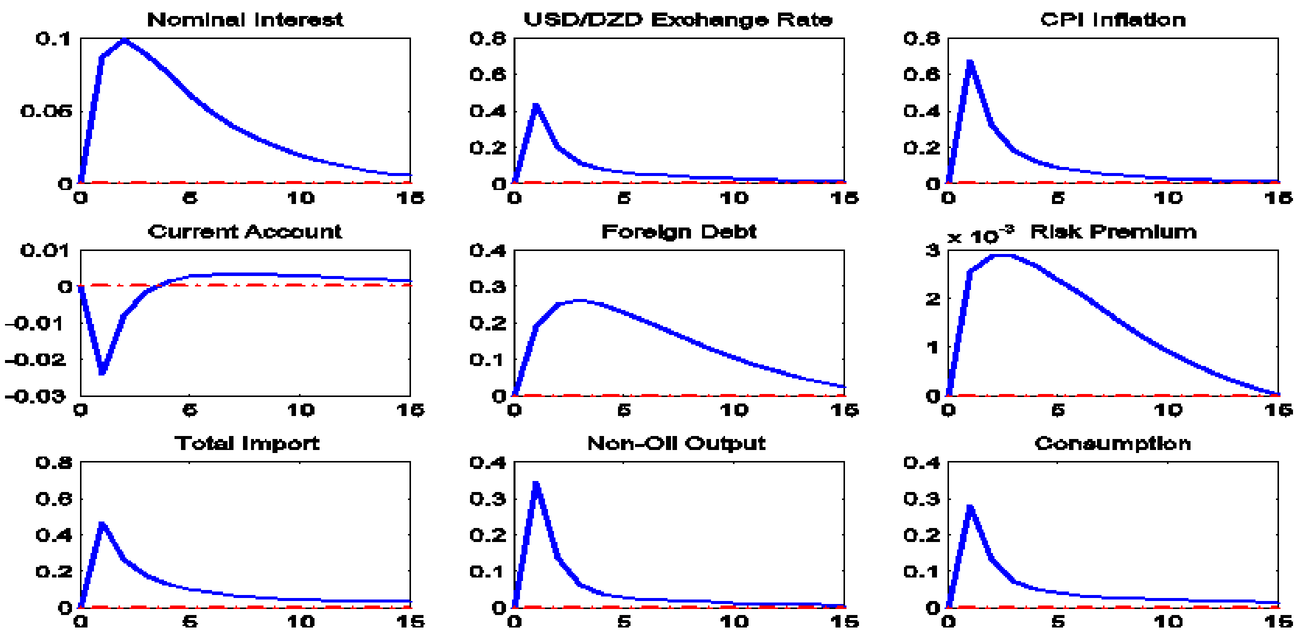
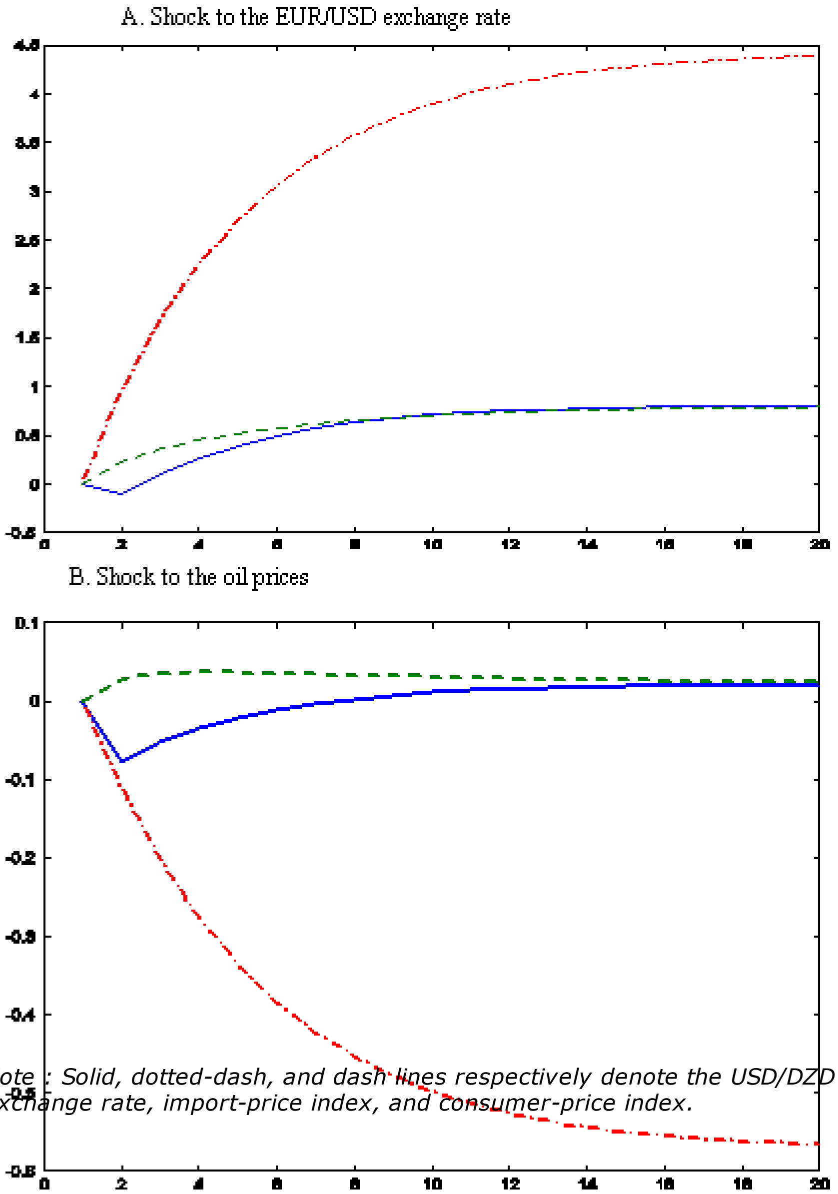


