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# MONETARY POLICY, OIL STABILIZATION FUND AND THE DUTCH DISEASE

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# Monetary Policy, Oil Stabilization Fund and the Dutch Disease

Jean-Pierre Allegret\*    Mohamed Tahar Benkhodja<sup>†</sup>  
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## Abstract

This paper contributes to the literature on the Dutch disease effect in a small open oil exporting economy. Specifically, our contribution to the literature is twofold. On the one hand, we formulate a DSGE model in line with the balanced-growth path theory. On the other hand, besides alternative monetary rules, the model introduces an oil stabilization fund, an oil price rule, and a fiscal rule. Our aim is to analyze to what extent the combinations between our alternative monetary rules and fiscal policy are effective to prevent a Dutch disease effect in the aftermath of a positive oil price shock. Our main findings show that the Dutch disease, through the spending effect, occurs only in the case of inflation targeting regime. An expansionary fiscal policy contributes to improve the state of the economy through its impact on the productivity of the manufacturing sector.

**Keywords:** Monetary Policy, Oil Stabilization Fund, Dutch disease, Oil Prices, DSGE model.

**JEL Classification:** E52, F41, Q40

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# 1 Introduction

For a long time, oil price fluctuations have always been at the center of macroeconomic analysis. Several studies have been undertaken to understand the consequences of this shock on economic activity. Much of the existing literature has been devoted to the examination of the monetary policy reaction to oil price shocks, especially in industrialized economies. Some others, examined the role of fiscal policy.

This paper analyzes the role of monetary and fiscal policies in an oil exporting economy to see to what extent in the aftermath of a positive oil price shock, the deindustrialisation phenomenon, as defined in the Dutch disease literature, occurs. In order to analyse this effect, we build a small open oil exporting model using a multi-sectoral medium-scale DSGE framework as in [Christoffel et al 2008](#) and [Stahler and Thomas 2012](#). We assume that the central bank sets the short-term nominal interest rate following an extended Taylor rule and accumulates foreign exchange reserves. We assume that the central bank adopts alternative monetary policy rules, namely a strict inflation targeting, a fixed exchange rate regime and a domestic oil price inflation as in [Frankel \(2011, 2017\)](#). We also assume that the government subsidize the price of domestically consumed refined oil as a combination of the current world price expressed in local currency and the last period's domestic price. Also, the government holds an oil stabilization fund and accumulates foreign exchange reserves. Importantly, this paper differs from previous papers by combining different monetary rules with fiscal policy to assess their effectiveness to face Dutch disease effect.

An extensive literature on oil exporting countries tends to focus either on high-income economies [Lama and Medina, 2012](#) or low-income and lower-middle-income economies ([IMF, 2012](#); [Berg et al., 2013](#)). A second significant difference from previous papers is that we analyze upper-middle-income oil exporters. More specifically, within this group, we consider oil-exporters sharing characteristics that bring them closer to lower-middle-income economies, i.e. Algeria and Venezuela. Appendix 1 exhibits several indicators stressing this important feature. Relative to other upper-middle-income and high-income oil-exporters, they experience a higher oil dependence as in lower-income economies. This oil dependence is observed both in terms of oil exports in total exports (Table 2) and oil exports as a share of GDP

(Table 3). Table 4 reveals another important fact for our purpose: government effectiveness in oil-exporters such as Algeria and Venezuela is relatively weak. Government effectiveness refers, among others, to institutional effectiveness, quality of infrastructure and public administration. In other words, the question of public investment efficiency (Berg et al., 2013) is especially sensitive in these countries.

Our main findings show that the Dutch disease occurs only under inflation targeting and oil price inflation rules. The fixed exchange rate monetary rule seems to be effective to prevent a Dutch disease effect. Also, under IT rule, the decline in export sector tends to shrink gradually as the rise in the share of OSF dedicated to the support export sector. The decline in export goods production is completely resorbed when we combine the share of oil stabilisation fund (OSF hereafter) with a positive coefficient of enhancing productivity. This is not the case when oil price inflation rule is considered. Finally, optimal monetary and fiscal policies do not give better results than ER rule which also gives the highest welfare gain.

The remainder of the paper is organized as follows. Section 2, presents the review of the literature dedicated to the Dutch disease effect that is modeled using DSGE models. Section 3, describes the model. Section 4, discusses the parameters calibration. Section 5 exposes the main results. Section 6 presents the conclusion.

## 2 Literature review

Our paper is related to three strands of the literature using dynamic stochastic general equilibrium (DSGE) models. This first one is the literature dedicated to the Dutch disease effect. Acosta et al. (2009) investigate the effects of remittances on resource reallocation and the real exchange rate. They show that sizeable remittances are associated to real exchange appreciation, which in turn, lead to a decline in the production of tradable goods. Cherif (2013) suggests that Dutch disease tends to be more severe in developing countries. The model includes two externalities -the presence of learning-by-doing in the tradable sector and cross-country knowledge spillovers. The spending effect tends to be stronger in developing countries insofar as the increase in income in terms of domestic wages in the aftermath of the foreign transfer is greater than in economies with lower technological gap. Alberola and Benigno (2017) consider an additional channel through the degree of financial open-

ness of the economy. Financial openness amplifies the domestic impacts of a positive shock on commodity price. More specifically, commodity exporters experience an improvement in their net foreign asset position. This positive wealth effect increases domestic demand leading to a permanent reallocation of resources from the tradable sector to the non-tradable one.

A second strand of literature focuses on resource-rich low-income countries [IMF \(2012\)](#). [Berg et al. \(2013\)](#) contribute to the debates on the management of revenues from nonrenewable resources in low-income countries. They advocate a “sustainable investing approach” combining a rise in public investment -to respond to capital-scarcity- and saving a part of the resources in a fund -to face both recurrent costs for operation and maintenance and resource exhaustion. The model has some interesting distinguishing features for our purpose. First, the Dutch disease effect is captured through a learning-by-doing externality in the traded sector. Second, public investment exerts an influence on the productivity in both the nontraded and traded good sectors. In other words, the government can implement an investment strategy to counterbalance the Dutch disease phenomenon resulting from a positive commodity shock. Third, public investment suffers from two important distortions: a low public investment efficiency on the one hand; absorptive capacity constraints in the economy in the other hand. In a relatively close perspective, [Alter et al. \(2017\)](#) investigate the public investment strategy in a context of natural resource depletion. The model includes institutional failures through project selection weakness. As [Berg et al. \(2013\)](#), they conclude in favor of a scaling-up investment strategy in which the government increases its investment in the economy promoting the diversification of the economy and the development of infrastructures while simultaneously taking into account the need to ensure fiscal stability over time.

The third strand of literature focuses on macroeconomic stabilization policy in the aftermath of oil price shocks. On the monetary policy side, [Lama and Medina \(2012\)](#) study the role of an exchange rate stabilization policy to face Dutch disease effect. Their model includes a real rigidity under the form of learning-by-doing externalities in the tradable sector. They find that exchange rate stabilization policy may prevent the real appreciation of the domestic currency, and hence a fall in the tradable production, but this policy may increase macroeconomic volatility to the detriment of the learning-by- doing externalities. Consequently, an exchange rate

stabilization policy is welfare-reducing relative to a floating regime. [Dagher et al. \(2012\)](#) analyze the short-run effects of oil windfalls in low-income countries. They assume the presence of bottlenecks in the economy and non-optimizing households. An important finding is the counterproductive effect of reserve accumulation in response to a positive oil shock as this strategy crowds out both private consumption and investment. [Dagher et al. \(2012\)](#) suggest that the best response is the coordination of reserve accumulation policy with the fiscal policy where reserves are saved externally in a sovereign wealth fund. [Faltermeir et al. \(2017\)](#) investigate whether the accumulation of foreign exchange reserves is welfare-improving in countries suffered from a Dutch disease effect. In an economy exhibiting nominal rigidities and learning-by-doing externalities in the tradable sector, they find that large and sustained accumulation of reserves is welfare-improving insofar as this strategy allows higher gains relative to a peg regime or a policy rate rule. On the fiscal side, an extensive literature has been dedicated to fiscal rules as public spending tend to go hand in hand with oil receipts, generating pro-cyclical policy ([Baunsgaard et al., 2012](#); [El Anshasy and Bradley, 2012](#)). [Arezki and Ismail \(2013\)](#) investigate the behavior of the real exchange rate during the boom-bust commodity price cycle. While the real exchange rate appreciates during the boom phase, the depreciation is smaller than the fall of commodity price during the bust period. This disconnection is due to the fiscal policy adopted by governments in rich-resource countries. The lack of fiscal discipline implies a bias in fiscal spending -due to political pressures- during the boom-bust cycle. As current spending exhibits a high domestic content, this bias tends to exert a structural pressure on non-tradable good prices, and, hence, on the real exchange rate appreciation. Fiscal smoothing plays a critical role to manage both short- and medium-term effects of a commodity windfall. [Pieschacón \(2012\)](#) -by comparing Mexican and Norwegian experiences- highlights the welfare improving of fiscal rules that insulate the domestic economy from oil price shocks.

