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ESSAYS ON MONETARY POLICY IN AN OIL EXPORTING ECONOMY

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Summary

The aim of this thesis is to analyze the impact of external shocks on oil exporting economies and the role of monetary policy in this context. It consists of three essays.

In the first essay, we build a Multi-sector Dynamic Stochastic General Equilibrium (DSGE) model to investigate the impact of both windfall (an increase in oil price) and boom (an increase in oil resource) on an oil exporting economy. Our model is built to see if the two oil shocks (windfall and boom) generate, in the same proportion, a Dutch Disease effect. Our main findings show that the Dutch disease effect under its two main mechanisms, namely spending effect and resource-movement effect, occurs only in the case of flexible wages and sticky prices, when exchange rate is fixed. We also compare the source of fluctuations that leads to a strong effect in term of de-industrialization. We conclude that the windfall leads to a stronger effect than a boom. Finally, the choice of flexible exchange rate regime helps to improve welfare.

In the second essay, we estimate, by using the Bayesian approach, a DSGE model for Algerian economy investigating the dynamic effect of four external shocks (oil price, real exchange rate, international interest rate and foreign inflation), and examining the appropriate monetary policy rule. Our main findings show that, over the period 1990Q1-2010Q4, core inflation target is the best monetary rule to stabilize both output and inflation.

In the third essay, we investigate the impact of the recent increase of oil price on a small open oil exporting economy. For this, we estimate a Dynamic, Stochastic, General equilibrium (DSGE) model for some oil producing countries using the Bayesian approach. We consider, in this essay, a sample of 16 oil exporting countries (Algeria, Argentina, Ecuador, Gabon, Indonesia, Kuwait, Libya, Malaysia, Mexico, Nigeria, Oman, Russia, Saudi Arabia, United Arab Emirates, and Venezuela) over the period from 1980 to 2010, except for Russia where our sample begins in 1992. In order to distinguish between high-dependent and low-dependent countries, we use two indicators: the ratio of fuel exports to total merchandise exports and the ratio of oil exports to GDP. We estimate the median for each ratio on our 16 studied countries. Countries above (below) the median are considered as high (low) oil dependent economies. We verify

if the first group is more sensitive to the Dutch disease effect. We also assess the role of monetary policy. Our main findings show that in the first sample, namely high oil dependant economies, 6 countries are affected by the Dutch disease (decrease in the manufacturing production). Low oil dependant countries, are less affected by the fluctuation of oil price. Indeed, only one country has suffered a Dutch disease effect after the shock. Nevertheless, Regarding the appropriate monetary policy rule, we find that both inflation targeting and exchange rate rules may be effective to contain the size of the Dutch disease effect. Our results suggest that in Algeria and Saudi Arabia, inflation targeting offers better performances. We observe the opposite in Gabon, Kuwait, Oman, and Venezuela. Such results are consistent with economic theory. Indeed, we see that in more open economies and smaller countries (in terms of economic size), the exchange rate rule is preferable to inflation rule. Venezuela seems an exception. Such country does not fulfill the traditional criteria favoring the choice of the exchange rule. In fact, this exception is only apparent. First, if we consider the volatility, we see that Venezuela is among the most volatile economy. Second, Venezuela suffers from a fiscal dominance effect: both inflation rate and fiscal deficit are the highest relative to other studied countries.

Keywords: Monetary policy, oil exporting economies, multisector DSGE model, Dutch disease effect, bayesian estimation, welfare analysis, exchange rate regimes.

Résumé

L'objectif de cette thèse est d'évaluer le rôle de la politique monétaire dans une économie exportatrice de pétrole faisant face à des chocs exogènes, en particulier les chocs pétroliers. Elle se compose de trois essais.

Dans le premier essai, nous avons étudié le rôle des autorités monétaires face à deux chocs pétroliers, l'un lié à la hausse des prix du pétrole (aubaine) et l'autre à la découverte de nouveaux gisements (boum). L'objectif de cet essai est, d'une part, de comparer l'impact de l'aubaine et du boom sectoriels sur l'économie d'un pays exportateur de pétrole et leur implication en terme de bien être et, d'autre part, d'évaluer la politique monétaire qui pourrait être conduite afin d'isoler l'économie des conséquences de ces chocs. Pour ce faire, nous avons construit un modèle Dynamique Stochastique d'Equilibre Général (DSGE) multisectoriel comportant des rigidités nominales et réelles. Nos principaux résultats montrent que le syndrome hollandais sous ses deux effets, dépense et ressource, semble avoir lieu dans le cas où les salaires sont flexibles et les prix rigides seulement sous un régime de change fixe. En d'autres termes, nos simulations montrent que le syndrome hollandais peut être évité si les prix sont rigides et les salaires flexibles lorsque les autorités monétaires adoptent une règle de ciblage d'inflation; les prix et les salaires sont rigides, quelque soit l'objectif de la Banque centrale et ce, dans les deux cas : aubaine et boom. Nous avons également comparé les sources de fluctuation qui conduisent au syndrome hollandais et nous avons conclu que la hausse des prix du pétrole (aubaine) conduit à une plus forte désindustrialisation de l'économie comparé à l'aubaine. Nous avons également montré que le régime de change flexible minimise le coût en bien être des ménages par rapport au change fixe.

