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Monetary policy, oil stabilization fund and the Dutch disease

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Abstract

This paper contributes to the literature on the Dutch disease effect in a small open oil exporting economy. To this end, we formulate a DSGE model in line with the balanced-growth path theory. Specifically, our main contribution to the literature is to highlight the importance of policy-mix in oil exporting countries by introducing a fiscal policy and an oil stabilization fund in the model besides alternative monetary rules. Our main findings show that the Dutch disease, through the spending effect, does not occur only in the case of fixed exchange rate regime. An expansionary fiscal policy contributes to improve the state of the economy through the impact of public spending on the productivity of the manufacturing sector.

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

JEL Classification: E52, F41, Q40

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1 Introduction

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 income shock, the deindustrialization phenomenon, as defined in the Dutch disease literature, occurs. In order to analyze 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 Stähler and Thomas 2012. We assume that the central bank may adopt alternative monetary policy rules such as a strict inflation targeting, a fixed exchange rate regime and a domestic oil price inflation regime as in Frankel 2011, 2017; and accumulates foreign exchange reserves. On the fiscal policy side, we assume that the government holds an oil stabilization fund (OSF, hereafter) which is financed by surplus of oil-revenues and interests earned from foreign exchange reserve that are entirely transferred by the central bank to the government. The OSF is mainly used to conduct macroeconomic stabilization policy and to support non-oil export sector and domestic producers. We also assume that the government subsidy 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.

Our paper is related to two strands of the literature using dynamic stochastic general equilibrium (DSGE) models. This first one focuses on the influence of public investment in resource-rich low-income countries Berg et al., 2013 and Alter et al., 2017. This literature has interesting distinguishing features for our purpose. On the one hand, public investment exerts an influence on the productivity in the nontraded and traded good sectors, this latter exhibiting learning-by-doing externalities. On the other hand, public investment suffers from distortions such as a low public investment efficiency, absorptive capacity constraints in the economy, and institutional failures through project selection weakness. The second strand of literature focuses on macroeconomic stabilization policy in the aftermath of oil price shocks. On the monetary policy side, the respective effectiveness of alternative rules and the role of foreign exchange reserve have been extensively investigated by Lama and Medina, 2012, Dagher et al., 2012, and Faltermeir et al., 2017. On the fiscal policy side, Pieschacon (2012) and Arezki and Ismail (2013) highlight the influence of fiscal smoothing rules to manage both short- and medium-term effects of a commodity windfall.

Our paper differs from the previous literature on two main points. On the one hand, we combine different monetary rules with fiscal policy to assess their effectiveness to face Dutch disease effect. From this standpoint, we depart from the literature that considers this policy-mix in a short-term stabilization perspective. On the other hand, while an extensive literature on oil exporting countries tends to focus either on high-income economies Arezki and Ismail (2013) and Lama and Medina, 2012 or low-income and lower-middle-income economies (IMF, 2012; Berg et al., 2013), 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, 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 as for lower-income countries. 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 (IT, hereafter) and oil price inflation rules. The fixed exchange rate monetary rule, (ER, hereafter) 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 share of OSF dedicated to the support export sector rises. 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 à la Frankel 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 this paper is organized as follows. Section 2 describes the model. Section 3, discusses the parameters calibration. Section 4 exposes the main results. Section 5 concludes.

2 The Model

The description of the model follows standard convention in the DSGE model literature. Therefore, we concentrate in the following on the intuition of the model and report technical details in the Appendix for sake of clarity.

The main purpose of this paper is to analyze the importance of policy-mix in oil exporting countries. As argued in the introduction, analysis of optimal policy for commodity-exporting countries is a widely discussed topic both in the empirical and the theoretical literature. Nonetheless, the interaction between monetary and fiscal policy and its effectiveness to address the phenomenon of deindustrialization, the Dutch disease effect, suffers from an unified theoretical framework. This paper builds this gap in the literature. In addition, the specification of the model permits to assess the effectiveness of the policy-mix both for macroeconomic stabilization and sustainable economic development purposes. It is worth to recall that the main objective of macroeconomic stabilization policy is to insulate the economy from the damaging effect of changes of oil-income due to volatility of the price of oil. It is therefore a short and medium term policy (Lama and Medina, 2012; Dagher et al., 2012; Faltermeir et al., 2017; Pieschacon, 2012; and Arezki and Ismail, 2013). In turn, policies such as energy subsidy and stabilization fund, that are part of sustainable economic development policy, are long term policies (Berg et al., 2013 and Alter et al., 2017). The model developed in this study therefore permits to verify the compatibility of short term policy and long term one. This is a useful tool for policymakers to evaluate the effectiveness of a given policy within an unified theoretical framework.

2.1 Households

The country is populated by an unit mass of households, $h = [0, 1]$. We assume perfect insurance markets within home country and that households share the same preference technology. Therefore, household's individual variable will be the same as the aggregate variable of the representative household.

Households maximize a string of discounted future value of utilities that depend positively on consumption (c_t) and the holding of real money balance (m_t), and depend negatively on labor supply (L_t) that is measured in terms of number of hours worked. Each period, the representative household faces the following budget constraint:

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

where τ_t^c represents consumption taxes perceived by the government, i_t^p households' investment, b_t^d domestic bonds, b_t^* foreign bonds which is assumed to be denominated in US Dollar, and $g_{\Theta,t}$ the growth rate of the labor augmenting technology process that arises from the intensive form representation of the model.[1] z_t denotes US Dollar bilateral real exchange rate. A decrease in z_t is interpreted as a home-currency appreciation.

Households' investment ($i_t^p = \sum_{i=X,H,O} i_{i,t}^p$) permits to accumulate units of private

[1] The use of the intensive form representation, known also as the balanced-growth path theory, has the main advantage of solving analytically the steady state value of variables. It permits to have a clear interpretation of the transmission mechanism of the model.

capital used in export ($k^p_{X,t}$), domestic non-tradable ($k^p_{H,t}$) and oil ($k^p_{O,t}$) firms. The law of motion of capital is standard. However, we follow Christiano et al. (2005) and Stähler and Thomas (2012), and assume that changing the level of investment is costly. Households have access to both domestic and private foreign bonds markets. We assume that international market is incomplete and domestic households trade only risk-free assets.