### 3 The Model

In line with the balanced-growth path theory, we assume that real variables will share the same evolution as the labor-augmenting technology process  $\Theta_t$ . Therefore, to render the model stationary, we scale real variables by  $\Theta_t$  and nominal variables

by the consumer price level  $P_t$ . Transformed variables are represented by lower-case letters which in the literature is known as "intensive form" representation. For instance,  $c_t = C_t/\Theta_t$  and  $p_{H,t} = P_{H,t}/P_t$  represent respectively the stationary level of consumption and relative price of domestic goods.<sup>1</sup> It is important to note that the level of hours worked  $L_t$  is already stationary and no further transformation is needed. The growth rate of the labor-augmenting technology process  $g_{\Theta,t} = \Theta_t/\Theta_{t-1}$  is assumed to evolve according to:

$$\ln(g_{\Theta,t}) = (1 - \rho_{g_{\Theta}}) \ln(\bar{g}_{\Theta}) + \rho_{g_{\Theta}} \ln(g_{\Theta,t-1}) + \eta_t^{g_{\Theta}}$$

where  $\eta_t^{g_{\Theta}} \rightsquigarrow \text{iid } \mathcal{N}(0, \sigma_{g_{\Theta}}^2)$  and  $\bar{g}_{\Theta}$  is the steady-state value of  $g_{\Theta,t}$ . For the sake of clarity, the following presentation of the model does not include productivity differential between home and foreign countries, price and wage dispersion across firms and households, and adjustment cost when changing the level of imported goods in the final-good production process.<sup>2</sup>

### 3.1 Households

The population size in the oil-exporting country is normalized to unity,  $h = [0, 1]$ . Representative household within the oil-exporting (Home) country maximizes a string of discounted future value of utilities given by:

$$E_t \sum_{k=0}^{\infty} \beta^k U_{t+k}(c_{t+k}(h), ha_{t+k}(h), m_{t+k}(h), L_{t+k}(h)) \quad (1)$$

where the period  $t$  utility function of the household is defined as:

$$U_t(\dots) = \epsilon_t^B \left( \ln(c_t - hg_{\Theta,t}^{-1}c_{t-1}) + \theta_M \epsilon_t^M \ln(m_t) - \epsilon_t^L \frac{(L_t)^{1+\psi}}{1+\psi} \right) \quad (2)$$

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<sup>1</sup>There are some noteworthy exception when scaling the level of capital and wage. Given the predetermined nature of the capital stock and the convention that  $K_t$  represents the stock of capital in the beginning of period, the stationary level of capital stock is defined as  $k_{t+1} = K_{t+1}/\Theta_t$ . Moreover, given the assumption that nominal wage evolves in line with labor-augmenting productivity growth, it is necessary to scale it both with  $\Theta_t$  and  $P_t$ . That is, stationary level of wage is defined as  $w_t = W_t/\Theta_t P_t$ .

<sup>2</sup>Technical appendix containing details of the model is available upon request for interested readers.



We assume perfect insurance markets within home country<sup>3</sup> and that households share the same preference technology. Thus,  $c_t$  represents the representative household's composite consumption index,  $m_t$  the holdings of real money balance,  $ha_t$  an external habit that is defined as  $ha_t = hg_{\Theta,t}^{-1}c_{t-1}$ , and  $L_t$  the representative household's differentiated labor supply (number of hours worked). In turn,  $\epsilon_t^B$ ,  $\epsilon_t^M$  and  $\epsilon_t^L$  are respectively the preference, the money demand and the labor supply shocks. Finally, parameters  $\theta_M$  and  $\psi$  represent the weight of real money balance on the utility of consumers and the inverse of Frisch elasticity of labor supply, respectively. Moreover, we assume that the aggregation of individual labor supply across oil, export and domestic sectors is represented by the following Cobb-Douglas aggregator:

$$L_t = \left[ v_O^{\frac{1}{\eta_L}} L_{O,t}^{\frac{\eta_L-1}{\eta_L}} + v_X^{\frac{1}{\eta_L}} L_{X,t}^{\frac{\eta_L-1}{\eta_L}} + v_H^{\frac{1}{\eta_L}} L_{H,t}^{\frac{\eta_L-1}{\eta_L}} \right]^{\frac{\eta_L}{\eta_L-1}} \quad (3)$$

where  $\eta_L$  is the household's labor supply elasticity of substitution between different sectors of production. The parameter  $v_i$ , for  $i = \{O, X, H\}$  and where  $\sum_i v_i = 1$ , represents labor supply share of household to sector  $i$ . The overall wage index evolves according to:

$$w_t = \left[ v_O w_{O,t}^{1-\eta_L} + v_X w_{X,t}^{1-\eta_L} + v_H w_{H,t}^{1-\eta_L} \right]^{\frac{1}{1-\eta_L}} \quad (4)$$

### 3.1.1 Consumption, price and demand

We assume that the consumption basket of a representative household is composed of non-oil goods  $c_{NO,t}$  and exclusively imported refined-oil  $c_{RO,t}$ . Thus, total consumption is represented by the following CES function:

$$c_t = \left[ (1 - v_C)^{\frac{1}{\eta_C}} (c_{NO,t})^{\frac{\eta_C-1}{\eta_C}} + v_C^{\frac{1}{\eta_C}} (c_{RO,t})^{\frac{\eta_C-1}{\eta_C}} \right]^{\frac{\eta_C}{\eta_C-1}}$$

where  $\eta_C$  is the elasticity of substitution between oil and non-oil goods, and  $v_C$  represents the share of refined-oil energy in the representative household's consumption

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<sup>3</sup>It implies that household's individual variable  $X_t(h)$  for  $X = \{C, M, L, K, W, B, B^*, DIV\}$  will be equal to the corresponding aggregate variable  $X_t$ . Formally, we allow individual household to receive net cash inflow from participating in a state-contingent securities that insures identical wage income and, hence, optimal allocation in equilibrium across households.

basket.

Given this consumption function index, the consumption-based price index (CPI), which we define henceforth the "*headline-CPI*", is defined as:

$$p_t = \left[ (1 - v_C) (p_{NO,t})^{1-\eta_C} + v_C (p_{RO,t})^{1-\eta_C} \right]^{\frac{1}{1-\eta_C}} \quad (5)$$

where  $p_{NO,t}$  is the core-consumption price index, henceforth "*core-CPI*", which is defined in equation (21).

### 3.1.2 Household's optimization problem

Households have access to both domestic and private foreign bonds markets which we denote respectively  $b_t^d$  and  $b_t^*$ . We assume that international market is incomplete and domestic households trade only risk-free assets. However, the nominal interest rate paid or received by households when selling or buying foreign bonds depends on financial intermediation premium through a risk-premium charges on top of nominal world interest rate  $R_t^*$ . This is done to ensure stationarity of equilibrium following [Schmitt-Grohé and Uribe \(2003\)](#). As in [Stähler and Thomas \(2012\)](#), the risk premium is defined to be an increasing function of the home country (net) debt position. That is,

$$z_t = \exp \left\{ -\psi \left( \frac{nfa_t}{y_t} - \frac{\overline{nfa}}{\bar{y}} \right) \right\}$$

with  $\psi > 0$  and where  $nfa_t$  and  $y_t$  are respectively the period  $t$  net foreign asset position and gross domestic products. Home-country net foreign assets in turn are composed of private net foreign assets  $b_t^*$ , public net foreign assets  $f_t$ , the stabilization fund, that come from oil exports, and exchange rate reserve  $res_t^*$ . Moreover, we assume that foreign assets are denominated in US Dollar. That is,

$$nfa_t = z_t (b_t^* + f_t + res_t^*) \quad (6)$$

where  $z_t$  denotes US Dollar-bilateral real exchange rate. Nominal exchange rates is expressed as the home-currency price of one unit of foreign currency. Therefore, a decrease in  $z_t$  is interpreted as a home-currency appreciation.

Each period, individual representative household faces the following budget constraint:

$$(1 + \tau_t^c)c_t + p_{I,t}i_t^p + m_t + (b_t^d + z_t b_t^*) = inc_t + \epsilon_{t-1}^Q R_{t-1} \frac{b_{t-1}^d}{g_{\Theta,t} \Pi_t} + \frac{m_{t-1}}{\Pi_t g_{\Theta,t}} + z_t (g_{\Theta,t}^* \Pi_t^*)^{-1} (\chi_{t-1} R_{t-1}^* b_{t-1}^*) \quad (7)$$

where  $\epsilon_t^Q$  is the risk premium shock that arises from the presence of domestic financial intermediation and  $i_t^p = \sum_{i=X,H,O} i_{i,t}^p$ . As is argued by [Christoffel et al. \(2008\)](#), the use of current real exchange rate  $z_t$  stems from the fact that net foreign asset position is a predetermined variable. Household's total income  $inc_t$  is composed of dividends derived from import, export, domestic non-tradable intermediate firms, and oil firm ( $div_t = \sum_{i=IM,X,H,O} \pi_{i,t}^p$ ), return on effective capital stock minus the cost associated with variations in the degree of capital utilisation  $u_t$ , labor income and lump-sum tax or transfer  $t_t$ . That is,

$$inc_t = div_t + \sum_{i=X,H,O} (r_{i,t}^k u_{i,t} - \Psi(u_{i,t}) p_{I,t}) g_{\Theta,t}^{-1} k_{i,t}^p + (1 - \tau_t^w) w_t L_t - t_t + p_{EO,t} e o_t$$

where  $r_{i,t}^k$  is the real return on effective capital and  $\Psi(u_{i,t})$  is the cost associated in changing the degree of capital utilisation  $u_{i,t}$  with  $\Psi(1) = 0$  and is defined as:

$$\Psi(u_{i,t}) = \gamma_{i,1} (u_{i,t} - 1) + \frac{\gamma_{i,2}}{2} (u_{i,t} - 1)^2 \text{ for } i = X, H, O$$

with  $\gamma_{i,1}, \gamma_{i,2} > 0$ . As the natural resource endowment  $e o_t$  is owned by the public,  $p_{EO,t} e o_t$  represents the natural resource revenue transferred to consumer.

Moreover, we assume that households accumulate units of private capital used in oil, export and domestic non-tradable firms. We follow [Christiano et al. \(2005\)](#) and [Stähler and Thomas \(2012\)](#), and assume that private capital evolves according to the following law of motion:

$$k_{i,t+1}^p = (1 - \delta) g_{\Theta,t}^{-1} k_{i,t}^p + \epsilon_t^I \left( 1 - S \left( g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right) \right) i_{i,t}^p \text{ for } i = X, H, O \quad (8)$$

where  $\epsilon_t^I$  is defined to be the (private) investment shock and  $S(\cdot) = \frac{\kappa_{i,I}}{2} \left( g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} - \bar{g}_{\Theta} \right)^2$

is a positive cost function for changing the level of investment which has the following properties:  $S(1) = 0$ ,  $S'(1) = 0$  and  $S''(1) > 0$ .