Dans le deuxième essai, nous avons comparé trois règles de politique monétaire (ciblage d'inflation, ciblage de taux de change et ciblage de l'inflation sous jacente) face à quatre chocs externes (prix du pétrole, taux de change, terme de l'échange et taux d'intérêt international) subis par un pays émergent exportateur de pétrole. Pour ce faire, nous estimons, en premier lieu, le modèle de base en se référant à l'interprétation des informations à postériori et les fonctions de réponses impulsionnelles. En second lieu, nous estimons le modèle sous différents règles de politique monétaire. Nos principaux

résultats montrent qu'au cours de la période 1990-2010, le ciblage de l'inflation sous-jacente semble être la meilleure politique qui stabilise à la fois l'output et l'inflation.

Le troisième et dernier essai a pour objectif d'évaluer l'hypothèse du syndrome hollandais dans des pays exportateurs de pétrole dont la dépendance à celui-ci diffère. Autrement dit, nous cherchons à vérifier si le phénomène du syndrome hollandais est lié à la dépendance des pays à leurs exportations pétrolières. Le cas échéant, nous évaluerons empiriquement le rôle de la politique monétaire en supposant deux règles alternatives: une règle de change fixe et une règle de ciblage d'inflation. Pour ce faire, nous estimons, par l'approche bayésienne, un modèle DSGE pour un échantillon de pays exportateurs de pétrole. Nos principaux résultats montrent que le syndrome hollandais a lieu, essentiellement, dans les pays fortement dépendants de leurs exportations pétrolières. Plus précisément, après un choc sur le prix du pétrole, nous remarquons une baisse de la production manufacturière dans six pays fortement dépendants et dans seulement un pays faiblement dépendant. Aussi, la politique monétaire la plus appropriée ne semble pas être unique pour l'ensemble des pays souffrant du syndrome hollandais. Nos résultats sont plus performants en Algérie et Arabie Saoudite sous le ciblage d'inflation et sous la règle du taux de change au Gabon, Koweït, Oman, et le Vénezuela. Ces résultats dépendent de la taille et du degré d'ouverture de chaque économie. La règle la plus appropriée est donc le ciblage d'inflation losque l'économie est de grande taille (en terme de superficie) et d'un degré d'ouverture relativement bas et la rège de taux de change lorsque l'économie est de petite taille et à fort taux d'ouverture.

Mots-clés: Politique monétaire, economies exportatrices de pétrole, modèle DSGE multisectoriel, syndrôme hollandais, estimation bayésienne, analyse du bien être, régimes de change.

Résumé de la thèse en français

Les économies exportatrices de pétrole se distinguent des autres économies par leur forte vulnérabilité aux chocs internationaux. La hausse des cours du pétrole, les fluctuations des taux de change et des taux d'intérêt internationaux, la hausse de l'inflation mondiale et d'autres chocs exogènes constituent un défi pour les autorités monétaires des pays producteurs de pétrole qui doivent faire face aux effets de ces chocs. En effet, la forte dépendance à l'exportation du pétrole, l'importante part des importations dans le panier de consommation, et l'importance de la dette extérieure des économies exportatrices de pétrole les rend considérablement exposés aux chocs internationaux. La variation du prix du pétrole, qui représente l'un des plus importants chocs, peut avoir des effets considérables sur l'activité économique. Plusieurs études dédiées aux conséquences macroéconomiques des fluctuations des prix du pétrole montrent que l'impact de ceux-ci diffère selon que l'économie soit exportatrice nette ou importatrice nette.

Concernant les pays importateurs de pétrole, à l'instar des Etats-Unis et de la Zone Euro, des études comme celles de Bernanke, Gertler et Watson (1997, 2004), Hamilton et Herrera, (2004), Harrera et Perseon (2007), Adjemian et Darracq Pariès (2008) et Blanchard et Gali (2010) montrent, globalement, que l'augmentation des prix du pétrole exerce un effet négatif à la fois sur l'inflation et la croissance mais également sur la volatilité économique de ces pays. En effet, selon ces auteurs, une augmentation des prix du pétrole impliquerait un ralentissement de la croissance économique et une hausse de l'inflation. Les canaux de transmission de ces chocs passent essentiellement par l'augmentation du coût des consommations intermédiaires qui freine la production et la productivité; le transfert de richesse entre les pays importateurs nets et exportateurs nets de pétrole; la hausse instantanée des prix à la consommation suivie

d'un effet de second tour lié à l'ajustement des salaires ainsi que la baisse de la consommation et de l'investissement en biens durables. Cette littérature montre que l'impact du choc pétrolier des années 2000 a été d'une ampleur moindre que celle constatée au cours des deux chocs pétroliers.