In terms of revenues, household's total income inc_t is composed of (i) dividends derived from import, export, domestic non-tradable intermediate firms, and oil firm, (ii) return on effective capital stock ($\tilde{k}^p_{i,t} = u_t g^{-1}_{\Theta,t} k^p_{i,t}$ for $i = X, H, O$) minus the cost associated with variations in the degree of capital utilisation u_t, (iii) labor income, (iv) lump-sum tax or transfer t_t, and (v) the natural resource revenue transferred by the government to consumers, reflecting that the natural resource endowment eo_t is owned by the public. Moreover, households earn interest, R_t and R^*_t, upon holding domestic and foreign bonds, respectively. ϵ^Q_t is the risk premium shock that arises from the presence of domestic financial intermediation. In turn, $\varkappa_t$ is a risk-premium charges on top of nominal world interest rate due to the presence of international financial intermediation. 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,

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

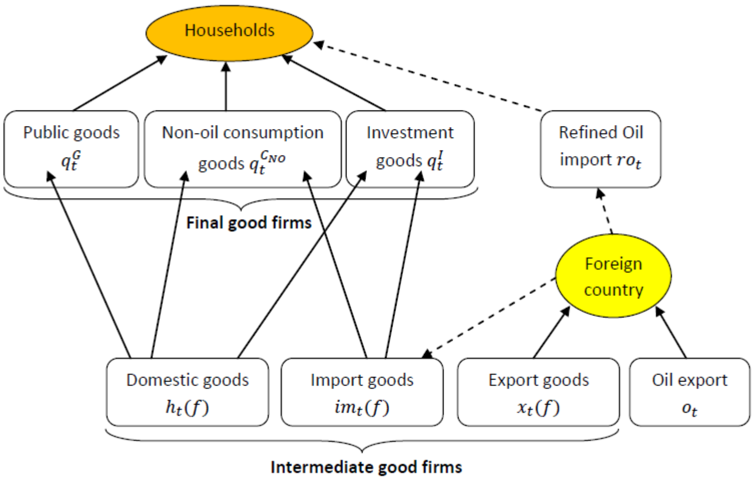
with $\psi > 0$ and where nfa_t and y_t are respectively the period t net foreign asset position and gross domestic products. Home-country net foreign assets in turn are composed of private net foreign assets b^*_t, the stabilization fund f_t that comes from oil exports, and foreign exchange reserve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

$$nfa_t = z_t\left(b^*_t + f_t + res^*_t\right) \tag{2}$$

2.2 Firms

There exists two types of non-oil firms in the economy: intermediate firms that behave as monopolistic suppliers of their differentiated goods and final good firms that use bundles of those intermediate goods to produce final goods to be consumed or invested by consumers.

In the domestic market, there exists three types of intermediate good firms: (i) a continuum of domestic intermediate good firms $h_t(f)$ indexed by $f \in [0, 1]$ which produce differentiated intermediate goods that are sold domestically, (ii) a continuum of export



intermediate good firms $x_t(f)$ which produce differentiated intermediate goods that are sold exclusively to domestic exporting firms, and (iii) a continuum of import intermediate good firms $im_t(f)$ which import differentiated intermediate goods that are produced abroad and sell them without any transformation to domestic final-good firms. Domestic and non-oil export intermediate good firms use both labor $L_{i,t}(f)$ and effective capital stock $\tilde{k}^p_{i,t}(f) = u_t g^{-1}_{\Theta,t} k^p_{i,t}(f)$ for $i = H, X$ to produce output $\upsilon_t(f)$ for $\upsilon = h, x$ according to the following constant returns to scale technology:

$$\upsilon_t(f) = \epsilon^a_t \left(k^g_{i,t}\right)^\eta \left[\tilde{k}^p_{i,t}(f)\right]^{\alpha_i} \left[L_{i,t}(f)\right]^{1-\alpha_i-\eta} - \Phi \tag{3}$$

where ϵ^a_t is the aggregate productivity shock, Φ a fixed cost, $k^g_{i,t}$ the public capital stock that is assumed as in Stahler and Thomas (2012) to be productivity-enhancing, and $\eta \in [0,1]$ the parameter that measures the degree of public investment into private production. This is the key channel through which government uses OSF to increase productivity of the traded sector to prevent from the Dutch disease effect. The effectiveness of such policy depends on the parameter η. It might also be used to take into account absorptive constraints in the economy and institutional failures through project selection weakness.

Final good firms that produce non-oil private consumption good $q_t^{C_{NO}}$ and investment good q_t^I transform a bundle of differentiated domestic and import intermediate goods using an aggregate production function. In contrast, we assume that final public consumption goods q_t^G are produced using solely domestic intermediate goods. The same assumption is made for exporting firms. Final export goods are produced using solely export intermediate goods.

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 eo_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

$$\Pi_{O,t} = (1 - \tau^o_t)\, o_t - \frac{w_{O,t}}{p_{O,t}} L_{O,t} - r^k_{O,t} \tilde{k}^p_{O,t} - \frac{p_{EO,t}}{p_{O,t}} eo_t$$

subject to production function

$$o_t = \epsilon^o_t \left(\tilde{k}^p_{O,t}\right)^{\alpha_o} (eo_t)^{\theta_o} (L_{O,t})^{1-\alpha_o-\theta_o} - \Phi_o$$

where Φ_o denotes production fixed-cost, $\alpha_o, \theta_o \in [0,1]$ and $\alpha_o + \theta_o \leq 1$. The oil-revenue perceived by the government takes the form of royalty denoted by τ^o_t. The natural resource revenue $p_{EO,t} eo_t$ in turn is directly transferred to consumers that own the resource endowment. Moreover, the latter is assumed to evolve according to:

$$\ln eo_t = (1 - \rho_{o,s}) \ln(\overline{eo}) + \rho_{o,s} \ln eo_{t-1} + \eta^{o,s}_t \text{ where } \eta^{o,s}_t \rightsquigarrow \text{iid } \mathcal{N}\left(0, \sigma^2_{o,s}\right)$$

where $\eta^{o,s}_t$ is an oil supply shock.

2.3 Central bank

Following Dagher et al. (2012) we assume that the central bank uses other instruments of monetary policy in addition to the short term interest rate. To that end, we introduce in the model the evolution of the supply of money m_t that is directly derived from the central bank balance sheet and is given by:

$$m_t - \frac{m_{t-1}}{g_{\Theta,t}\Pi_t} = b^m_t - \frac{b^m_{t-1}}{g_{\Theta,t}\Pi_t} + z_t \left(res^*_t - \frac{res^*_{t-1}}{g^*_{\Theta,t}\Pi^*_t} \right) \tag{4}$$

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

$$z_t res^*_t = z_t \frac{res^*_{t-1}}{g^*_{\Theta,t}\Pi^*_t} + \phi_{res} \tau^o_t (p_{O,t} - \bar{p}_O)\, o_t$$

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

Finally, the central bank chooses its policy rate R_t according to the following Taylor rule :

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_R} \left[\left(\frac{y_t}{y_{t-1}}\right)^{r_y} \left(\frac{\Omega_t}{\bar{\Omega}}\right)^{r_\omega}\right]^{1-\rho_R} \exp\left(\eta_t^R\right) \tag{5}$$

where parameter ρ_R indicates the degree of interest-rate smoothing. Parameters r_y and r_ω in turn are policy coefficients that measure the degree of central bank response to output and to policy variable $\Omega = \{\Pi, \Pi_{PO}, \Delta Z\}$. This specification permits to handle different monetary policy scenarios. In case of the standard inflation targeting, the central bank reacts to change in the consumer price index inflation (henceforth, IT rule) Π. The peg to oil price à la Frankel is the case in which the central bank reacts to change in the domestic oil price inflation Π_{PO}. The last case considered in this study is the exchange rate targeting rule (henceforth, ET rule) where the central bank fixes nominal US-Dollar exchange rate Z in which oil-revenues are denominated.