Finally, households choose  $\{c_{t+k}, m_{t+k}, b_{t+k}^d, b_{t+k}^*, k_{i,t+k+1}^p, i_{i,t+k}^p, u_{i,t+k}\}_{k=0}^{\infty}$  to maximize the discounted future value of their utilities (1) subject to their budget constraints (7) and the law of motion for capital (8). Solving this maximization problem yields the following standard first order conditions:

$$\Lambda_t = \frac{\epsilon_t^B (c_t - h g_{\Theta,t}^{-1} c_{t-1})^{-1}}{1 + \tau_t^c} \quad (9a)$$

$$1 = E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} (g_{\Theta,t+1} \Pi_{t+1})^{-1} \epsilon_t^Q R_t \right\} \quad (9b)$$

$$1 = \frac{\theta_M \epsilon_t^B \epsilon_t^M}{\Lambda_t m_t} + E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} (g_{\Theta,t+1} \Pi_{t+1})^{-1} \right\} = \frac{\theta_M \epsilon_t^B \epsilon_t^M}{\Lambda_t m_t} + \frac{1}{\epsilon_t^Q R_t} \quad (9c)$$

$$1 = E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} (g_{\Theta,t+1} \Pi_{t+1}^*)^{-1} \frac{z_{t+1}}{z_t} \varkappa_t R_t^* \right\} \quad (9d)$$

$$Q_{i,t} = E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} g_{\Theta,t+1}^{-1} [r_{i,t+1}^k u_{i,t+1} - \Psi(u_{i,t+1}) p_{I,t+1} + (1 - \delta) Q_{i,t+1}] \right\} \quad (9e)$$

$$p_{I,t} = Q_{i,t} \epsilon_t^I \left[ 1 - S \left( g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right) - S' \left( g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right) g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right] + \quad (9f)$$

$$E_t \left\{ Q_{i,t+1} \epsilon_{t+1}^I \frac{\beta \Lambda_{t+1}}{\Lambda_t} S' \left( g_{\Theta,t+1} \frac{i_{i,t+1}^p}{i_{i,t}^p} \right) g_{\Theta,t+1} \left( \frac{i_{i,t+1}^p}{i_{i,t}^p} \right)^2 \right\}$$

$$r_{i,t}^k = \Psi'(u_{i,t}) p_{I,t} \quad (9g)$$

### 3.1.3 Wage setting

Households supply monopolistically a distinctive variety of labor and set nominal wages in staggered contracts fashion à la [Calvo \(1983\)](#). Each period, individual household is allowed to set its nominal wage only after receiving a random signal with constant probability  $(1 - \theta_{W_i})$ , so that  $w_{i,t}(h) = \tilde{w}_{i,t}^o(h)$ . However, whenever household is not allowed to adjust its contracts, wage is indexed to last period CPI

inflation<sup>4</sup> rate according to the following indexation rule:

$$w_{i,t}(h) = \frac{\prod_{t-1}^{\gamma_{W_i}}}{\prod_t} w_{i,t-1}(h) \quad (10)$$

If  $\gamma_{W_i} = 0$  there is no indexation and if  $\gamma_{W_i} = 1$  there is a perfect indexation of wage to past inflation. In turn, households that are allowed to adjust nominal wage will optimally choose:

$$\tilde{w}_{i,t}^o(h) = \frac{f_{W,t}^{i,1}}{f_{W,t}^{i,2}}$$

where

$$\begin{aligned} f_{W,t}^{i,1} &= (\lambda_{W,t}^i)^{-1} \epsilon_t^B \epsilon_t^L (L_{i,t})^{1+\psi} (1 + \lambda_{W,t}^i) + \beta \theta_{W_i} E_t \{ f_{W,t+1}^{i,1} \} \\ f_{W,t}^{i,2} &= (\lambda_{W,t}^i)^{-1} L_{i,t} \epsilon_t^B (c_t - h g_{\Theta,t}^{-1} c_{t-1})^{-1} \left( \frac{1 - \tau_t^w}{1 + \tau_t^c} \right) + \beta \theta_{W_i} E_t \left\{ \frac{\prod_t^{\gamma_{W_i}}}{\prod_{t+1}} f_{W,t+1}^{i,2} \right\} \end{aligned}$$

## 3.2 Firms

### 3.2.1 Intermediate good firms

In the domestic market, there exists three types of intermediate good firms that behave as monopolistic suppliers of their differentiated intermediate goods: a continuum of domestic intermediate good firms  $h_t(f)$  indexed by  $f \in [0, 1]$  which produce a differentiated intermediate goods that are sold domestically, a continuum of export intermediate good firms  $x_t(f)$  which produce a differentiated intermediate goods that are sold exclusively to domestic exporting firms, and a continuum of import intermediate good firms  $im_t(f)$  which import a differentiated intermediate goods that are produced abroad and sell them without any transformation to domestic final-good firms.

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<sup>4</sup>We follow Erceg et al. (2000), Smets and Wouters (2003), and Adolfson et al. (2007) when taking CPI inflation as wage indexation to past inflation. Some open DSGE model such as the SIGMA model by Erceg et al. (2006) and that of Jacquinot et al. (2006) instead use wage inflation to index wage to past inflation.

### Domestic and export intermediate good firms

Domestic intermediate good firms use both labor  $L_{H,t}(f)$  and effective capital stock  $\tilde{k}_{H,t}^p(f) = u_t g_{\Theta,t}^{-1} k_{H,t}^p(f)$  to produce output according to the following constant returns to scale technology:

$$h_t(f) = \epsilon_t^a (k_{H,t}^g)^\eta \left[ \tilde{k}_{H,t}^p(f) \right]^{\alpha_H} [L_{H,t}(f)]^{1-\alpha_H-\eta} - \Phi \quad (11)$$

where  $\epsilon_t^a$  is the aggregate productivity shock,  $k_{H,t}^g$  the public capital stock that is assumed as in [Stähler and Thomas \(2012\)](#) to be productivity-enhancing,  $\eta \in [0, 1]$  the parameter that measures the degree of public investment into private production, and  $\Phi$  a fixed cost.

Cost minimization problem of the firm yields capital-labor ratio and marginal cost that are identical across intermediate good producers. They are given respectively by:

$$\frac{\tilde{k}_{H,t}^p}{L_{H,t}} = \frac{\alpha_H}{1 - \alpha_H - \eta} \frac{w_{H,t}/p_{H,t}}{r_{H,t}^k} \quad (12)$$

$$MC_{H,t} = \frac{1}{\epsilon_t^a (k_{H,t}^g/L_{H,t})^\eta} \left( \frac{w_{H,t}/p_{H,t}}{1 - \alpha_H - \eta} \right)^{1-\alpha_H} \left( \frac{r_{H,t}^k}{\alpha_H} \right)^{\alpha_H} \quad (13)$$

Moreover, domestic intermediate good firms behave as a monopolistic supplier of their goods. They offer their goods in the quantity demanded at the current price  $p_{H,t}(f)$  which is assumed to be sticky and set in staggered fashion à la [Calvo \(1983\)](#). That is, a fraction  $(1 - \theta_H)$  of randomly selected firms is able to set new prices  $\tilde{p}_{H,t}^o(f)$  each period, whereas a fraction  $\theta_H$  of firms keeps their prices unchanged and simply follow the following indexation rule:

$$p_{H,t}(f) = \frac{\Pi_{H,t-1}^{\gamma_H}}{\Pi_t} p_{H,t-1}(f)$$

where the parameter  $\gamma_H$  measures the degree of indexation to past inflation. Firms that are able to adjust prices use the following optimal pricing decision:

$$\frac{\tilde{p}_{H,t}^o}{p_{H,t}} = \frac{f_{H,t}^1}{f_{H,t}^2} \quad (14)$$

where

$$\begin{aligned} f_{H,t}^1 &= \Lambda_t \varkappa_H h_t (\lambda_{H,t}^p)^{-1} (1 + \lambda_{H,t}^p) MC_{H,t} + \beta \theta_H E_t \{ f_{H,t+1}^1 \} \\ f_{H,t}^2 &= \Lambda_t \varkappa_H h_t (\lambda_{H,t}^p)^{-1} + \beta \theta_H E_t \{ \Pi_{H,t}^{\gamma_H} (\Pi_{H,t+1})^{-1} f_{H,t+1}^2 \} \end{aligned}$$

The term  $(1 + \lambda_{H,t}^p)$  denotes time-varying mark-up of prices over marginal costs at domestic intermediate good firms' level and is assumed to evolve according to the following rule:

$$\ln(1 + \lambda_{H,t}^p) = \ln(1 + \lambda_H^p) + \eta_{H,t}^p$$

where  $\eta_{H,t}^p$  is a domestic good markup shock or domestic firm cost-push shock that evolves according to:

$$\eta_{H,t}^p \hookrightarrow \text{i.i.d } \mathcal{N}\left(0, \sigma_{\lambda_H^p}^2\right)$$

Finally, export intermediate good firms follow the same optimal decision as for domestic intermediate good firms.

### Import intermediate good firms

There exists a continuum of domestic retailer firms which import goods in international trade market where the law of one price holds "*at the dock*". In order to generate incomplete exchange rate pass-through into import prices, we follow [Monacelli \(2003\)](#) and assume that intermediate importing firms behave as a monopolistic firm when setting home currency price of imported goods. Therefore, deviations from the law of one price assumption, hence incomplete exchange rate pass-through, occur due to the optimal mark-up problem that importing firms have to face when setting prices. We assume that prices are sticky and set in staggered fashion à la [Calvo \(1983\)](#). A fraction  $(1 - \theta_{IM})$  of randomly selected importing firms is able to set new prices  $\tilde{p}_{IM,t}^o(f)$  each period, whereas a fraction  $\theta_{IM}$  of importing firms keeps their prices unchanged and simply follow the following indexation rule:

$$p_{IM,t}(f) = \frac{\Pi_{IM,t-1}^{\gamma_{IM}}}{\Pi_t} p_{IM,t-1}(f)$$

where the parameter  $\gamma_{IM}$  measures the degree of indexation to past inflation. Firms

that are allowed to set prices will choose the following optimal pricing decision:

$$\frac{\tilde{p}_{IM,t}^o}{p_{IM,t}} = \frac{f_{IM,t}^1}{f_{IM,t}^2} \quad (15)$$

where

$$\begin{aligned} f_{IM,t}^1 &= \Lambda_t im_t (\lambda_{IM,t}^p)^{-1} (1 + \lambda_{IM,t}^p) MC_{IM,t} + \beta \theta_{IM} E_t \{ f_{IM,t+1}^1 \} \\ f_{IM,t}^2 &= \Lambda_t im_t (\lambda_{IM,t}^p)^{-1} + \beta \theta_{IM} E_t \{ \Pi_{IM,t}^{\gamma_{IM}} (\Pi_{IM,t+1})^{-1} f_{IM,t+1}^2 \} \end{aligned}$$

with

$$MC_{IM,t} = z_t \frac{p_{X,t}^*}{p_{IM,t}} \quad (16)$$

and  $p_{X,t}^*$  represents the foreign price of imported goods set by foreign firms.