Concernant les pays exportateurs de pétrole, l'impact le plus cité dans la littérature est celui du syndrome Hollandais ("Dutch disease").[1]Ce dernier qui définit le déclin de l'activité économique, suite à un choc pétrolier[2]a fait l'objet d'une large analyse théorique et empirique. Depuis les deux premiers chocs pétroliers (1973-1979), le phénomène du Dutch disease a suscité un intérêt particulier chez les économistes. En effet, suite à cette période, une abondante littérature stipulant l'existence d'une relation directe, significativement négative, entre l'abondance de la ressource naturelle et la croissance a vu le jour. Ce courant théorique est représenté essentiellement par Corden et Neary (1982), Neary (1984), Gelb (1988), Sach et Warner (1997), Gylfason et al (1999) et Gylfason (2001). Dans leur article de base, Corden et Neary (1982) représentent le Dutch disease sous deux principaux effets: l'effet dépense et l'effet réallocation des ressources. Ce dernier se réalise en supposant que l'offre de pétrole est imparfaitement inélastique. Dans ce cas, la hausse du prix du pétrole accroit la demande de travail et du capital dans le secteur pétrolier, ce qui conduit à l'accroissement des salaires et du rendement du capital. Si les facteurs de production sont mobiles, alors le travail et le capital se déplaceront des secteurs manufacturiers et des services vers le secteur pétrolier. Ceci mènera à la hausse de la production dans le secteur en boum, alors que le travail et la production dans les deux autres secteurs connaitront une baisse. C'est ce que les auteurs appellent la désindustrialisation directe. Alors que le prix des biens échangeables ne varie pas (car il est déterminé sur le marché international), celui des biens non-échangeables connaitra une hausse étant donné la baisse de la production dans le secteur des services. Ce mouvement des prix conduira à la hausse des prix relatifs et donc à l'appréciation du taux de change. Cette appréciation se ré-

[1]D'une manière générale, le terme Dutch disease est employé pour les économies exportatrices de matières premières (cuivre, café, cacao, pétrole, gaz...). Dans cette thèse nous nous référons aux seuls pays exportateurs de pétrole.

[2]Nous représentons un choc pétrolier sous deux formes: la hausse des prix du pétrole (ou aubaine) et une augmentation de la réserve pétrolière (ou boum).

percutera à son tour sur la compétitivité prix des biens échangeables et contribuera, de ce fait, à la baisse de la production dans ce secteur. Il s'agit de l'effet dépense.

Face à ces chocs, les réponses des politiques économiques (budgétaire et monétaire notamment) se doivent d'être appropriées afin d'éviter les effets procycliques qui peuvent en découler . En effet, une littérature importante met en exergue le rôle crucial de la politique monétaire dans les économies productrices de pétrole. Des études comme de DeLong (1997), Hooker (1999), Barsky et Kilian (2001), Clarida, Gali et Gertler (2000), Bohi (1989), et Bernanke, Gertler et Watson (1997) sont parmi celles qui arguent l'existence d'un rôle central pour la politique monétaire lors d'un choc pétrolier. Ces études montrent, effectivement, que la réponse de la politique monétaire peut avoir des effets de contraction qui conduisent à amplifier l'effet de récession d'un choc pétrolier. En effet, Bohi (1989) et Bernanke, Gertler et Watson (1997) expliquent la récession américaine des années 1970 comme une conséquence à la réponse de la réserve fédérale au choc pétrolier. D'autres auteurs comme Hamilton et Harrera (2001, 2004) affirment que les chocs pétroliers ont été la cause de la récession et que la politique monétaire n'a qu'un effet négligeable face à ces chocs.

De part leur rareté, la plupart des études dédiées aux économies exportatrices de pétrole s'intéressent davantage aux pays producteurs industrialisés qu'aux pays émergents. En effet, la prise en compte du niveau de développement d'une économie peut s'avérer crucial quant à la l'approche adoptée pour l'analyse d'un choc pétrolier. Ce dernier peut, effectivement, avoir des implications économiques plus importantes dans les pays émergents étant donné leur forte dépendance au revenu pétrolier. En effet, parmi les quinze premiers pays exportateurs de pétrole, seulement deux pays développés y figurent (Canada et Norvège). Selon le Tableau 1, les pays en développement et émergents occupent une large part de la production et de l'exportation mondiale de pétrole. La part des exportations dans le commerce extérieur de ces pays montre que leurs performances économiques reposent, principalement, sur la performance de leur secteur pétrolier.

Par ailleurs, la part des revenus pétroliers dans les revenus fiscaux tend à être encore plus importante dans ces économies. Cette dépendance est d'autant plus visible dans des pays comme le Venezuela où les exportations totales s'appuient sur une part moyenne de 75% de produits pétroliers ce qui contribue à plus de 45% des revenues

de l'Etat. D'autres pays, comme l'Algérie et le Mexique, ont des revenus fiscaux qui dépendent largement des revenues pétroliers et dont la part approxime les 40%. A cet effet, les prix du pétrole jouent un rôle important dans la stabilité des comptes de l'Etat et conditionne, de ce fait, la mise en œuvre de la politique budgétaire qui, à son tour, conditionne celle de la politique monétaire.

Table 1: Top 15 des pays producteurs exportateurs de pétrole.

	X_o**	Y_o*	$\frac{X_o}{X}$**	$\frac{X_o}{GDP}$**
Arabie Saoudite	6,273	10,521	87,58	48,07
Russie	5,430	10,146	66,69	13,94
Iran	2,407	4,252	82,79	19,91
Emirats Arabes Unis	2,270	2,813	64,81	25,66
Norvège	2,125	2,134	64,88	11,11
Koweït	2,124	2,450	93,21	46,54
Nigeria	1,939	2,458	90,36	34,36
Angola	1,874	1,987	94,83	60,46
Iraq	1,764	2,408	98,61	61,73
Algérie	1,773	2,078	97,70	35,59
Venezuela	1,719	2,375	95,90	21,25
Libye	1,525	1,789	92,61	59,30
Canada	1,355	3,483	25,03	3,08
Mexique	1,299	2,983	13,51	4,03
Kazakhstan	1,299	1,610	70,58	24,96

Les pays sont classés en fonction de leurs exportations de pétrole.