2.4 Government

The specificity of the model for oil exporting is that an important part of government's revenue and spending depend on oil revenue. In this study, the oil revenue is introduced through royalties τ_t^o that government collects from oil firms. More importantly, 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 an OSF f_t. In addition, the government uses interests earned from the fund and the exchange rate reserve res_t^* holds by the central bank. Thus, the government is subject each period to the following budget constraint:

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

where g_t is the public purchases or the government spending commonly defined in the litterature and b_t^m the government bonds held by the central bank.

Following Benkhodja (2014), refined-oil consumed domestically is produced abroad with price assumed to evolve according to:

$$p_{RO,t} = (1 - \upsilon_{RO})\, g_{\Theta,t}^{-1} p_{RO,t-1} + \upsilon_{RO} z_t p_{O,t}^* \tag{6}$$

where $p_{O,t}^*$ is the international oil price and $\upsilon_{RO} \in [0, 1]$ indicates the degree of domestic refined-oil price subsidy from the government.

We further 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:

$$\begin{aligned} z_t\tilde{\Theta}_t\left(f_t-\bar{f}\right) &= z_t\tilde{\Theta}_t\left(g^*_{\Theta,t}\Pi^*_t\right)^{-1}\left(f_{t-1}-\bar{f}\right)+\tau^o_t\left(p_{O,t}-\bar{p}_O\right)o_t \\ &\quad -\left(sfg_t-\overline{sfg}\right)-\left(sft_t-\overline{sft}\right) \end{aligned}$$

where earned interests are entirely transfered to the government. Terms sfg_t and sft_t represent the amount taken by the government from the OSF to finance temporary fiscal deficit and to support lagging sector that migh be hurt by the Dutch disease phenomenon. They are defined as:

$$\begin{aligned} sfg_t &= \upsilon_{sfg}z_t\tilde{\Theta}_t\left(g^*_{\Theta,t}\Pi^*_t\right)^{-1}f_{t-1} \\ sft_t &= \upsilon_{sft}z_t\tilde{\Theta}_t\left(g^*_{\Theta,t}\Pi^*_t\right)^{-1}f_{t-1} \end{aligned}$$

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

$$p_{I,t}i^g_{H,t} = \frac{1}{2}\phi_{I^g}\tau^o_t\bar{p}_O o_t \qquad (7a)$$

$$p_{I,t}i^g_{X,t} = \frac{1}{2}\phi_{I^g}\tau^o_t\bar{p}_O o_t+sft_t \qquad (7b)$$

where public investment dedicated to the trading sector can be financed by the OSF on top of oil revenues. It is worth mentioning that the public investment is financed on the basis of stable oil prices $\bar{p}_O$.

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

$$k^g_{i,t+1}=(1-\delta)g^{-1}_{\Theta,t}k^g_{i,t}+i^g_{i,t}\text{ for }i=\{H,X\} \qquad (8)$$

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

$$\frac{g_t}{\bar{g}}=\left(\frac{g_{t-1}}{\bar{g}}\right)^{\rho_G}\left[\left(\frac{y_t}{y_{t-1}}\right)^{g_y}\left(\frac{sfg_t}{\overline{sfg}}\right)^{g_{sfg}}\right]^{1-\rho_R}\exp\left(\eta^G_t\right)$$

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

3 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 (see table 1).

The subjective discount factor $\beta = \overline{g}_z / \left(1 + \left(\overline{R}/4\right)\right)$, 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 $\overline{g}_z = 1.004$. Thus, the parameters of capital utilisation cost for our three firms $\gamma_{i,1}$ and $\gamma_{i,2} = \overline{g}_z\,(1/\beta) - 1 + \delta$ are equal to 0.034. 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 α_o, α_H and α_X are associated with the capital elasticity in production function of oil, home and exports firms and θ_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 adjustement cost coefficient for non-oil consumption γ_a^c and investmenent γ_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 θ_{WO}, θ_{WX} and θ_{WH} are set at the same level. On average, price adjustement occurs every 4 quarters. Also, the prices $(\gamma_O, \gamma_X, \gamma_H)$ and wages $(\gamma_{W_O}, \gamma_{W_X}, \gamma_{W_H})$ 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, υ_H, υ_O and υ_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 $(\upsilon_{C,NO} = 0,47)$ is assumed to be higher relative to the one used to produce final investment goods $(\upsilon_I = 0,25)$. 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[2] respectively.

The steady state values parameters are taken from Algerian time series 1980-Q1-2014-Q4. The 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).

4 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 OSF 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 (IRFs) 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. Our IRFs represent this gap.

4.1 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

[2] This value is taen from ONS data.

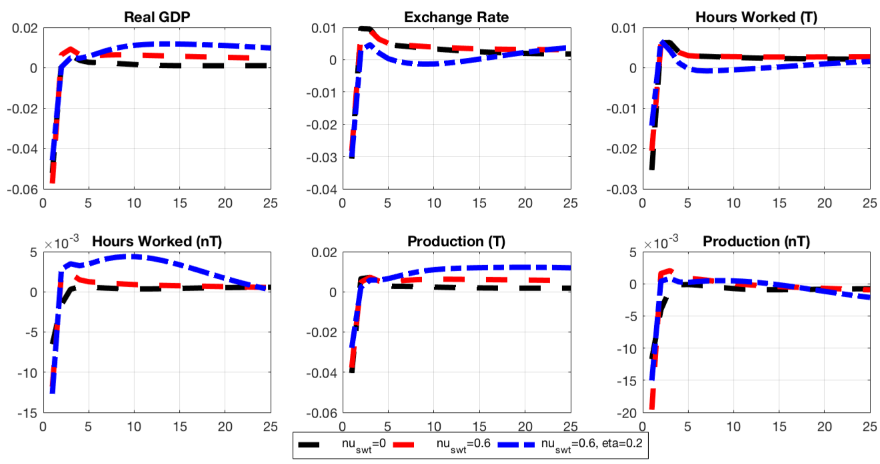
constraints of OPEC membership, we focus below on responses in trade and non-tradable sectors.

4.1.1 Inflation targeting regime

As exhibited in Figure 1 and 2, in the aftermath of an international oil price shock, production and investment in the export sector decrease significantly. This suggests the presence of the deindustrialization phenomenon resulting from oil resource's abundance. 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.

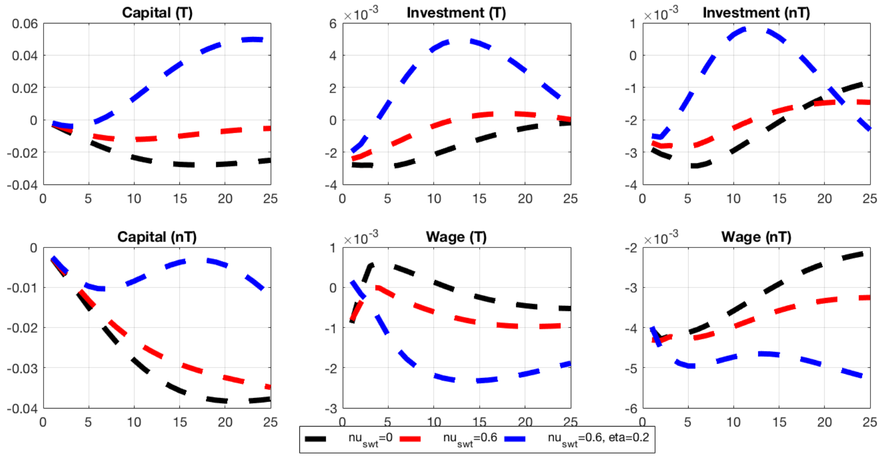
Importantly, the decline in export sector tends to shrink gradually as the rise in the share of OSF dedicated to the support export sector. The decline in export goods production is completely resorbed when we combine the share of OSF with a positive coefficient of enhancing productivity (η).