### 3.2.2 Oil firm

In contrast to other sectors, oil firm takes international price as given and operates in perfect competition environment. It uses capital, labor and oil endowment  $e_{O,t}$  to produce crude oil  $o_t$  which is entirely exported abroad. Oil firm takes as given international world crude oil prices  $p_{O,t} = z_t p_{O,t}^*$  and maximizes profit

$$\Pi_{O,t} = (1 - \tau_t^o) o_t - \frac{w_{O,t}}{p_{O,t}} L_{O,t} - r_{O,t}^k \tilde{k}_{O,t}^p - \frac{p_{EO,t}}{p_{O,t}} e_{O,t}$$

subject to production function

$$o_t = \epsilon_t^o \left( \tilde{k}_{O,t}^p \right)^{\alpha_o} (e_{O,t})^{\theta_o} (L_{O,t})^{1-\alpha_o-\theta_o} - \Phi_o$$

where  $\Phi_o$  denotes production fixed-cost,  $\alpha_o, \theta_o \in [0, 1]$  and  $\alpha_o + \theta_o \leq 1$ .  $\tau_t^o$  is a royalty that the government takes from oil firms. The results of this optimization problem lead to the following expressions of capital-labor and oil endowment-capital



ratio:

$$\frac{\tilde{k}_{O,t}^p}{L_{O,t}} = \frac{\alpha_o}{1 - \alpha_o - \theta_o} \frac{(w_{O,t}/p_{O,t})}{r_{O,t}^k} \quad (17a)$$

$$\frac{e_{O,t}}{\tilde{k}_{O,t}^p} = \frac{\theta_o p_{O,t} r_{O,t}^k}{\alpha_o p_{EO,t}} \quad (17b)$$

$$\frac{w_{O,t}}{p_{EO,t}} = \frac{1 - \alpha_o - \theta_o}{\theta_o} \frac{e_{O,t}}{L_{O,t}} \quad (17c)$$

Natural oil resource endowment is assumed to evolve according to:

$$\ln e_{O,t} = (1 - \rho_{o,s}) \ln(\bar{e}_O) + \rho_{o,s} \ln e_{O,t-1} + \eta_t^{o,s} \text{ where } \eta_t^{o,s} \rightsquigarrow \text{iid } \mathcal{N}(0, \sigma_{o,s}^2)$$

### 3.2.3 Final-good firms

#### Final private consumption-good and investment-good firms

Non-oil final private consumption-good firms produce homogeneous goods  $q_t^{CNO}$  using a bundle of domestic  $h_t^{CNO}$  and imported  $im_t^{CNO}$  intermediate goods. The production function that transforms intermediate goods into final consumption output is given by:

$$q_t^{CNO} = \left[ v_{C,NO}^{\frac{1}{\eta_{C,NO}}} (h_t^{CNO})^{\frac{\eta_{C,NO}-1}{\eta_{C,NO}}} + (1 - v_{C,NO})^{\frac{1}{\eta_{C,NO}}} (im_t^{CNO})^{\frac{\eta_{C,NO}-1}{\eta_{C,NO}}} \right]^{\frac{\eta_{C,NO}}{\eta_{C,NO}-1}} \quad (18)$$

where  $\eta_{C,NO}$  is the elasticity of substitution between home and foreign non-oil bundles of goods, and  $v_{C,NO}$  measures the degree of home production bias. The optimal allocation of expenditure between the bundle of home-produced  $h_t^{CNO}$  and imported  $im_t^{CNO}$  goods to produce non-oil final private consumption-good  $q_t^{CNO}$  is given by:

$$h_t^{CNO} = v_{C,NO} \left( \frac{p_{H,t}}{p_{NO,t}} \right)^{-\eta_{C,NO}} q_t^{CNO} \quad (19)$$

$$im_t^{CNO} = (1 - v_{C,NO}) \left( \frac{p_{IM}^{CNO,t}}{p_{NO,t}} \right)^{-\eta_{C,NO}} q_t^{CNO} \quad (20)$$

The aggregate price index of non-oil final private consumption-good  $p_{NO,t}$ , which we denote "*core-CPI*", is given by:

$$p_{NO,t} = \left[ (1 - v_{C,NO}) (p_{IM^{CNO},t})^{1-\eta_{C,NO}} + v_{C,NO} (p_{H,t})^{1-\eta_{C,NO}} \right]^{\frac{1}{1-\eta_{C,NO}}} \quad (21)$$

In turn, final investment-good firms have the same structure as non-oil final private consumption-good firms.

### Public final consumption-good firms

In contrast to final private consumption and investment goods, final public consumption-goods are produced using only a bundle of domestic intermediate goods. That is, there exists a full home bias production for the public consumption-goods and the production technology is given by the following CES aggregation function:

$$q_t^G = \left[ \int_0^1 (h_t^G(f)) \frac{1}{1+\lambda_{H,t}^p} df \right]^{1+\lambda_{H,t}^p} \quad (22)$$

Given the assumption of full home bias production for final public consumption-goods, aggregate public consumption price index is equal to home price index. That is,  $p_{G,t} = p_{H,t}$ .

### Export final-good firms

As for final public consumption-goods, exporting firms produce homogeneous tradeable goods  $x_t$  using export intermediate goods  $x_t(f)$ . The production function that transforms export intermediate goods into final export-goods is given by:

$$x_t = \left[ \int_0^1 (x_t(f)) \frac{1}{1+\lambda_{X,t}^p} df \right]^{1+\lambda_{X,t}^p} \quad (23)$$

We assume as for imports that the law of one price holds "*at the dock*" to have symmetry in the invoicing strategy of domestic and foreign tradeable firms. Therefore, exporting firms will follow the producer currency pricing (PCP) strategy and set the price of their goods in domestic currency. We assume that the structure of demand in foreign country for domestic exported goods follows the same structure

as the demand of foreign goods in (19). That is,

$$x_t = \kappa_x \left( \frac{p_{X,t}}{z_t} \right)^{-\eta_x} y_t^* \quad (24)$$

where, as in [Christoffel et al. \(2008\)](#),  $\kappa_x$  represents the export share of domestic exporting firms,  $p_{X,t}$  the export price index, and  $y_t^*$  the global demand.

### 3.3 Central bank

Given the specificities of oil exporting countries, we assume that the central bank does not only restrain their policies by managing the short-term interest rate. We follow [Dagher et al. \(2012\)](#) and introduce other instruments of monetary policy. The evolution of the supply of money is directly derived from the central bank balance sheet and, thus, evolve according to:

$$m_t - \frac{m_{t-1}}{g_{\Theta,t}\Pi_t} = b_t^m - \frac{b_{t-1}^m}{g_{\Theta,t}\Pi_t} + z_t \left( res_t^* - \frac{res_{t-1}^*}{g_{\Theta,t}^*\Pi_t^*} \right) \quad (25)$$

In the literature on Dutch disease and energy currency, the management of exchange rate reserve permits to release appreciation pressure on exchange rate following an oil windfall. In this paper, we assume that the central bank controls the evolution of the exchange rate reserve according to the following law of motion:

$$z_t res_t^* = z_t \frac{res_{t-1}^*}{g_{\Theta,t}^*\Pi_t^*} + \phi_{res} \tau_t^o (p_{O,t} - \bar{p}_O) \alpha_t$$

and transfers entirely the interest earned on exchange reserve to the government.

Moreover, if the monetary authority adjusts the short term nominal interest rate  $R_t$  in order to pursue a chosen monetary policy rule, it is assumed to use the Taylor rule defined by:

$$\frac{R_t}{\bar{R}} = \left( \frac{R_{t-1}}{\bar{R}} \right)^{\rho_R} \left[ \left( \frac{y_t}{y_{t-1}} \right)^{r_y} \left( \frac{\Pi_{PO,t}}{\bar{\Pi}_{PO}} \right)^{r_{po}} \left( \frac{\Pi_t}{\bar{\Pi}} \right)^{r_\pi} \left( \frac{\Delta Z_t}{\Delta \bar{Z}} \right)^{r_z} \right]^{1-\rho_R} \exp(\eta_t^R) \quad (26)$$

where parameter  $\rho_R$  indicates the degree of interest-rate smoothing. Parameters  $r_y$ ,  $r_{po}$ ,  $r_\pi$ ,  $r_z$  in turn are policy coefficients that measure the degree of central bank re-

response to output, domestic oil prices, headline-CPI and US-Dollar nominal exchange rate changes, respectively. Variables  $\bar{\Pi}_{PO}$ ,  $\bar{\Pi}$  and  $\Delta\bar{Z} = \bar{\Pi}/\bar{\Pi}^*$  are steady-state values of  $\Pi_{PO,t}$ ,  $\Pi_t$  and  $\Delta Z_t$ , respectively. Finally  $\eta_t^R \rightsquigarrow \text{iid } \mathcal{N}(0, \sigma_R^2)$  is an exogenous monetary policy shock.

In the analysis, we consider different types of monetary policy rule and allow the central bank either to target a given variable of interest.

$r_\pi = r_z = 0$ : peg to oil price à la Frankel.

$r_{po} = r_z = 0$ : CPI inflation targeting (IT rule)

$r_{po} = r_\pi = 0$ : exchange rate targeting rule (ET rule), we allow the central bank to fix nominal US-Dollar exchange rate  $Z_t$  in which oil-revenues are denominated.