*Y_o : Production pétrolière. Source: Energy Information Administration EIA (International Energy data and Analysis). Année 2010 en millier de baril par jour.

**X_o : total des exportations de pétrole. Année 2009 en millier de barils par jour.

$\frac{X_o}{X}$: Exportations de pétrole (en % des exportations totales).

$\frac{X_o}{GDP}$: Exportations de pétrole (en % du PIB).

Source: International Monetary Fund, World Economic Outlook Database, October 2011.

Ainsi, l'étude de la politique monétaire dans les pays en développement exportateurs de pétrole mérite une attention particulière étant donné leurs forte vulnérabilité aux variations des prix du pétrole comparés aux pays industrialisés[3]. La réponse de la politique monétaire se doit donc d'être appropriée.

[3]Plusieurs études et analyses montrent que le PIB des pays industrialisés (ceux de l'OCDE en particulier) est moins affecté par la hausse des prix du pétrole que pour les pays en développement. Des estimations du FMI de 2004 (International Energy Agency, 2004, Analysis of the Impact of

Cette thèse aborde le rôle de la politique monétaire dans une économie exportatrice de pétrole sous forme de trois essais. Chaque essai tente d'apporter des réponses à une problématique liée à la réaction des autorités monétaires face aux chocs externes, en particulier le choc pétrolier. A ce titre, nous construisons trois modèles dynamiques et stochastiques d'équilibre général (DSGE) multisectoriels que nous calibrons et estimons sur des pays exportateurs de pétrole.

La modélisation DSGE connait depuis quelques temps un intérêt croissant aussi bien dans le monde académique qu'institutionnel. En effet, au cours des 15 dernières années, des progrès remarquables ont été observés dans la spécification et l'estimation des modèles DSGE. De ce fait, plusieurs institutions, nationales et internationales, en particulier les banques centrales, ont adopté ces modèles comme outil d'analyse politique[4].

Cet intérêt grandissant à l'égard des modèles DSGE relève du fait qu'ils représentent un outil performant qui offre un cadre cohérent pour les analyses et les études de politiques économiques. Il permet d'identifier les sources de fluctuation cycliques, répondre aux questions relatives aux changements structurels, prévoir et prédire les effets des politiques conjoncturelles, et effectuer des expériences contrefactuelles. Il permet également d'établir un lien entre les caractéristiques structurelles de l'économie et les paramètres de la forme réduite, ce qui n'était pas toujours possible avec les modèles macroéconomiques de grande taille. Toutefois, comme tout nouvel outil, les modèles DSGE doivent affirmer leur capacité à ajuster les données et confirmer leur utilité comme outils d'aide à la décision. En fait, c'est seulement récemment, avec les travaux de Christiano et al (2005) qu'a été démontré que les modèles fondé sur l'optimisation avec des rigidités réelles et nominales pourraient représenter avec succès les effets d'un choc de politique monétaire. Aussi, il a fallut attendre les travaux de

High Oil Prices on the Global Economy, May 2004.) pour un échantillon de pays en développement, montrent qu'une hausse permanente de 10$ engendre une baisse de 0.3-0.4% du PIB des pays de l'OCDE alors qu'elle implique une réduction de 1.5% dans les pays en développement.

[4]Etant un instrument performant qui offre un cadre cohérent pour les analyses et les études de politiques économiques, l'utilisation des modèles DSGE s'est de plus en plus orientée vers l'analyse de la politique monétaire. Son utilisation par les banques centrales, en particulier celles du G7, s'est largement répandu ((Bank of Canada (ToTEM), Bank of England (BEQM), ECB (NAWM), Norges Bank (NEMO), Sveriges Riksbank (RAMSES) ou the US Federal Reserve (SIGMA)), grâce notamment à la prise en compte de fondement micro-économiques des rigidités nominales et/ou réelle ainsi qu'aux progrès considérables réalisés dans l'estimation et l'évaluation de ces modèles.

Smets et Wouters (2003) pour démontrer les capacités prédictives des modèles Néo-Keynésiens estimés. En effet, ces auteurs montrent que la qualité d'ajustement du modèle DSGE est comparable, voire meilleure, à celle d'un modèle VAR Bayésien-un modèle statistique dont les performances en termes de prévisions sont reconnues. Dès lors, l'estimation bayésienne des modèles DSGE est devenue une pratique courante dans l'évaluation des politiques économiques à l'aide des séries chronologiques. Cette technique est largement utilisée pour, notamment, sa capacité à éviter la mauvaise identification des paramètres structurels. Autrement dit, lorsque le modèle contient un nombre important de paramètres à estimer, il est souvent difficile d'obtenir des informations correctes sur eux. Cette difficulté engendre essentiellement l'aplatissement de la vraisemblance dans certaines directions. Autrement dit, les différentes valeurs de paramètres mènent vers une même distribution de probabilité pour les données observées, ce qui rend la maximisation de la vraisemblance très difficile. Il en résulte des pics de vraisemblance dans des "zone étranges" produisant des estimations qui sont en désaccord avec les informations supplémentaires que le chercheur peut avoir, conduisant à ce qu'on appelle communément "*dilemma of absurd parameter estimates*" (An and Schorfheid 2007). Ainsi, l'adoption de l'approche bayésienne permet de déformer la fonction de vraisemblance par l'utilisation d'information à priori sur les paramètres. En effet, dans l'inférence bayésienne, la fonction de vraisemblance est "re-pondérée" par des informations à priori, ce qui permet d'obtenir plus de courbure et de minimiser, ainsi, à la fois l'aplatissement de la vraisemblance et le "*dilemma of absurd parameter estimates*".