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



Our model shows also that the oil price shock causes a resource movement effect, particularly at short-term. Indeed, hours worked and wages in the export 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, Figure 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.

Figure 2: (continued) Responses to a positive oil price shock (IT rule)



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.

4.1.2 Fixed exchange rate

Figure 3: Responses to a positive oil price shock (ER rule)

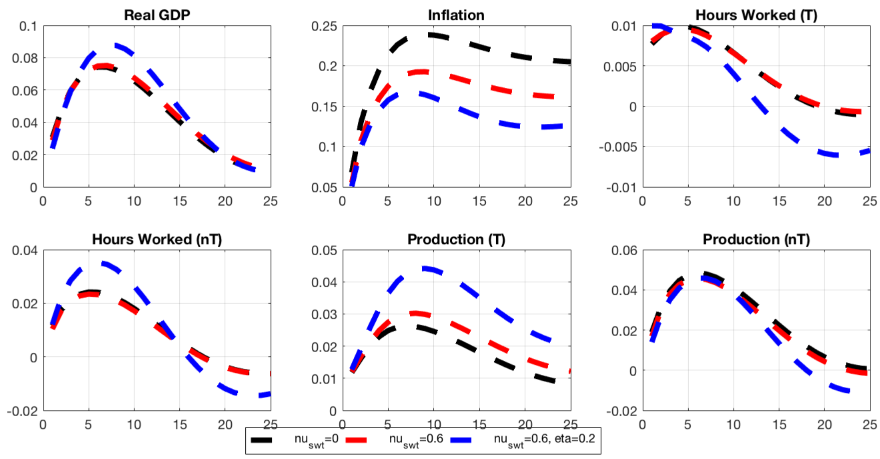


Figure 4: (continued) Responses to a positive oil price shock (ER rule)

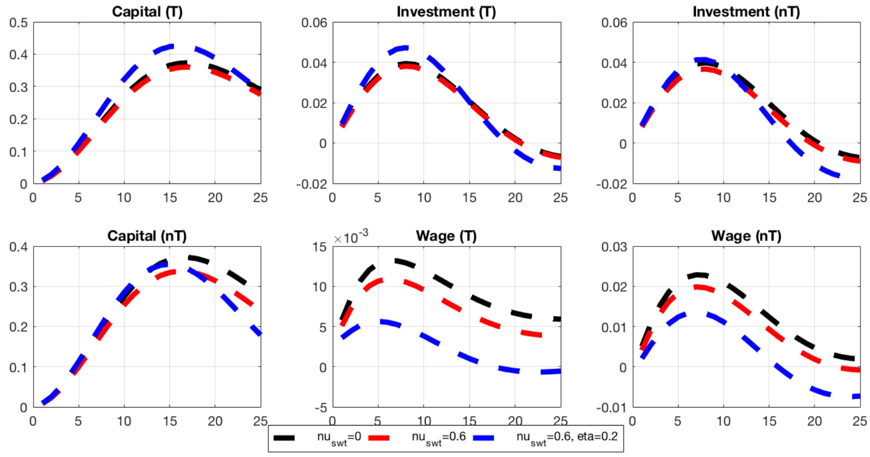


Figure 3 and 4 exhibits a striking result: the fixed exchange rate monetary rule is particularly effective to prevent a Dutch disease effect. Indeed, relative to the baseline model, not only the real GDP and domestic consumption are higher, but we observe also positive responses of macroeconomic variables 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.

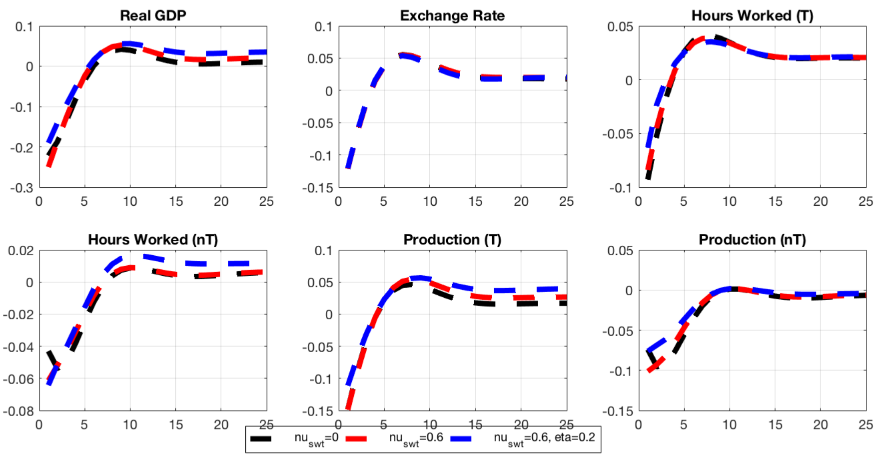
The dynamics of our main macroeconomic variables in the aftermath of a positive oil price shock rests on the two mechanisms of the Dutch disease effect. On the one hand, the exchange rate rule impedes the distortions due to the spending effect. On the other hand, as the real exchange rate does not appreciate 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.

Our result differs from Lama and Medina (2012) and Faltermeier et al. (2017) who find that the exchange rate rule is ineffective because the decrease in the domestic interest rate to stabilize the exchange rate leads to a suboptimal expansion in the nontradable sector. Specifically, in our model, the effectiveness of the exchange rate rule is strenghthened by the presence of a reserve accumulation rule in which authorities increase their foreign reserve when the international oil price deviates from the target oil price. As a consequence, the pass-through from oil price to exhange rate is broken with the accumulation rule instead of through the domestic interest rate as in Lama and Medina (2012) and Faltermeier et al. (2017).

4.1.3 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 sector (Figure 5 and 6). 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, 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.