### 3.4 Government

Each period, the government is subject to the following budget constraint:

$$\begin{aligned} \epsilon_{t-1}^Q R_{t-1} \frac{b_{t-1}^d}{g_{\Theta,t} \Pi_t} + p_{H,t} g_t + \frac{b_{t-1}^m}{g_{\Theta,t} \Pi_t} &= b_t^d + b_t^m + \tau_t^w w_t L_t + \tau_t^c c_t + t_t + (1 - \phi_{I^g}) \tau_t^o \bar{p}_O o_t \\ &+ z_t (\chi_{t-1} R_{t-1}^* - 1) \frac{res_{t-1}^* + f_{t-1}}{g_{\Theta,t}^* \Pi_t^*} \\ &+ (p_{RO,t} - z_t p_{O,t}^*) c_{RO,t} + swg_t \end{aligned}$$

where  $g_t$  is the public purchases or the government spending commonly defined in the literature and  $b_t^m$  the government bonds held by the central bank. In this model, the oil revenue is introduced through royalties  $\tau_t^o$  that government collects from oil firms. Moreover, we assume that the government establishes their budget on the basis of fixed oil price  $\bar{p}_O$  whereas the windfall  $(p_{O,t} - \bar{p}_O) o_t$  is saved in a sovereign wealth fund  $f_t$ . The government uses interests earned from the fund and the exchange rate reserve  $res_t^*$  holds by the central bank. Finally, as in [Benkhodja \(2014\)](#), refined-oil consumed domestically is produced abroad with price assumed to evolve according to:

$$p_{RO,t} = (1 - v_{RO}) g_{\Theta,t}^{-1} p_{RO,t-1} + v_{RO} z_t p_{O,t}^* \quad (27)$$

where  $p_{O,t}^*$  is the international oil price and  $v_{RO} \in [0, 1]$  indicates the degree of

domestic refined-oil price subsidy from the government.

Moreover, we assume that the government uses the surplus of revenues earned from oil-exporting sector to stabilize oil-revenues against international oil-price fluctuations and to support lagging sector (export) and domestic producers, especially if oil-resources is intended to be depleted. Namely, it is done by letting stabilization fund  $f_t$  evolves according to :

$$\begin{aligned} z_t \tilde{\Theta}_t (f_t - \bar{f}) &= z_t \tilde{\Theta}_t (g_{\Theta,t}^* \Pi_t^*)^{-1} (f_{t-1} - \bar{f}) + \tau_t^o (p_{O,t} - \bar{p}_O) o_t \\ &\quad - (sfg_t - \overline{sfg}) - (sft_t - \overline{sft}) \end{aligned}$$

where earned interests are entirely transferred to the government. Terms  $sfg_t$  and  $sft_t$  represent the amount taken by the government from the oil stabilization fund to finance temporary fiscal deficit and to support lagging sector that might be hurt by the Dutch disease phenomenon, respectively. They are defined as:

$$\begin{aligned} sfg_t &= v_{swg} z_t \tilde{\Theta}_t (g_{\Theta,t}^* \Pi_t^*)^{-1} f_{t-1} \\ sft_t &= v_{swt} z_t \tilde{\Theta}_t (g_{\Theta,t}^* \Pi_t^*)^{-1} f_{t-1} \end{aligned}$$

with  $0 < v_{swg}, v_{swt} < 1$ . The public investment  $i_{i,t}^g$ , for  $i = \{H, X\}$ , is assumed to be productivity-enhancing for the lagging sector and domestic producers, and evolves according to:

$$p_{I,t} i_{H,t}^g = \frac{1}{2} \phi_{I^g} \tau_t^o \bar{p}_O o_t \quad (28a)$$

$$p_{I,t} i_{X,t}^g = \frac{1}{2} \phi_{I^g} \tau_t^o \bar{p}_O o_t + sft_t \quad (28b)$$

where public investment dedicated to the trading sector can be financed by the oil stabilization fund on top of oil revenues.

In turn, the law of motion for public capital stock evolves according to:

$$k_{i,t+1}^g = (1 - \delta) g_{\Theta,t}^{-1} k_{i,t}^g + i_{i,t}^g \text{ for } i = \{H, X\} \quad (29)$$

Finally, the public spending is governed by the following rule:

$$\frac{g_t}{\bar{g}} = \left( \frac{g_{t-1}}{\bar{g}} \right)^{\rho_G} \left[ \left( \frac{y_t}{y_{t-1}} \right)^{g_y} \left( \frac{sf g_t}{sf \bar{g}} \right)^{g_{swg}} \right]^{1-\rho_R} \exp(\eta_t^G)$$

where parameter  $\rho_G$  indicates the degree of interest-rate smoothing and  $\eta_t^G \rightsquigarrow \text{iid } \mathcal{N}(0, \sigma_G^2)$  is an exogenous government spending policy shock. Parameters  $g_y$  and  $g_{swg}$  in turn are policy coefficients that measure the degree of government response to output and oil stabilization fund changes, respectively.

### 3.5 The international oil market

The domestic currency price of crude oil is defined as:

$$p_{O,t} = z_t p_{O,t}^* \tag{30}$$

where the international price of oil  $p_{O,t}^*$  is set in the international market and is labelled in US Dollar. Thus, it is assumed to be exogenous for oil firm and evolves according to:

$$\ln p_{O,t}^* = (1 - \rho_{p_O^*}) \ln(\bar{p}_O^*) + \rho_{p_O^*} \ln p_{O,t-1}^* + \eta_t^{p_O^*} \text{ where } \eta_t^{p_O^*} \rightsquigarrow \text{iid } \mathcal{N}(0, \sigma_{p_O^*}^2)$$

where  $\bar{p}_O^*$  is the steady state value of crude-oil price and  $\eta_t^{p_O^*}$  the crude-oil price shock. Moreover, we assume that demand for crude-oil is exogenous and evolves according to:

$$o_t = \kappa_o (p_{O,t}^*)^{-\eta_o} y_t^*$$

where  $y_t^*$  represents the global demand that is defined as

$$\ln y_t^* = \rho_{o,d} \ln y_t^* + \eta_t^d, \eta_t^d \rightsquigarrow \text{iid } \mathcal{N}(0, \sigma_d^2)$$

where  $\eta_t^{o,d}$  represents the global-demand shock including oil. For instance, a positive shock may be interpreted as an exogenous increase in the demand of crude-oil.

### 3.6 Market Clearing

Final goods market clears when supply of final goods equals demand. That is,

$$\begin{aligned} q_t^{CNO} &= c_{NO,t} \\ q_t^I &= i_t^p + \Psi(u_t) g_{\Theta,t}^{-1} k_t^p + i_t^g = i_t \\ q_t^G &= g_t \end{aligned} \quad (31)$$

where  $i_t^g = i_{H,t}^g + i_{X,t}^g$ . From the last equation we obtain the following expression of nominal aggregate resource using optimal allocation of expenditure between different domestic and imported bundles of differentiated goods and the expression of nominal total consumption expenditure. That is,

$$p_{Y,t} y_t = p_t c_t + p_{I,t} i_t + p_{H,t} g_t + (p_{X,t} x_t + p_{O,t} o_t) - (p_{IM,t} im_t + p_{RO,t} c_{RO,t}) \quad (32)$$

where

$$\begin{aligned} i_t &= i_t^p + \Psi(u_t) g_{\Theta,t}^{-1} k_t^p + i_t^g \\ im_t &= im_t^{CNO} + im_t^I \end{aligned}$$

Finally, given the definition of domestic net foreign asset in (6), it evolves according to:

$$z_t (b_t^* + f_t + res_t^*) = z_t (g_{\Theta,t}^* \Pi_t^*)^{-1} \varkappa_{t-1} R_{t-1}^* (b_{t-1}^* + f_{t-1} + res_{t-1}^*) + tb_t \quad (33)$$

with trade balance  $tb_t$  defined as:

$$tb_t = (p_{X,t} x_t + p_{O,t} o_t) - z_t (p_{X,t}^* m_t + p_{O,t}^* c_{RO,t})$$

## 4 Calibration

In this section, we calibrate the model to match some features of oil exporting economies. Our parameters' values are taken, mostly, from the literature on DSGE models and adapt them to characterize Algerian economy (Table 1.1-1.3).

The subjective discount factor  $\beta = \bar{g}_z / (1 + (\bar{R}/4))$ , is set at 0.995 which implies an annual steady-state real interest rate of 3.5% with a steady state level of labor augmenting technology  $\bar{g}_z = 1.004$ . Thus, the parameters of capital utilisation cost for our three firms  $\gamma_{i,1}$  and  $\gamma_{i,2} = \bar{g}_z(1/\beta) - 1 + \beta$  are equal to 0.35. Following [Devereux et al \(2006\)](#) among others, the inverse of the elasticity of labor supply is set at 2. The capital depreciation rate is set at 0.025. This value is common to all sectors of production.

As in [Medina and Solo \(2005\)](#) and [Ben Aissa and Rebei \(2010\)](#), we fix the mean of the habit formation parameter equal to 0.5. The parameters  $\alpha_o, \alpha_H$  and  $\alpha_X$  are associated with the capital elasticity in production function of oil, home and exports firms and  $\theta_O$  the crude oil elasticity in oil's production function. We set the share of capital in the production of oil, home and export firms to 0.35, 0.28 and 0.28 respectively. The share of oil crude is set at 0.2.

Following [Christoffel et al \(2008\)](#), we set the parameter in the investment cost  $\kappa_{i,I}$  and adjustment cost coefficient for non-oil consumption  $\gamma_a^c$  and investment  $\gamma_a^I$  equal to 4 and 2.5 respectively.

As in the standard literature of DSGE models, we set the parameter of Calvo price setting and equal to 0.75. Wage stickiness in the three sectors  $\theta_{WO}, \theta_{WX}$  and  $\theta_{WH}$  are set at the same level. On average, price adjustment occurs every 4 quarters. Also, the prices  $(\gamma_O, \gamma_X, \gamma_H)$  and wages  $(\gamma_{WO}, \gamma_{WX}, \gamma_{WH})$  indexations parameters are set to 0.75.

We set values of the labor elasticity of substitution to match the share of households' labor supply in the three sectors of algerian economy (domestic, oil and export firms), so that,  $v_H, v_O$  and  $v_X$  are equal to 0.45, 0.1 and 0.45 respectively. As in [Stähler and Thomas \(2012\)](#), the parameter in the risk-premium terms is set to 0.01. The weight of home goods in the production process of final non-oil consumption ( $v_{C,NO} = 0,47$ ) is assumed to be higher relative to the one used to produce final investment goods ( $v_I = 0,25$ ). This reflects the importance of imports in the production process of final investment goods.

The degree of domestic refined-oil price subsidy and royalties parameters are set to 0.3 as in [Benkhodja \(2014\)](#) and 0.2<sup>5</sup> respectively.

The steady state values parameters in Table 1.3 are taken from Algerian time

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<sup>5</sup>This value is taen from ONS data.



series 1980-Q1-2014-Q4 only for steady-state values of wages mark-up for our three sector and domestic, export and import price mark-up that are set to 0.3 and 0.35 respectively, as in [Christoffel et al \(2008\)](#).