Pour ces raisons, nous avons adopté l'approche bayésienne dans l'estimation de deux modèles, l'un pour l'Algérie, et l'autre pour un ensemble de pays émergents exportateurs de pétrole. Dans ces pays, le manque d'information dans les données disponibles justifie, en effet, l'utilisation de cette approche.

Dans le premier essai, nous avons étudié le rôle de la politique monétaire face à deux chocs pétroliers, l'un lié à la hausse des prix du pétrole et l'autre à la découverte de nouveaux gisements. Le premier choc est identifié dans la littérature comme étant une aubaine (windfall) et le second choc comme un boum (boom). Ces deux chocs causent, selon Corden et Neary (1982), entre autres, une désindustrialisation de l'économie, appelée communément syndrome hollandais. L'objectif de cet essai est, d'une part,

de comparer l'impact de l'aubaine et du boom sectoriels sur l'économie d'un pays exportateur de pétrole et leur implication en terme de bien être et, d'autre part, évaluer la politique monétaire qui pourrait être conduite afin d'en isoler les conséquences. Pour ce faire, nous avons construit un modèle DSGE multisectoriel comportant des rigidités nominales et réelles. Ce modèle est proche de celui proposé par Dib (2008). Il s'agit d'un modèle de petite économie ouverte habitée par huit agents économiques: les ménages, les firmes pétrolières, les producteurs de biens échangeables et non-échangeables, les importateurs, le producteur de bien final, une Banque centrale et un gouvernement.

Les ménages ont accès au marché financier international où ils peuvent acheter ou vendre des titres. Le choix de cette hypothèse nous permet de répliquer la dynamique du compte courant qui, dans notre cas, joue un rôle important dans la définition de l'effet dépense. Aussi, l'hypothèse d'incomplétude des marchés financiers, ne permet pas de lisser la consommation des ménages qui, dans les pays exportateurs de pétrole, dépend fortement de la volatilité des prix de pétrole. Les ménages reçoivent aussi un salaire nominal pour leur offre de travail dans les trois secteurs, pétrolier, échangeable, et non-échangeable. Dans les deux premiers secteurs, il est supposé que les producteurs opèrent dans un environnement concurrentiel. Dans le secteur des biens non-échangeables, les firmes agissent dans un cadre de concurrence monopolistique dans lequel ils ajustent leur prix avec une certaine probabilité indépendante du temps comme dans Calvo (1983). Si les firmes ne peuvent pas fixer les prix, alors ils les indexent sur l'inflation à l'état stationnaire comme dans Yun (1996). Cette hypothèse nous permet d'introduire des rigidités sur les prix, permettant, de ce fait, à la politique monétaire de jouer un rôle actif. Dans ce cas, le modèle permet d'obtenir des effets réels de court terme sur la politique monétaire. Quant aux ménages, et au même titre que les firmes, ils font face à une restriction de type Calvo (1983) et Yun (1996) lorsqu'ils fixent leur salaire de manière optimale. L'introduction des salaires rigides permet notamment de réduire la volatilité de l'inflation qui dépend des coûts marginaux réels de la production. La rigidité des salaires permet ainsi de lisser le comportement des coûts marginaux et stabilise de ce fait l'évolution des prix.

Etant donné les caractéristiques des pays exportateurs de pétrole, essentiellement la pratique de subvention des prix de pétrole, nous introduisons dans le modèle une règle des prix, inspirée de Bouakez et al (2008). Il s'agit d'une combinaison convexe du

prix international du pétrole exprimé en monnaie locale et du prix domestique de la période précédente. Par l'adoption de cette règle, nous supposons que la firme pétrolière exporte la totalité de sa production brute à l'étranger. Une partie de celle-ci est ensuite importée sous forme raffinée pour être enfin utilisée comme intrants par les firmes domestiques productrices de biens échangeables et non-échangeables. Le gouvernement, propriétaire de la firme pétrolière, subventionne la différence des prix, paye les salariés et rémunère le capital.

Enfin, la Banque centrale, adopte une règle de politique monétaire qui lui permet d'avoir, par la manipulation du taux d'intérêt, deux principales cibles: l'inflation et le taux de change.
Pour analyser les effets des chocs pétroliers, (l'aubaine et le boum), nous simulons le modèle en étalonnant les paramètres structurels par des valeurs tirées essentiellement de la littérature économique et des séries chronologiques en se basant notamment sur l'Algérie. L'exercice de l'étalonnage est très ardu dans la mesure où l'essentiel de la littérature ne traite que des pays développés exportateurs de pétrole. Nous avons de ce fait approximé certaines de nos valeurs à celle du Canada qui demeure, malgré son développement, l'un des plus grand pays exportateur de pétrole.