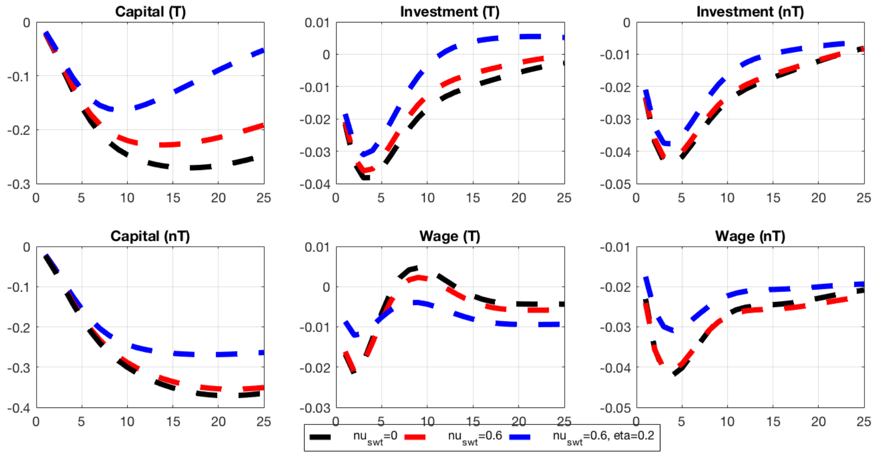
Figure 5: Responses to a positive oil price shock (Frankel rule)



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.

This result is partly in line with Vogel et al. (2015) who stress that Frankel disregards general-equilibrium effects of the real oil price targeting rule, and then, overestimates its effectiveness. However, we depart from Vogel et al. by stressing the effectiveness of the rule is confirme even after taking into account the effects of fiscal policy.

Figure 6: (continued) Responses to a positive oil price shock (Frankel rule)



4.2 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.

4.2.1 Optimal Policy

We compare the reponses 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 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

Figure 7: Responses to oil price shock under alternative policy rules

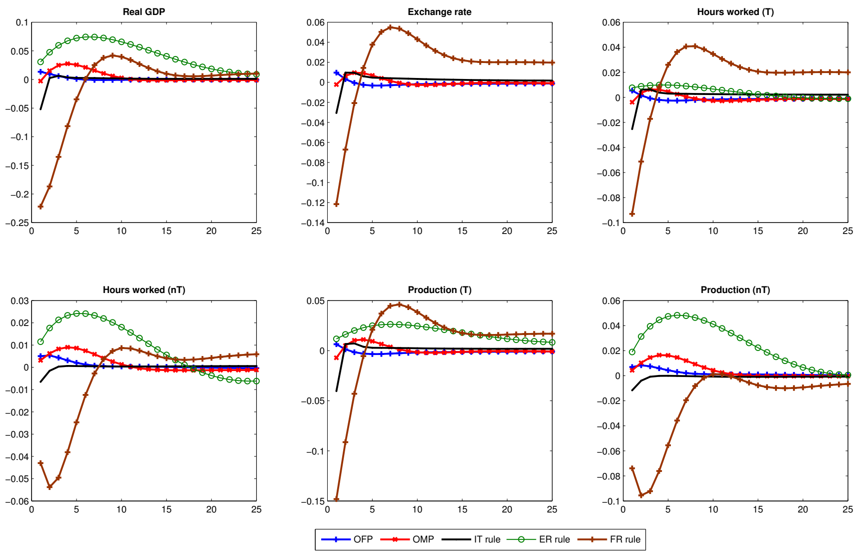
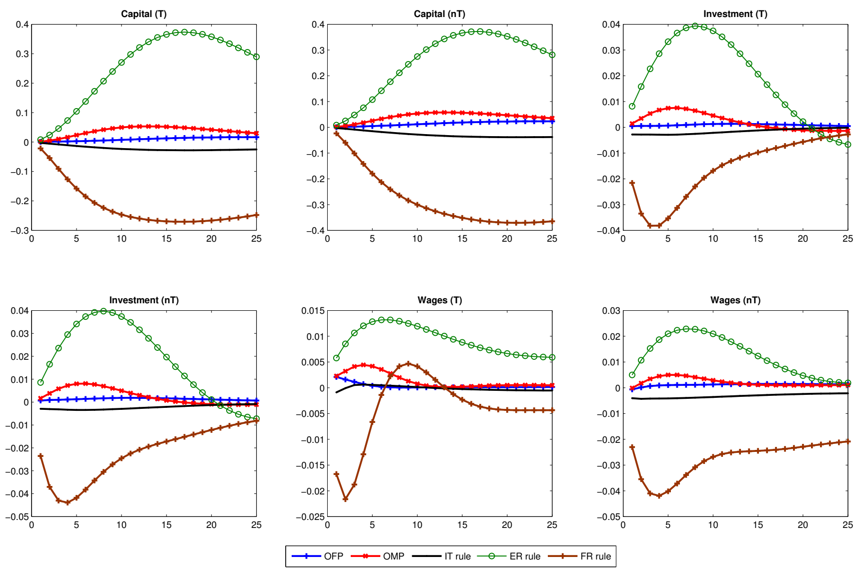


Figure 8: (continued) Responses to oil price shock under alternative policy rules



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.

4.2.2 Welfare Analysis

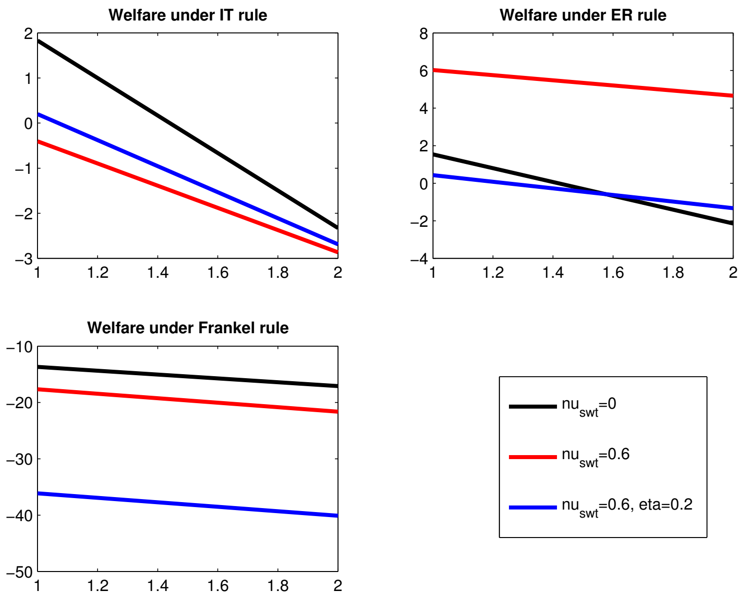
To assess the impact of windfall on the welfare, we solve the model using a second order approximation of the utility function for different policies but also for different values of two parameters: share of oil stabilization fund dedicated to support trading (export) sector υ_{swt}, and parameter of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

$$U_t\left(.\right) = \epsilon_t^B \left(\ln\left(c_t - h g_{\Theta,t}^{-1} c_{t-1} \right) + \theta_M \epsilon_t^M \ln\left(m_t\right) - \epsilon_t^L \frac{\left(L_t\right)^{1+\psi}}{1+\psi} \right) \tag{9}$$

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.

The results are shown in Figure 9. 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.