Table 1.1 Calibration of structural parameters

Description	Parameters	Values
Structural parameters		
Discount factor	$\beta$	0.995
Real money balance weight in the utility function	$\theta_M$	0.5
Depreciation rate of capital	$\delta$	0.025
Frisch elasticity of labor supply	$\psi$	2
International oil price elasticity of demand	$\eta_O$	0.80
Export price elasticity of demand	$\eta_X$	0.80
Household's labor supply elasticity of substitution	$\eta_I$	0.8
Parameter for risk premium	$\psi$	0.01
Share of home export in global demand	$\kappa_X$	0.05
Parameter of productivity enhancing public capital	$\eta$	0.05
Share of oil proceed accumulated as exchange rate reserves	$\phi_{res}$	0.3
Share of oil proceed dedicated to public investment	$\phi_{Ig}$	0.5
Weight of home goods (production process of final non-oil cons)	$v_{C,NO}$	0.47
Constant elasticity of substitution (final non-oil consumption)	$\eta_{C,NO}$	0.80
Weight of home goods (production process of final invest goods)	$v_I$	0.25
Constant elasticity of substitution (final investment goods)	$\eta_I$	0.70
Weight of energy goods (refined-oil) in the final consumption	$v_C$	0.023
Constant elasticity of substitution between non-oil and refined-oil	$\eta_C$	0.47
First parameter of capital utilisation cost for Oil firms	$\gamma_{O,1}$	0.035
Second parameter of capital utilisation cost for Oil firms	$\gamma_{O,2}$	0.035
First parameter of capital utilisation cost for Export firms	$\gamma_{E,1}$	0.035
Second parameter of capital utilisation cost for Export firms	$\gamma_{E,2}$	0.035
First parameter of capital utilisation cost for Home firms	$\gamma_{H,1}$	0.035
Second parameter of capital utilisation cost for Home firms	$\gamma_{H,2}$	0.035

Table 1.2 Calibration of structural parameters (continued)

Description	Parameters	Values
Habit form parameter	$h$	0.5
Parameter in the investment cost function (Oil firms)	$\kappa_{O,I}$	4
Parameter in the investment cost function (Export firms)	$\kappa_{E,I}$	4
Parameter in the investment cost function (Home firms)	$\kappa_{H,I}$	4
Adjustment cost coefficient for non-oil consumption	$\gamma_a^c$	2.5
Adjustment cost coefficient for investment	$\gamma_a^I$	2.5
Capital elasticity (home intermediate goods firms)	$\alpha_H$	0.28
Capital elasticity (export intermediate goods firms)	$\alpha_X$	0.28
Capital elasticity in production function of oil	$\alpha_O$	0.35
Crude oil elasticity in production function of oil	$\theta_O$	0.2
Share of households labor supply to domestic firms	$v_H$	0.45
Share of households labor supply to domestic oil firms	$v_O$	0.10
Share of households labor supply to export firms	$v_X$	0.45
Royalties	$\tau_t^o$	0.2
Degree of domestic refined-oil price subsidy	$v_{RO}$	0.3
Calvo price setting (home)	$\theta_H$	0.75
Indexation: domestic-prices	$\gamma_H$	0.75
Calvo price setting (export)	$\theta_X$	0.75
Indexation: export-prices	$\gamma_X$	0.75
Calvo price setting (import)	$\theta_{IM}$	0.75
Indexation: import-prices	$\gamma_M$	0.75
Calvo wage setting (oil firms)	$\theta_{WO}$	0.75
Indexation: wage (oil firms)	$\gamma_{WO}$	0.75
Calvo wage setting (export firms)	$\theta_{WX}$	0.75
Indexation: wage (export firms)	$\gamma_{WX}$	0.75
Calvo wage setting (home firms)	$\theta_{WH}$	0.75
Indexation: wage (home firms)	$\gamma_{WH}$	0.75

Table 1.3 Calibration of structural parameters (continued)

Description	Parameters	Values
Monetary Policy		
Inflation coefficient	$r_\pi$	$\infty, 0, 0$
Core-inflation coefficient	$r_{\pi_{no}}$	$0, \infty, 0$
Exchange rate coefficient	$r_z$	$0, 0, \infty$
Response core-inflation	$r_{\pi_o}$	0.30
Interest rate smoothing	$\rho_r$	0.65
Steady-state		
Constant growth rate of labor-aumenting technology process	$\bar{g}_\Theta$	1.004
Government spending - output ratio	$\bar{g}_y$	0.46
Foreign CPI inflation	$\bar{\Pi}^*$	1.004
Share of exchange rate reserve in terms of gdp	$\bar{res}_y^*$	0.86
Share of oil stabilization fund in terms of gdp	$\bar{res}_f$	0.32

## 5 Is there a Dutch disease effect?

This section analyzes the impulse responses functions of several keys macroeconomic variables in the aftermath of an international oil price shock. Importantly, our impulse responses functions investigate the effectiveness of alternative monetary rules to limit a Dutch disease effect by combining them with fiscal policy. In our framework, fiscal policy rests on two variables: on the one hand, different values of the parameter of share of oil stabilization fund (OSF hereafter) dedicated to support trading (export) sector, and, on the other hand, the inclusion of the enhancing productivity coefficient (EPC) associated to public spending as in [Berg et al \(2013\)](#). Three monetary policy rules are calibrated: an inflation targeting rule (hereafter IT rule), a fixed exchange rate rule (hereafter ER rule) and domestic oil price inflation rule (Frankel rule).

To interpret our results, it important to note that the impulse responses functions related to the baseline model represent the optimal responses of the economy to the oil shocks. In this perspective, to draw lessons about the effectiveness of fiscal and monetary policy to limit the Dutch disease effect, we introduce a set of nominal and real frictions. Such frictions lead the economy to respond in a suboptimal way to

shocks. The final step is to compare the baseline model and the responses of the model under different rules. The response of our selected variables will be relative to that of our baseline model. In these cases, this is the gap between both responses (baseline and sticky price-sticky wage models with monetary rules) that will provide information on the occurrence of the Dutch disease effect.

## 5.1 Impulse Response Analysis

In this sub-section, we assess the effectiveness of alternative monetary rules by stressing the impact of fiscal policy on this effectiveness. Assuming that oil production is largely exogenous with respect to price changes, due not only to the inertia of supply but also to the constraints of OPEC membership, we focus below on responses in trade and non-tradable sectors.

### 5.1.1 Inflation targeting regime

As exhibited in Figure 1, in the aftermath of an international oil price shock, the model gives us an important result. Indeed, the responses of our variables show that the production and investment in the export sector decrease significantly. This suggesting the presence of the deindustrialization phenomenon resulting from oil resource's abundance. In this case, it seems that the spending effect is active. The spending effect matters to explain the responses of home production and investment in export sector. More specifically, the positive oil price shock tends to induce both an increase in capital inflows and a rise in the domestic absorption. These two effects lead to a real appreciation of the domestic currency-as capital inflows cause a nominal appreciation and non-tradable prices rise with higher domestic absorption-exerting damaging consequences on the competitiveness in the tradable sector.

Importantly, the decline in export sector tends to shrink gradually as the rise in the share of oil stabilization fund dedicated to the support export sector. The decline in export goods production is completely resorbed when we combine the share of OSF with a positive coefficient of enhancing productivity ( $\eta$ ).

Our model shows also that the oil price shock causes a resource movement effect, particularly at short-term. Indeed, hours worked in the export sector and wages in this sector decrease in the aftermath of the shock. Under the inflation targeting

framework, while the effectiveness of fiscal policy to face the resource movement effect is mixed at short-term, Figures 1 suggests the opposite at a longer horizon. The presence of a OSF in the economy is associated with a rise in hours worked in the export sector.

Overall, targeting inflation alone does not spare the economy from the Dutch disease effect. However, combined with fiscal policy, we see that the damaging effects of positive oil price shocks are lessened significantly. As expected, the higher the efficacy of public spending-proxied by the value of the productivity enhancing parameter- the higher the effectiveness of the inflation targeting.

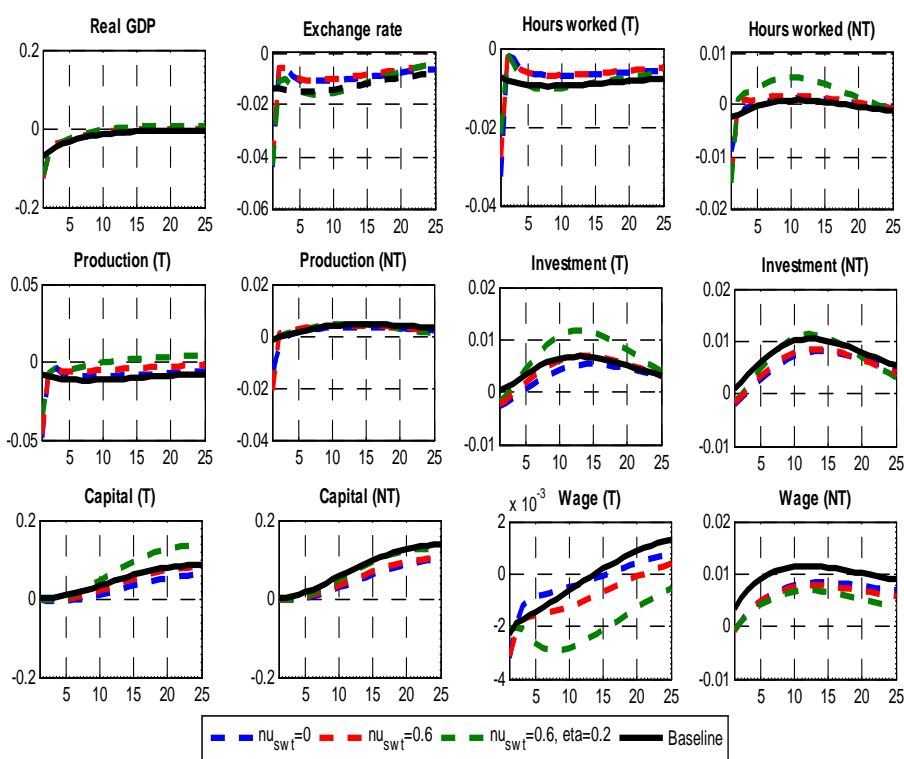


Figure 1. Responses to a positive oil price shock (IT rule)

### 5.1.2 Fixed exchange rate

Figure 2 exhibits a striking result: the fixed exchange rate monetary rule is particularly effective to prevent a Dutch disease effect. Indeed, relative to the baseline model, not only the real GDP and domestic consumption are higher, but we

observe also positive responses of macroeconomic variables related to the export sector. More specifically, production and investment in this sector tend to increase over 10 periods relative to the baseline model. As for the inflation targeting monetary rule, fiscal policy heightens the effectiveness of the exchange rate rule. Thus, both production and investment in the export sector improve with the presence of a OSF and a higher productivity enhancing effect associated with public spending. The dynamics of our main macroeconomic variables in the aftermath of a positive oil price shock rests on the two mechanisms of the Dutch disease effect. On the one hand, the exchange rate rule impedes the distortions due to the spending effect. On the other hand, as the real exchange rate does not appreciate after the oil shock, the resource movement effect does not play. For instance, our results show that hours worked in the export sector respond positively to the oil shock even if this response is short-lived. However, at short-medium run, the exchange rate rule exhibits better performances than the baseline model. In a similar way, wages and capital increase in the aftermath of the oil shock. These responses are persistent over time.