Figure 5 : Pass-through of exchange rate effects



Note : Solid, dotted-dash, and dash lines respectively denote the USD/DZD exchange rate, import-price index, and consumer-price index.

Notes

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[1] Bailliu, Dib, Kano and Schambri (2007) study the impacts of multilateral adjustments to the U.S. imbalances on the Canadian, Australian, and New Zealand dollars. The results show that these imbalances significantly account for the recent appreciation of the Canadian dollar against the U.S. dollar.

[2] In 2006, the United States was running a current account deficit of roughly 6.5% of its gross domestic product. Many

observers felt was unsustainable at the existing exchange rate levels

[3] The effects of the U.S. dollar depreciations should be smaller on oil-exporting economies that mainly export, import, and borrow in the U.S. dollar. In this case, exogenous movements of the U.S. dollar do not have direct impacts on the terms of trade or the valuation of the external debt.

[4] The bank of Canada, The US Federal Reserve Bank, the European Central Bank, the Bank of Norway, and the International Monetary Funds have already developed DSGE models to use for projection and policy analysis.

[5] In 2003, only 39% of Algerian external debt is in the US dollar, see the Algerian central bank report of 2003.

[6] d_t^* is the stock of the real foreign debt if it is negative, i.e. $d_t^* < 0$.

[7] We assume that the two capital stocks are not perfectly mobile across sectors.

[8] Let s_t and ξ_t be the USD/DZD and EUR/USD nominal exchange rates, respectively. Let P_t, P_t^* and $\tilde{P}_t^*$ denote the level of prices expressed in terms of the Algerian dinar, the U.S. dollar, and the euro, respectively. Therefore, the USD/DZD real exchange rate is $s_t = S_t P_t^* / P_t$, while the UR/USD real exchange rate is $\xi_t = \Xi_t \tilde{P}_t^* / P_t^*$.

[9] If domestic and foreign interest rates are equal, the time paths of domestic consumption and wealth follow random walks. For alternative ways of ensuring stationary paths exist for consumption in small open economy models, see Schmitt-Grohé and Uribe (2003).

[10] The central bank can conduct it monetary policy using either Taylor rule, equation (42), or money supply rule, equation (44).

[11] The allocation is $\{c_t, y_{ot}, y_{nt}, y_{ft}, k_{nt}, k_{ot}, z_t, m_t, h_t, \mu_t, d_t^*\}_{t=0}^{\infty}$, the sequence of prices and co-state variables is,

$$\{R_t, w_t, q_{ot}, q_{nt}, p_{Lt}, p_{nt}, p_{ft}, \pi_t, \pi_{nt}, \pi_{ft}, \lambda_t, \zeta_t^*, s_t\}_{t=0}^{\infty}$$

while the stochastic processes are given by

$$\{p_t^*, \xi_t, \chi_t, \varepsilon_{nt}, A_t, L_t, g_t, R_t^*, \pi_t^*\}_{t=0}^{\infty}$$

[12] For each variable x_t, $\hat{x}_t = \log(x_t / x)$ where x is the steady-state value of x_t.

[13]

$$S_t=\left(k_{nt-1},k_{ot-1},m_{t-1},d^*_{t-1},p_{nt-1},R_{t-1},A_{t-1},p^*_{ot-1},L_{t-1},\chi_{t-1},\xi^e_{t-1},g_{t-1},R^*_{t-1},\pi^*_{t-1}\right)'$$

$$D_t=\left(\lambda_t,\zeta_t,q_{ot},q_{nt},p_{ft},m_t,p_{Lt},R_t,c_c,y_{ot},y_{nt},y_{ft},\pi_t,\pi_{nt},\pi_{ft}\right)'$$

$$\varepsilon_t=\left\{\varepsilon_{pt},\varepsilon_{\xi t},\varepsilon_{\chi t},\varepsilon_{rt},\varepsilon_{\mu t},\varepsilon_{gt},\varepsilon_{Lt},\varepsilon_{Rt},\varepsilon_{\pi t}\right\}$$

[14] For example, Christiano, Eichenbaum and Evans (2005) and Dib (2008).

[15] The series used in the estimation of the exogenous stochastic processes are either stationary or linearly detrended. The sample is annual from 1992 to 2005.

[16] Following the annual economic reports of the Bank of Algeria, the share of Algerian imports from the Euro Area is about 65% of total imports.

[17] These statistics are calculated for the period 1992 to 2005.

[18] Under fixed exchange rate regime (or pegged exchange rate), the exchange rate will not adjust leading to higher increases in import prices and much larger impact on CPI inflation, so the economy is importing foreign inflation. Floating the exchange rate is a buffer against the negative shocks hitting the economy.