Figure 9: Welfare responses under alternative policy rules



5 Conclusion

In this paper, we studied the role of fiscal and monetary policies during a windfall 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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Appendix

A Stylized facts

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

B Calibration

Table 1.1 Calibration of structural parameters

Description	Parameters	Values
Structural parameters		
Discount factor	β	0.995
Real money balance weight in the utility function	θ_M	0.5
Depreciation rate of capital	δ	0.025
Frish elasticity of labor supply	ψ	2
International oil price elasticity of demand	η_O	0.80
Export price elasticity of demand	η_X	0.80
Household's labor supply elasticity of substitution	η_I	0.8
Parameter for risk premium	ψ	0.01
Share of home export in global demand	κ_X	0.05
Parameter of productivity enhancing public capital	η	0.05
Share of oil proceed accumalted as exchange rate reserves	ϕ_{res}	0.3
Share of oil proceed dedicated to public investment	ϕ_{Ig}	0.5
Weight of home goods (production process of final non-oil cons)	$\upsilon_{C,NO}$	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)	υ_I	0.25
Constant elasticity of substitution (final investment goods)	η_I	0.70
Weight of energy goods (refined-oil) in the final consumption	υ_C	0.023
Constant elasticity of substitution between non-oil and refined-oil	η_C	0.47
First parameter of capital utilisation cost for Oil firms	$\gamma_{O,1}$	0.034
Second parameter of capital utilisation cost for Oil firms	$\gamma_{O,2}$	0.034
First parameter of capital utilisation cost for Export firms	$\gamma_{E,1}$	0.034
Second parameter of capital utilisation cost for Export firms	$\gamma_{E,2}$	0.034
First parameter of capital utilisation cost for Home firms	$\gamma_{H,1}$	0.034
Second parameter of capital utilisation cost for Home firms	$\gamma_{H,2}$	0.034

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	γ_a^c	2.5
Adjustment cost coefficient for investment	γ_a^I	2.5
Capital elasticity (home intermediate goods firms)	α_H	0.28
Capital elasticity (export intermediate goods firms)	α_X	0.28
Capital elasticity in production function of oil	α_O	0.35
Crude oil elasticity in production function of oil	θ_O	0.2
Share of households labor supply to domestic firms	υ_H	0.45
Share of households labor supply to domestic oil firms	υ_O	0.10
Share of households labor supply to export firms	υ_X	0.45
Royalties	τ_t^o	0.2
Degree of domestic refined-oil price subsidy	υ_{RO}	0.3
Calvo price setting (home)	θ_H	0.75
Indexation: domestic-prices	γ_H	0.75
Calvo price setting (export)	θ_X	0.75
Indexation: export-prices	γ_X	0.75
Calvo price setting (import)	θ_{IM}	0.75
Indexation: import-prices	γ_M	0.75
Calvo wage setting (oil firms)	θ_{WO}	0.75
Indexation: wage (oil firms)	γ_{W_O}	0.75
Calvo wage setting (export firms)	θ_{WX}	0.75
Indexation: wage (export firms)	γ_{W_X}	0.75
Calvo wage setting (home firms)	θ_{WH}	0.75
Indexation: wage (home firms)	γ_{W_H}	0.75

Table 1.3 Calibration of structural parameters (continued)

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

C 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 Θ_t. Therefore, to render the model stationary, we scale real variables by Θ_t and nominal variables by the consumer price level P_t. Tranformed 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.[3] 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 $\eta_t^{g_\Theta} \rightsquigarrow$iid $\mathcal{N}\left(0, \sigma_{g_\Theta}^2\right)$ 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.[4]

C.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:

$$E_t \sum_{k=0}^{\infty} \beta^k U_{t+k} \left(c_{t+k}(h), ha_{t+k}(h), m_{t+h}(h), L_{t+k}(h)\right) \tag{10}$$

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

$$U_t(\cdots) = \epsilon_t^B \left(\ln\left(c_t - h g_{\Theta,t}^{-1} c_{t-1}\right) + \theta_M \epsilon_t^M \ln(m_t) - \epsilon_t^L \frac{(L_t)^{1+\psi}}{1+\psi} \right) \tag{11}$$

[3]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 Θ_t and P_t. That is, stationary level of wage is defined as $w_t = W_t/\Theta_t P_t$.

[4]Technical appendix containing details of the model is available upon request for interested readers.

We assume perfect insurance markets within home country[5] 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, ϵ_t^B, ϵ_t^M and ϵ_t^L are respectively the preference, the money demand and the labor supply shocks. Finally, parameters θ_M and ψ represent the weight of real money balance on the utility of consumers and the inverse of Frisch elasticity of labor supply, respectively.

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

$$\begin{aligned}(1+\tau_t^c)c_t + p_{I,t}i_t^p + m_t + \left(b_t^d + z_t b_t^*\right) &= inc_t + \epsilon_{t-1}^Q R_{t-1}\frac{b_{t-1}^d}{g_{\Theta,t}\Pi_t} + \frac{m_{t-1}}{\Pi_t g_{\Theta,t}} \\ &\quad + z_t\left(g_{\Theta,t}^*\Pi_t^*\right)^{-1}\left(\varkappa_{t-1}R_{t-1}^* b_{t-1}^*\right)\end{aligned} \tag{12}$$

where ϵ_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 steems 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,

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

where $r_{i,t}^k$ is the real return on effective capital and $\Psi\left(u_{i,t}\right)$ is the cost associated in changing

[5] 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.

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 eo_t is owned by the public, $p_{EO,t}eo_t$ represents the natural resource revenue transfered 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:

$$k^p_{i,t+1} = (1-\delta)g^{-1}_{\Theta,t}k^p_{i,t} + \epsilon^I_t\left(1 - S\left(g_{\Theta,t}\frac{i^p_{i,t}}{i^p_{i,t-1}}\right)\right)i^p_{i,t} \text{ for } i = X, H, O \tag{13}$$

where ϵ^I_t is defined to be the (private) investment shock and $S(.) = \frac{\kappa_{i,I}}{2}\left(g_{\Theta,t}\frac{i^p_{i,t}}{i^p_{i,t-1}} - \bar{g}_\Theta\right)^2$ 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 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 $w_{i,t}(h) = \tilde{w}^o_{i,t}(h)$. However, whenever household is not allowed to adjust its contracts, wage is indexed to last period CPI inflation[6].

C.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:

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

where η_C is the elasticity of substitution between oil and non-oil goods, and υ_C represents the share of refined-oil energy in the representative household's consumption basket.

[6]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.

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

$$p_t = \left[(1 - \upsilon_C) (p_{NO,t})^{1-\eta_C} + \upsilon_C (p_{RO,t})^{1-\eta_C} \right]^{\frac{1}{1-\eta_C}} \tag{14}$$

where $p_{NO,t}$ is the core-consumption price index, henceforth "*core-CPI*", which is defined in equation (20). In turn, optimal allocation of expenditure between non-oil goods and refined-oil energy is given by:

$$c_{NO,t} = (1 - \upsilon_C) (p_{NO,t})^{-\eta_C} c_t \tag{15a}$$

$$c_{RO,t} = \upsilon_C (p_{RO,t})^{-\eta_C} c_t \tag{15b}$$

Therefore, and as is standard in the literature, combining the expression of headline-CPI and that of optimal allocation of expenditure yields the following definition of total nominal expenditure:

$$c_t = p_{NO,t} c_{NO,t} + p_{RO,t} c_{RO,t} \tag{16}$$

C.1.2 Household's optimization problem

households choose $\left\{ c_{t+k}, m_{t+k}, b^d_{t+k}, b^*_{t+k}, k^p_{i,t+k+1}, i^p_{i,t+k}, u_{i,t+k} \right\}_{k=0}^{\infty}$ to maximize the discounted futur value of their utilities (10) subject to their budget constraints (12) and the law of motion for capital (13). Solving this maximization problem yields the following standard first order conditions:

$$\Lambda_t = \frac{\epsilon_t^B \left(c_t - h g_{\Theta,t}^{-1} c_{t-1}\right)^{-1}}{1+\tau_t^c} \tag{17a}$$

$$1 = E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} \left(g_{\Theta,t+1} \Pi_{t+1}\right)^{-1} \epsilon_t^Q R_t \right\} \tag{17b}$$

$$1 = \frac{\theta_M \epsilon_t^B \epsilon_t^M}{\Lambda_t m_t} + E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} \left(g_{\Theta,t+1} \Pi_{t+1}\right)^{-1} \right\} = \frac{\theta_M \epsilon_t^B \epsilon_t^M}{\Lambda_t m_t} + \frac{1}{\epsilon_t^Q R_t} \tag{17c}$$

$$1 = E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} \left(g_{\Theta,t+1} \Pi_{t+1}^*\right)^{-1} \frac{z_{t+1}}{z_t} \varkappa_t R_t^* \right\} \tag{17d}$$

$$Q_{i,t} = E_t \left\{ \frac{\beta \Lambda_{t+1}}{\Lambda_t} g_{\Theta,t+1}^{-1} \left[r_{i,t+1}^k u_{i,t+1} - \Psi\left(u_{i,t+1}\right) p_{I,t+1} + (1-\delta) Q_{i,t+1} \right] \right\} \tag{17e}$$

$$p_{I,t} = Q_{i,t}\epsilon_t^I \left[1 - S\left(g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right) - S'\left(g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right) g_{\Theta,t} \frac{i_{i,t}^p}{i_{i,t-1}^p} \right] + \tag{17f}$$

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

$$r_{i,t}^k = \Psi'\left(u_{i,t}\right) p_{I,t} \tag{17g}$$

C.2 Firms

C.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 differentiated intermediate goods that are sold domestically, a continuum of export intermediate good firms $x_t(f)$ which produce differentiated intermediate goods that are sold exclusively to domestic exporting firms, and a continuum of import intermediate good firms $im_t(f)$ which import differentiated intermediate goods that are produced abroad and sell them without any transformation to domestic final-good firms.

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:

$$h_t(f) = \epsilon_t^a \left(k_{H,t}^g\right)^\eta \left[\tilde{k}_{H,t}^p(f)\right]^{\alpha_H} \left[L_{H,t}(f)\right]^{1-\alpha_H-\eta} - \Phi \tag{18}$$

where ϵ_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 Φ a fixed cost.

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 θ_H of firms keeps their prices unchanged.

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 θ_{IM} of importing firms keeps their prices unchanged.

C.2.2 Final-good firms

Final private consumption-good and investment-good firms

Non-oil final private consumption-good firms produce homogeneous goods $q_t^{C_{NO}}$ using a bundle of domestic $h_t^{C_{NO}}$ and imported $im_t^{C_{NO}}$ intermediate goods. The production function that transforms intermediate goods into final consumption output is given by:

$$q_t^{C_{NO}} = \left[\upsilon_{C,NO}^{\frac{1}{\eta_{C,NO}}} \left(h_t^{C_{NO}} \right)^{\frac{\eta_{C,NO}-1}{\eta_{C,NO}}} + (1-\upsilon_{C,NO})^{\frac{1}{\eta_{C,NO}}} \left(im_t^{C_{NO}} \right)^{\frac{\eta_{C,NO}-1}{\eta_{C,NO}}} \right]^{\frac{\eta_{C,NO}}{\eta_{C,NO}-1}} \tag{19}$$

where $\eta_{C,NO}$ is the elasticity of substitution between home and foreign non-oil bundles of goods, and $\upsilon_{C,NO}$ measures the degree of home production bias.

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

$$p_{NO,t} = \left[(1-\upsilon_{C,NO}) \left(p_{IM^{C_{NO}},t} \right)^{1-\eta_{C,NO}} + \upsilon_{C,NO} \left(p_{H,t} \right)^{1-\eta_{C,NO}} \right]^{\frac{1}{1-\eta_{C,NO}}} \tag{20}$$

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:

$$q_t^G = \left[\int_0^1 \left(h_t^G(f) \right)^{\frac{1}{1+\lambda_{H,t}^p}} df \right]^{1+\lambda_{H,t}^p} \tag{21}$$

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:

$$x_t = \left[\int_0^1 \left(x_t(f) \right)^{\frac{1}{1+\lambda_{X,t}^p}} df \right]^{1+\lambda_{X,t}^p} \tag{22}$$

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. That is,

$$x_t = \kappa_x \left(\frac{p_{X,t}}{z_t} \right)^{-\eta_x} y_t^* \tag{23}$$

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

C.3 The international oil market

The domestic currency price of crude oil is defined as:

$$p_{O,t} = z_t p^*_{O,t} \tag{24}$$

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:

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

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:

$$o_t = \kappa_o \left(p^*_{O,t}\right)^{-\eta_o} y^*_t$$

where y^*_t represents the global demand that is defined as

$$\text{ln} y^*_t = \rho_{o,d} \text{ln} y^*_t + \eta^d_t,\ \eta^d_t \rightsquigarrow \text{iid } \mathcal{N}\left(0, \sigma^2_d\right)$$

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.

C.4 Market Clearing

C.4.1 Labor market clearing

Labor market clears when labor demand of different sectors $i = \{O, X, H\}$ match excactly labor supply of households at the wage level set monopolistically. That is,

$$\int_0^1 L_{i,t}(f) df = L_{i,t} = \left[\int_0^1 L_{i,t}(h)^{\frac{1}{1+\lambda^i_{W,t}}} dh\right]^{1+\lambda^i_{W,t}} \tag{25}$$

Aggregating over households h the labor demand in (**??**) yields:

$$\int_0^1 L_{i,t}(h) dh = \int_0^1 \left(\frac{w_{i,t}(h)}{w_{i,t}}\right)^{-\frac{1+\lambda^i_{W,t}}{\lambda^i_{W,t}}} L_{i,t} dh$$

that is,

$$\int_0^1 L_{i,t}(h)dh = \varkappa_{w_i,t} L_{i,t} \tag{26}$$

where $\varkappa_{w_i,t}$ measures the degree of wage dispersion across households and evolves according to:

$$\varkappa_{w_i,t} = (1-\theta_{W_i})\left(\frac{\tilde{w}^o_{i,t}}{w_{i,t}}\right)^{-\frac{1+\lambda^i_{W,t}}{\lambda^i_{W,t}}} + \theta_{W_i}\left(\frac{\Pi^{\gamma_{W_i}}_{t-1}}{\Pi_t}\frac{w_{i,t-1}}{w_{i,t}}\right)^{-\frac{1+\lambda^i_{W,t}}{\lambda^i_{W,t}}} \varkappa_{w_i,t-1} \tag{27}$$