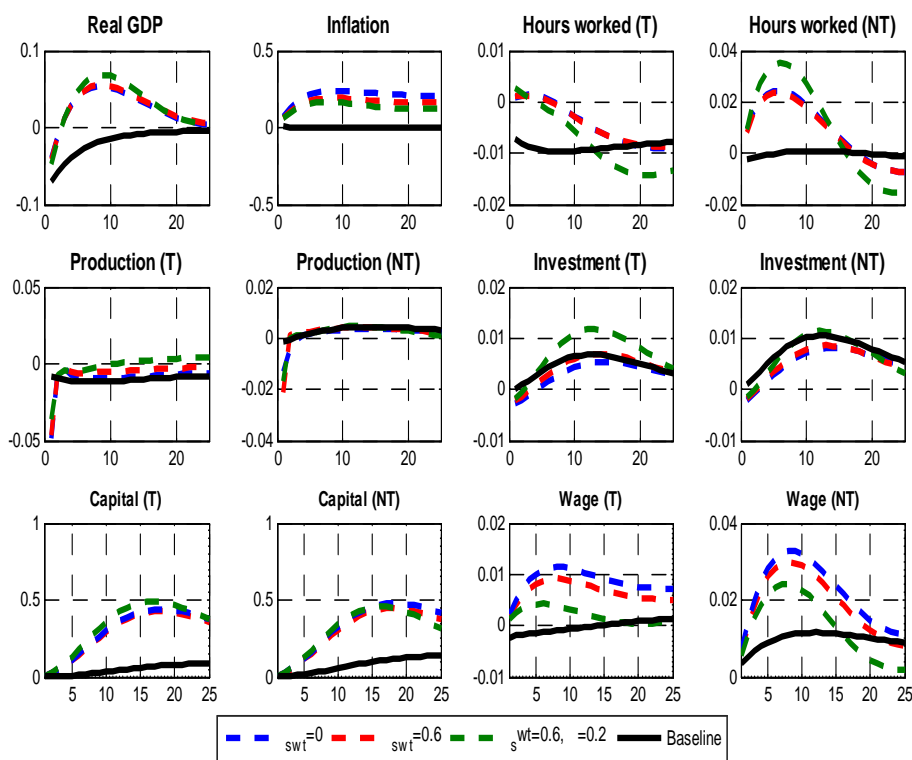


Figure 2. Responses to a positive oil price shock (ER rule)

### 5.1.3 Real oil price targeting (Frankel rule)

The real oil price shock targeting -the so-called Frankel rule- clearly underperforms in comparison with the alternative monetary rules. The ineffectiveness of the real oil price targeting is especially noticeable at short-medium run as suggested by the dynamics of production and investment in the export effort (Figure 3). We also see that the resource movement effect is effective at short-medium term. Specifically, the positive oil shock is associated with a contraction in the export sector through the evolution of capital and wages and hours worked. In addition, our results show that not only the Frankel rule does not prevent the Dutch disease effect but, at the same time, it leads to higher macroeconomic volatility.

Last but not least, unlike other monetary rules, the combination with fiscal policy does not improve the effectiveness of monetary policy to cope with the Dutch disease effect.

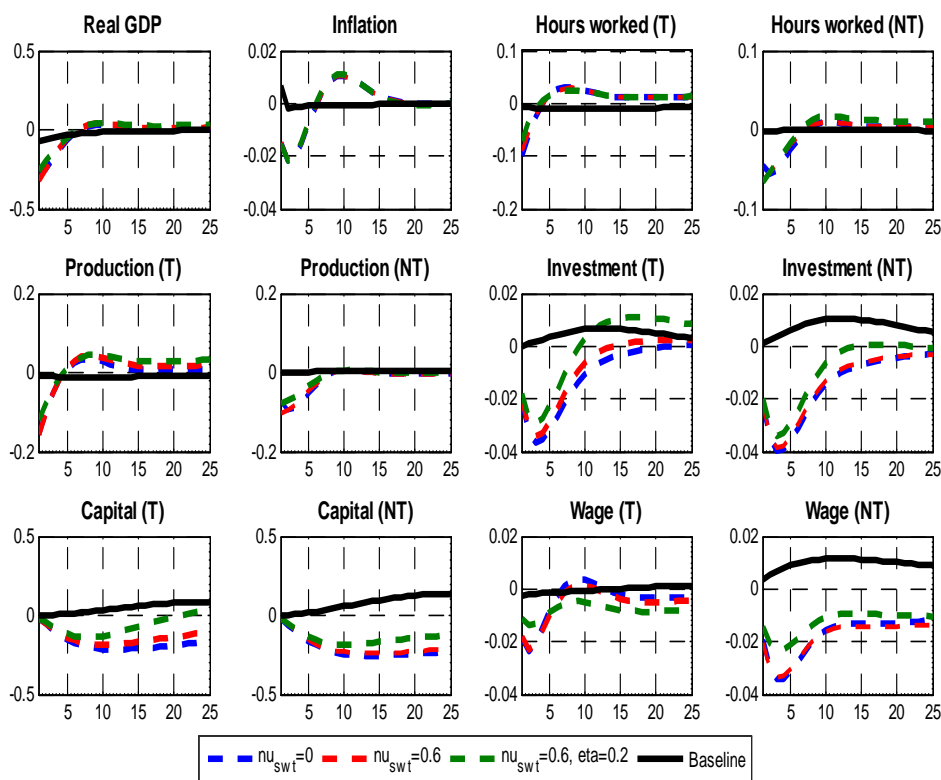


Figure 3. Responses to a positive oil price shock (Oil price rule)

## 5.2 Optimal policy and Welfare analysis

In this sub-section, we evaluate, at the first stage, the dynamic of our model under a set of policy rules implemented during a windfall and, at the second stage, the response of welfare to windfall.

### 5.2.1 Optimal Policy

We compare the responses of our main variables under alternative monetary and fiscal policy rules in the aftermath of an oil price shock. These results are obtained with the standard (or baseline) calibration (see section 2). For this, we use four rules: inflation targeting rule (IT rule), fixed exchange rate rule (ER rule), domestic oil price targeting or Frankel rule and optimal monetary (OMP) and fiscal policies (OFP).

Three lessons are drawn from the analysis of optimal policy. Firstly, in line with findings from the impulse responses functions, the real oil price shock targeting exhibits the worst performances. Under this monetary rule, the real GDP is below its stationary level over 7 periods. In a similar way, domestic consumption exhibits a sizable negative dynamics. While the real exchange rate does not appreciate, this movement does not prevent a contraction of export sector as in a typical Dutch disease effect. Thus, investment, capital, wages and hours worked in this sector are consistently below their stationary level. In addition, we see that Frankel rule does not allow macroeconomic stabilization as many of our macroeconomic variables exhibit large fluctuations over time.

Secondly, while the fixed exchange rate tends to be associated with ample fluctuations of macroeconomic variables, the best performances of the export sector is observed in this monetary rule. More specifically, all variables related to this sector are persistently above their stationary level. The overall impact of the exchange rate rule is noticeable as both real GDP and domestic consumption stay above their stationary level over the whole period.

Thirdly, other policies, i.e. the inflation targeting rule, the optimal monetary policy and the optimal fiscal policy, are associated with macroeconomic outcomes located between the two previous policies. On the one hand, these policies are relatively similar in terms of stabilization properties. Thus, real GDP and domestic



consumption as well as export sector variables experience small fluctuations around their stationary level. On the other hand, relative to the Frankel rule, these policies perform better in terms of export sector dynamics.