Afin de répondre à notre problématique, nous simulons trois modèles distincts: un modèle à prix et salaires flexibles, un modèle à prix rigides et salaire flexible et un modèle à prix et salaires rigides. Nous examinons ensuite la dynamique de nos variables sous les deux règles de politiques monétaire: taux de change fixe et ciblage d'inflation.

Dans le cadre du modèle à prix et salaires flexibles, les résultats de la simulation montrent qu'une hausse du prix international du pétrole conduit au déclin du secteur des biens échangeables. En effet, les variables sélectionnées (production, capital, investissement, salaire et heures travaillées) répondent négativement au choc dans le secteur échangeable alors que ces mêmes variables dans les secteurs pétrolier et des biens non-échangeables croissent. Cette réaction est identique à l'effet du syndrome hollandais sous ses deux effets: dépense et ressource. En effet, la baisse de la production, des salaires et des heures travaillées dans le secteur des biens échangeables suivie d'une hausse de ces mêmes variables dans les deux autres secteurs, s'apparente clairement à l'effet ressource. Par ailleurs, l'appréciation du taux de change suite au choc pétrolier,

et la baisse de la production des biens non-échangeables, peut être, à son tour, expliquée par l'effet dépense. Ces résultats sont identiques aussi bien dans le cas d'un boum que d'une aubaine.

Dans le cas du modèle à prix rigides, le choix de la règle monétaire joue un rôle central dans la stabilisation de l'économie. Nous avons donc simulé le modèle distinctement sous les deux règles de politique monétaire. Nous avons ainsi comparé la réponse du présent modèle au modèle de base (prix et salaires flexibles). Dans le cas d'un régime de change fixe, la réponse des variables sélectionnées (production, capital et investissement) montre un déclin dans le secteur des biens échangeables comparativement aux réponses du modèle de base aussi bien dans le cas d'un boum que d'une aubaine. Dans les deux autres secteurs, la situation est différente. Le choc pétrolier (boum et aubaine) génère une hausse de la production dans le secteur pétrolier assortie d'un taux de change relativement stable par rapport au modèle de base. L'adoption de la règle de change fixe a ainsi permis d'éviter l'appréciation du taux de change et par conséquent l'occurrence du syndrome hollandais sous son effet dépense. Toutefois, le déclin du secteur échangeable est imputable à l'effet ressource qui semble avoir eu lieu suite aux deux chocs pétroliers.

Dans le cas d'un régime de change flexible, nos résultats montrent que suite aux deux chocs pétroliers (aubaine et boum), le secteur des biens échangeables connait une hausse de la production contrairement au modèle de base. Ce résultat peut s'expliquer par le fait que le politique de change flexible (ou de ciblage d'inflation) empêche les prix et les salaires d'augmenter dans le secteur des bien non-échangeables et donc de rendre ce dernier plus attractif à la main-d'œuvre du secteur échangeable ce qui empêche l'occurrence de l'effet ressource et donc du syndrome hollandais. D'autre part, la flexibilité du taux de change n'a pas permis le déclin de la production manufacturière, empêchant de ce fait l'occurrence de l'effet dépense. Ceci est probablement dû au fait que l'appareil productif du secteur échangeable (manufacturier), dans les pays exportateurs de pétrole n'est pas très compétitif. La part des biens non-échangeables dans le total des exportations avoisinent les 3%, ce qui est le cas notamment en Algérie. La flexibilité du taux de change ne change donc pas grand-chose à la compétitivité de ce secteur.

Dans le cadre du modèle à prix et salaires rigides, le syndrome hollandais est totalement absent quelque soit la règle de politique monétaire. En effet, suivant les deux chocs pétroliers (aubaine et boum), la dynamique de nos variables montre une trajectoire ne permettant pas de conclure à un syndrome hollandais. Dans le cas d'un régime de change fixe, la production du secteur manufacturier baisse mais à degré moindre qu'au modèle de base, ce qui signifie une amélioration de la production dans ce secteur et donc l'absence d'un effet négatif qu'on peut qualifier de syndrome hollandais. Ceci est probablement dû au fait que l'effet ressource a été affaibli par la rigidité des salaires qui ne permet pas, du moins dans le court terme, d'accroitre l'offre de travail dans les secteurs pétroliers et non-échangeables. Dans le cas d'un change flexible, les résultats sont presque similaires dans la mesure où le syndrome hollandais n'apparait sous aucune de ses deux principales formes, à savoir l'effet dépense et l'effet ressource.

Dans cet essai, nous avons comparé l'importance de la désindustrialisation de l'économie (définie comme la baisse de la production dans le secteur manufacturier) suite aux deux chocs: l'aubaine et le boum. Notre objectif étant d'identifier la source de fluctuation qui conduit à un plus fort syndrome hollandais. Le résultat montre que la désindustrialisation est nettement plus importante dans le cas d'une aubaine (hausse des prix du pétrole) que dans le cas d'un boum (hausse de la ressource pétrolière).

Enfin, nous évaluons le coût en bien être conditionnel de l'aubaine et du boum sous différentes règles monétaires. Nos résultats montrent, globalement, que le régime de change flexible améliore le bien être des individus par rapport au change fixe dans les deux cas: aubaine et boum.