It is worth noting that wage dispersion equals to one in the steady state and vanishes in the first-order approximation around steady state. Aggregate total wage paid by the firms in turn is given by:

$$\int_0^1 w_{i,t}(h)L_{i,t}(h)dh = w_{i,t}L_{i,t}$$

C.4.2 Capital market clearing

Capital market clears when the effective use of capital services equals demand from firms in different sectors $i = \{O, X, H\}$. That is,

$$u_{i,t}\int_0^1 g^{-1}_{\Theta,t}k^p_{i,t}(h)dh = u_{i,t}g^{-1}_{\Theta,t}k^p_{i,t} = \tilde{k}^p_{i,t} = \int_0^1 \tilde{k}^p_{i,t}(f)df \tag{28}$$

C.4.3 Intermediate goods market clearing

Market clears for each intermediate-good firms when the supply of their products equals domestic or foreign total demands. Aggregating over firms f yields:

$$\begin{aligned}
\int_0^1 h_t(f)df &= \varkappa_{H,t}h_t \\
\int_0^1 x_t(f)df &= \varkappa_{X,t}x_t \\
\int_0^1 m_t(f)df &= \varkappa_{M,t}m_t
\end{aligned}$$

where $\varkappa_{i,t}$, for $i = \{H, X, M\}$, are price dispersion across firms that evolves according to:

$$\varkappa_{i,t} = (1-\theta_i)\left(\frac{\tilde{p}^o_{i,t}}{p_{i,t}}\right)^{-\frac{1+\lambda^p_{i,t}}{\lambda^p_{i,t}}} + \theta_i\left(\frac{\Pi^{\gamma_i}_{i,t-1}}{\Pi_{i,t}}\right)^{-\frac{1+\lambda^p_{i,t}}{\lambda^p_{i,t}}} \varkappa_{i,t-1} \tag{29}$$

and

$$
\begin{aligned}
h_t(f) &= h_t^{C_{NO}}(f) + h_t^I(f) + h_t^G(f) \\
h_t &= h_t^{C_{NO}} + h_t^I + q_t^G \\
m_t(f) &= m_t^I(f) + m_t^{C_{NO}}(f) \\
m_t &= m_t^I + m_t^{C_{NO}}
\end{aligned}
$$

Therefore, aggregate real ressource of the oil exporting economy consists of non-tradable goods h_t, tradable manufactured goods x_t and crude oil o_t. That is,

$$y_t = \varkappa_{H,t} h_t + \varkappa_{X,t} x_t + o_t \tag{30}$$

In nominal terms, domestic aggregate ressource is given by:

$$
\begin{aligned}
p_{Y,t} y_t &= \int_0^1 p_{H,t}(f) h_t(f) df + \int_0^1 p_{X,t}(f) x_t(f) df + p_{O,t} o_t \\
p_{Y,t} y_t &= p_{H,t} h_t + p_{X,t} x_t + p_{O,t} o_t \qquad (31)
\end{aligned}
$$

That is, the GDP deflator can be obtained as:

$$p_{Y,t} = p_{H,t} \frac{h_t}{y_t} + p_{X,t} \frac{x_t}{y_t} + p_{O,t} \frac{o_t}{y_t}$$

C.4.4 Final goods market clearing

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

$$
\begin{aligned}
q_t^{C_{NO}} &= c_{NO,t} \\
q_t^I &= i_t^p + \Psi(u_t)\, g_{\Theta,t}^{-1} k_t^p + i_t^g = i_t \qquad (32) \\
q_t^G &= g_t
\end{aligned}
$$

from which we obtain the following expression of nominal aggregate ressource using optimal allocation of expenditure between different domestic and imported bundles of differentiated goods and the expression of nominal total consumption expenditure. That is,

$$p_{Y,t} y_t = p_t c_t + p_{I,t} i_t + p_{H,t} g_t + (p_{X,t} x_t + p_{O,t} o_t) - (p_{M,t} \tilde{m}_t + p_{RO,t} c_{RO,t}) \tag{33}$$

where

$$\begin{aligned} i_t &= i_t^p + \Psi(u_t)\, g_{\Theta,t}^{-1} k_t^p + i_t^g \\ \tilde{m}_t &= \Theta_t^{m^{C_{NO}}} m_t^{C_{NO}} + \Theta_t^{m^I} m_t^I \end{aligned}$$

and

$$\begin{aligned} \Theta_t^{m^{C_{NO}}} &= \frac{\left(1 - \Gamma_t^{m^{C_{NO}}}\right)}{1 - \Gamma_t^{m^{C_{NO}}} - \left(\Gamma_t^{m^{C_{NO}}}\right)' \frac{m_t^{C_{NO}}/q_t^{C_{NO}}}{m_{t-1}^{C_{NO}}/q_{t-1}^{C_{NO}}}} \\ \Theta_t^{m^I} &= \frac{\left(1 - \Gamma_t^{m^I}\right)}{1 - \Gamma_t^{m^I} - \left(\Gamma_t^{m^I}\right)' \frac{m_t^I/q_t^I}{m_{t-1}^I/q_{t-1}^I}} \end{aligned}$$

C.4.5 Bonds market clearing

In equilibrium, holdings of government domestic bonds equals to zero each period given the assumption that government budget constraint is closed each period by lump-sum taxes. That is,

$$\int_0^1 b_t^d(h)dh = b_t^d = 0$$

Morever, market clears in the international market of foreign private bonds when supply match exactly holdings of foreign bonds by domestic households. That is,

$$\int_0^1 b_t^*(h)dh = b_t^*$$

Given the definition of domestic net foreign asset in (2), it evolves according to:

$$\begin{aligned} \frac{Z_t \Theta_t^* P_t^*}{\Theta_t P_t} \frac{(B_t^* + F_t + RES_t^*)}{\Theta_t^* P_t^*} &= \frac{Z_t \Theta_t^* P_t^*}{\Theta_t P_t} \frac{\Theta_{t-1}^* P_{t-1}^*}{\Theta_t^* P_t^*} \frac{\varkappa_{t-1} R_{t-1}^* \left(B_{t-1}^* + F_{t-1} + RES_{t-1}^*\right)}{\Theta_{t-1}^* P_{t-1}^*} + \frac{TB_t}{\Theta_t P_t} \\ z_t \tilde{\Theta}_t \left(b_t^* + f_t + res_t^*\right) &= z_t \tilde{\Theta}_t \left(g_{\Theta,t}^* \Pi_t^*\right)^{-1} \varkappa_{t-1} R_{t-1}^* \left(b_{t-1}^* + f_{t-1} + res_{t-1}^*\right) + tb_t \qquad (34) \end{aligned}$$

with trade balance tb_t defined as:

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

where Ξ_t is a friction that arise due to the presence of import adjustment cost in final-good firms. It is defined as

$$\Xi_t = p_{M,t}\left(\left(1-\Theta_t^{m^{C_{NO}}}\right)m_t^{C_{NO}}+\left(1-\Theta_t^{m^I}\right)m_t^I\right)$$

and is equal to zero in the steady state, $\bar{\Xi}=0$.