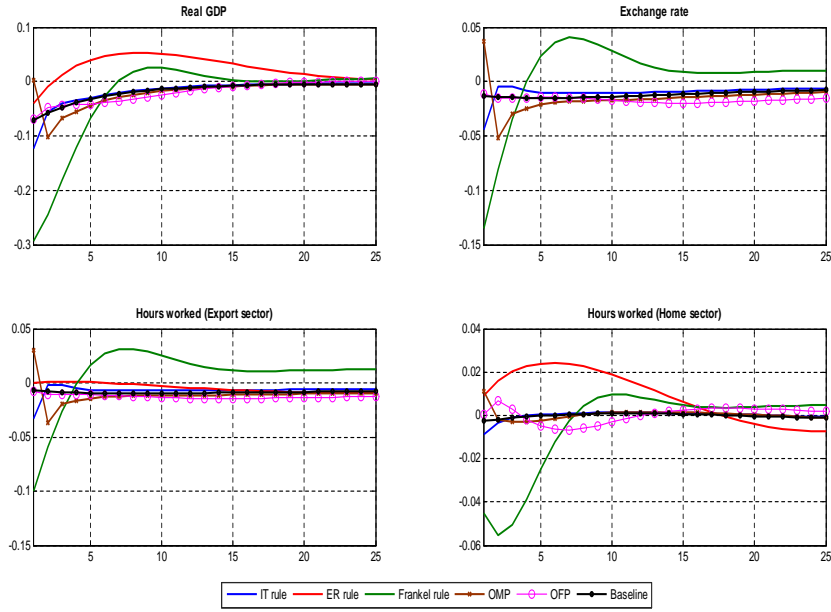


Figure 4.1 Responses under alternative policy rules

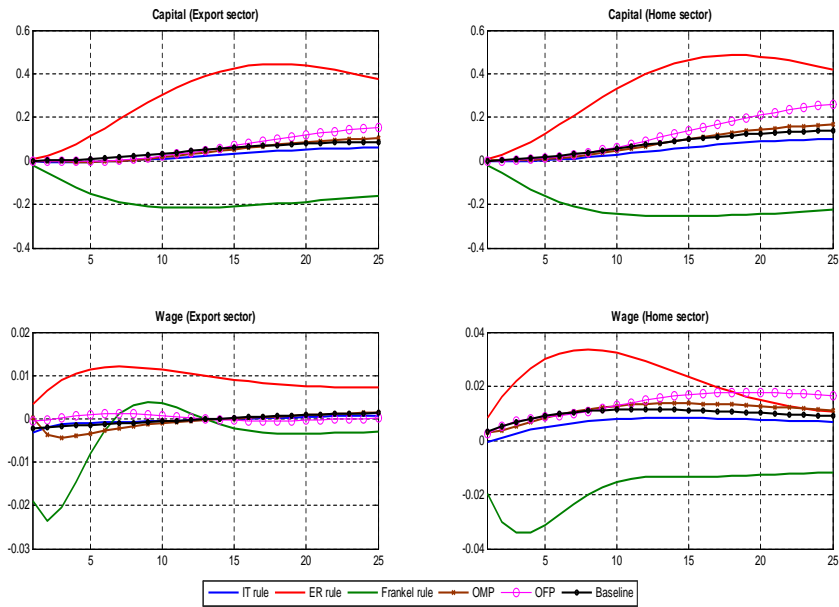


Figure 4.2. (Continued) Responses under alternative policy rules

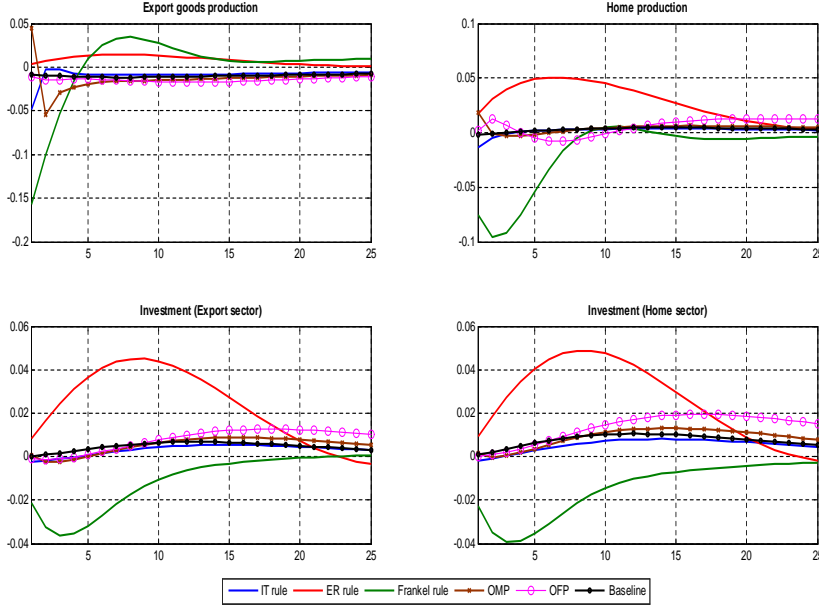


Figure 4.3. (Continued) Responses under alternative policy rules.

### 5.2.2 Welfare Analysis

To assess the impact of windfall on the welfare, we solve the model using a second order approximation of the utility function for different policies but also for different values of two parameters: share of oil stabilization fund dedicated to support trading (export) sector  $v_{swt}$ , and parameter of productivity enhancing public capital  $\eta$ . Formally, the welfare criterion is derived from the following single utility function:

$$U_t(.) = \epsilon_t^B \left( \ln(c_t - hg_{\Theta,t}^{-1}c_{t-1}) + \theta_M \epsilon_t^M \ln(m_t) - \epsilon_t^L \frac{(L_t)^{1+\psi}}{1+\psi} \right) \quad (34)$$

As in the impulse response analysis, three monetary policy rules are considered: an inflation targeting rule (hereafter IT rule), a fixed exchange rate rule (hereafter ER rule) and domestic oil price inflation rule (Frankel rule). In each case, the black, red and blue lines represent the response of the welfare under the baseline model, a positive parameter of share of OSF dedicated to support trading (export) sector, and, the combination of a positive OSF and the enhancing productivity coefficient (EPC) associated to public spending, respectively.

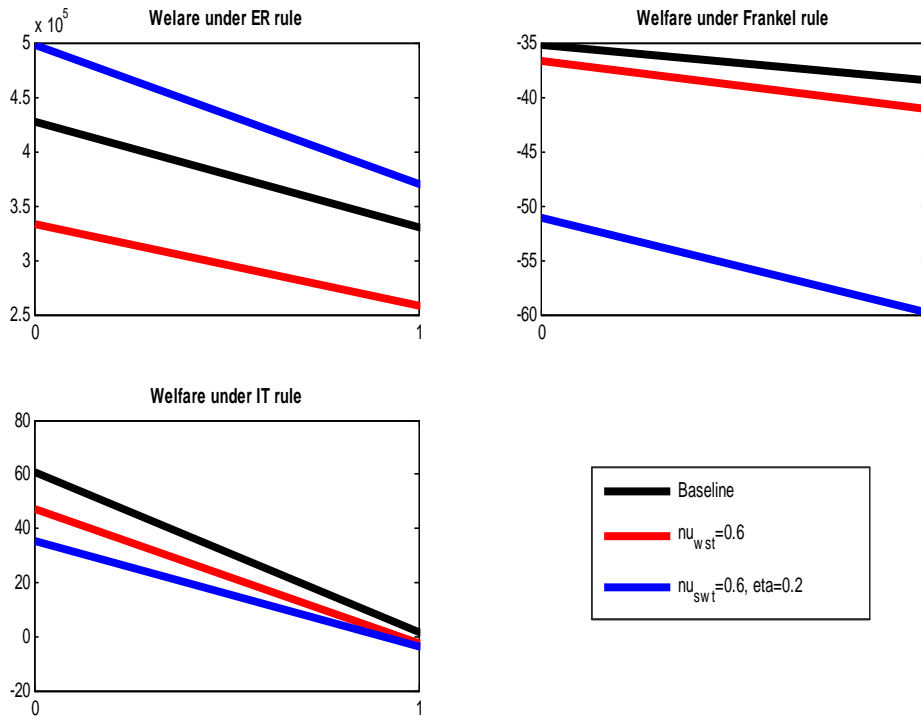


Figure 5. Welfare responses under alternative policy rules

The results are shown in figure 5. Our main findings are in line with the impulse response function's results. Indeed, under ER rule, the impact of oil price shock generate a welfare gain contrary to IT rule and Frankel rule. The appearance of the Dutch disease in the last two cases seems to have a negative impact on the welfare gain. However, the welfare is negative when monetary authority adopts Frankel rule.

## 6 Conclusion

In this paper, we studied the role of fiscal and monetary policies during a wind-fall episode in an oil exporting economy. Our main purpose was to compare the responses of our model's variables in the aftermath of a positive oil price shock under three monetary rules (Inflation targeting rule, Exchange rate peg and Frankel rule) combined with government intervention (a share of oil stabilisation fund dedicated to support trading (export) sector, and the inclusion of the enhancing productivity coefficient (EPC) associated to public spending as in [Berg et al \(2013\)](#)). Our main findings show that the Dutch disease occurs only under inflation targeting and oil price inflation rules. The fixed exchange rate monetary rule seems to be effective to prevent a Dutch disease effect. Also, under IT rule, the decline in export sector tends to shrink gradually as the rise in the share of oil stabilisation fund. The decline in export goods production is completely resorbed when we combine the share of OSF with a positive coefficient of enhancing productivity. This is not the case when oil price inflation rule is considered. Finally, optimal monetary and fiscal policies do not give better results than ER rule which provides also the highest welfare gain.

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## A Appendix

Table 2. Oil export in total export

	Upper-Middle-Income				High-Income		Lower-Middle-Income	
	Algeria	Venezuela	Russia	Ecuador	Norway	Canada	Angola	Congo
1990	96,5	80,1		51,9	47,8	10,0	93,5	89,1
1995	94,6	76,7	43,11*	35,9	47,3	9,2	94,8	87,6
2000	97,2	86,1	50,6	49,4	63,9	14,2	94,8	87,6
2005	98,0	88,0	61,8	58,4	67,7	21,6	96,5	67,7
2010	97,3	93,4	65,6	55,3	63,8	26,3	96,6	77,7
2013	96,7	97,7	71,2	57,0	67,7	27,3	97,2	78,9
Average	96,8	88,4	62,3	51,2	62,1	19,7	96,0	79,9

Table 3. Oil export in term of GDP

	Upper-Middle-Income				High-Income		Lower-Middle-Income	
	Algeria	Venezuela	Russia	Ecuador	Norway	Canada	Angola	Congo
1990	20,0	29,1	16,0*	11,6	9,9	2,0	32,5	39,7
1995	23,1	17,9	5,4	6,7	10,2	2,4	64,5	45,6
2000	38,5	23,7	13,0	13,3	17,2	4,7	77,0	74,9
2005	44,1	33,6	14,3	14,1	14,6	6,0	80,9	72,5
2010	34,8	21,2	12,6	13,9	10,9	5,0	58,8	70,4
2014	30,6	39,4	12,9	14,1	9,9	6,2	53,6	61,2

Table 4. Government effectiveness

	Upper-Middle-Income				High-Income		Lower-Middle-Income	
	Algeria	Venezuela	Russia	Ecuador	Norway	Canada	Angola	Congo
1996	-1,089	-0,541	-0,452	-0,475	1,951	1,742	-0,860	-1,169
2000	-0,964	-0,737	-0,720	-0,766	1,897	1,931	-1,462	-1,265
2005	-0,468	-0,931	-0,500	-0,947	1,864	1,887	-1,137	-1,271
2010	-0,480	-1,112	-0,469	-0,717	1,879	1,783	-1,118	-1,228
2016	-0,545	-1,293	-0,216	-0,432	1,883	1,798	-1,039	-1,096
Average	-0,662	-0,988	-0,443	-0,678	1,905	1,838	-1,163	-1,189



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