Au total, les principaux résultats montrent que le syndrome hollandais sous ses deux effets, dépense et ressource, semble avoir lieu dans les cas suivants : salaires et prix flexible ; salaires flexibles et prix rigides seulement dans le cas d'un régime de change fixe. En d'autres termes, nos simulations montrent que le syndrome hollandais peut être évité si les prix sont rigides et les salaires sont flexibles lorsque les autorités monétaires adoptent une règle de ciblage d'inflation ; les prix et les salaires sont rigides, quelque soit l'objectif de la Banque centrale et ce, dans les deux cas : aubaine et boom. Nous avons également comparé les sources de fluctuation qui conduisent au syndrome hollandais et nous avons conclu que la hausse des prix du pétrole (aubaine) conduit à une plus forte désindustrialisation de l'économie comparé au boum. Nous avons également montré

que le régime de change flexible améliore le bien être des ménages par rapport au change fixe.

Dans le deuxième essai, nous avons comparé trois règles de politique monétaire (ciblage d'inflation, ciblage de taux de change et ciblage de l'inflation sous jacente) face à quatre chocs externes (prix du pétrole, taux de change, inflation mondiale et taux d'intérêt international) subis par un pays émergent exportateur de pétrole. En effet, ce dernier est spécialement vulnérable aux chocs externes relativement aux autres pays non producteurs de matières premières. Plusieurs canaux expliquent cette vulnérabilité. D'abord, les pays émergents exportateurs de pétrole sont fortement dépendants vis-à-vis de l'activité économique des pays industrialisés (*trade channel* ou canal des échanges commerciaux) et du marché international des capitaux pour financer leurs investissements (*financial channel*, canal financier). En outre, en dépit d'une tendance à la baisse cette dernière décennie, les prix domestiques des pays émergents et en développement restent relativement sensibles aux fluctuations du taux de change (*pass-through channel*). En effet, les pays exportateurs de pétrole sont fortement dépendants de leurs revenus d'exportations, basés essentiellement sur la production pétrolière, et leur activité économique est fortement dépendante des importations ce qui les rend très sensibles à la volatilité du taux de change.

L'Algérie, pays exportateurs net de pétrole, représente des caractéristiques qui le rend très exposé aux chocs externes et doit, de ce fait, adopté une politique monétaire appropriée. Autrement dit, quelle pourrait être la réaction des autorités monétaires face aux chocs exogènes subit par l'économie algérienne afin d'en limiter les conséquences? En effet, outre les critères cités ci-dessus, l'économie algérienne a des caractéristiques qui la rendent très vulnérable aux chocs exogènes: a) une gestion du taux de change avec le dollar comme monnaie d'ancrage ; b) une très forte dépendance aux exportations de pétrole libellées en dollar et dont le prix est fixé sur la marché mondial ; c) une part importante (près de 65%) des importations libellées en euro ; d) une position débitrice nette vis-à-vis du reste du monde ; e) une composition diversifiée de la dette extérieure libellée à 60% en Dollar et 40% d'autres monnaies ; f) une position du compte courant sensiblement liée aux fluctuations des prix du pétrole.

Au cours de la période 2000-2010, en dépit d'importantes recettes pétrolières, les performances de l'économie algérienne ont été peu satisfaisantes. D'une part, le taux de

croissance du PIB s'est situé autour des 3,5% représentant un niveau significativement bas comparé aux autres pays de la région MENA (Moyen Orient et Afrique du Nord) dont le taux moyen était de 5,6%. D'autre part, la production industrielle n'a connu aucun boum et les exportations hors hydrocarbure demeurent encore très faibles.

Ces différentes caractéristiques nous mènent à la question posée initialement et qui concerne le rôle de la politique monétaire en Algérie dans un tel environnement économique. Pour y répondre, nous avons estimé, par la méthode bayésienne, un modèle DSGE pour l'économie algérienne évaluant les effets dynamiques de quatre chocs externes (prix du pétrole, taux de change réel, taux d'intérêt international, et inflation mondiale) afin d'examiner la forme appropriée de la politique monétaire dans ce pays. L'objectif est de comparer, dans un premier temps, l'importance de chaque choc comme source de fluctuation de l'économie algérienne et, dans un second temps, de définir une règle de politique monétaire qui permet d'isoler l'économie des effets de ces chocs.

Le modèle est composé de sept agents économiques: un ménage représentatif, un producteur de pétrole, des producteurs de biens non-pétroliers, un importateur, un producteur de bien final, une Banque centrale et un gouvernement. Notre modèle se distingue de la récente littérature par ce qui suit: i) étant donné que dans de nombreux pays exportateurs de pétrole, les gouvernements subventionnent les prix domestiques du pétrole, nous introduisons une règle des prix donnée par une combinaison convexe du prix international du pétrole exprimé en monnaie local et du prix domestique de la période précédente. Par l'adoption de cette règle, nous supposons que la firme pétrolière exporte la totalité de sa production brute à l'étranger. Une partie de celle-ci est ensuite importée sous forme raffinée pour être enfin utilisée comme intrants par les firmes domestiques productrices de biens non-pétroliers. Cette règle nous permet ainsi de répliquer la subvention des prix du pétrole qui est une pratique courante en Algérie ; ii) dans notre modèle nous supposons l'existence de deux taux de change: USD/DZD et l'EUR/USD. Le premier taux de change représente la monnaie d'exportation et le second une partie de la monnaie d'importation ; iii) notre modèle représente une petite économie ouverte exportatrice de pétrole et ce, pour différentes raisons: a) nous incorporons au modèle un secteur pétrolier pour modéliser la production pétrolière ; b) la ressource pétrolière est utilisée comme intrant dans la fonction de production de la

firme pétrolière ; c) le pétrole raffiné est utilisé comme intrant dans le secteur des biens non-pétroliers ; et enfin d) le prix du pétrole est subventionné.

Pour l'évaluation de la politique monétaire, nous estimons trois règles: règle de taux de change, règle de ciblage d'inflation, et règle de ciblage d'inflation sous-jacente. Le choix de ces trois règles est justifié par le fait que: i) elles décrivent la conduite de la politique monétaire dans un grand nombre de pays émergents et en développement ; ii) dans les pays exportateurs de pétrole, la présence du pétrole dans la composition de l'indice des prix à la consommation soulève la question de savoir si la mesure de l'inflation en Algérie doit être l'inflation globale ou l'inflation sous-jacente. Autrement dit, est-ce que la politique monétaire en Algérie doit réagir à l'inflation globale ou à l'inflation sous-jacente ?

Pour répondre à notre problématique, nous estimons, en premier lieu, le modèle de base en se basant sur l'interprétation des informations à postériori et les fonctions de réponses impulsionnelles. En second lieu, nous estimons le modèle sous différentes règles de politique monétaire.

Nos principaux résultats montrent qu'au cours de la période 1990-2010, le ciblage de l'inflation sous-jacente semble être la meilleure politique qui stabilise à la fois l'output et l'inflation. Ces résultats ont deux principales implications pour les futures politiques : d'abord, ils suggèrent que la Banque d'Algérie devrait changer l'orientation de sa politique monétaire en adoptant une cible d'inflation sous-jacente au lieu de cibler la stabilité de l'indice des prix à la consommation. Ceci implique la réalisation par la Banque d'Algérie de certaines réformes notamment celles qui concernent son indépendance. Ensuite, les autorités algériennes doivent renforcer l'utilisation du taux d'intérêt comme canal de transmission de sa politique monétaire. A cet effet, elles devraient promouvoir les prêts bancaires au secteur privé et développer leur marché des capitaux. Sur ces deux points, l'Algérie accuse un retard significatif par rapport aux autres pays à revenu moyen, notamment ceux de la région MENA.

Le troisième et dernier essai a pour objectif d'évaluer l'hypothèse du syndrome hollandais dans des pays exportateurs de pétrole dont la dépendance à celui-ci diffère. Autrement dit, nous cherchons à vérifier si le phénomène du syndrome hollandais est lié à la dépendance des pays à leurs exportations pétrolières. Le cas échéant, nous

évaluerons empiriquement le rôle de la politique monétaire en supposant deux règles alternatives: une règle de change fixe et une règle de ciblage d'inflation. Pour ce faire, nous estimons, par l'approche bayésienne, un modèle DSGE pour un échantillon de pays exportateurs de pétrole. Nous construisons, de ce fait, un modèle d'une petite économie ouverte comportant trois secteurs de production en l'occurrence les secteurs pétrolier, manufacturier et non-échangeable. Le choix de ces secteurs est justifié en recourant à la théorie du syndrome hollandais qui stipule l'existence de trois secteurs (voir Corden et Neary (1982)): 1) le secteur en boum (*booming sector*): souvent considéré comme le secteur des matières premières qui subit une hausse des prix, ou de la production grâce notamment à la découverte de nouveau gisements (dans le cas du secteur pétrolier) ou encore un progrès technique dans le secteur; 2) le secteur en retard (*lagging sector*): il se réfère généralement au secteur manufacturier qui subit une dégradation de sa production suite au choc des matières premières; 3) le secteur des biens non-échangeables (*non-traded goods sector*): il inclut essentiellement les services.

Notre modèle s'inspire particulièrement du modèle de Dib (2008) et comporte huit agents économiques: les ménages, une firme productrice de pétrole, des producteurs des biens manufacturiers et non-échangeables, un importateur, un producteur de bien final, une Banque centrale et un gouvernement. Nous supposons que les ménages ont accès au marché financier international où ils peuvent acheter ou vendre des titres. Ils reçoivent aussi un salaire nominal pour leur offre de travail dans les trois secteurs, pétrolier, échangeable, et non-échangeable. Dans le premier secteur, il est supposé que la firme pétrolière opère dans un environnement concurrentiel. Dans les secteurs des biens manufacturiers et non-échangeables, les firmes agissent dans un cadre de concurrence monopolistique dans lequel ils ajustent leur prix avec une certaine probabilité indépendante du temps comme dans Calvo (1983). Si les firmes ne peuvent pas fixer les prix, alors ils les indexent sur l'inflation à l'état stationnaire comme dans Yun (1996). Aussi, les ménages font face à une restriction de type Calvo (1983) et Yun (1996) lorsqu'ils fixent leur salaire de manière optimale.

Dans l'exercice d'estimation, nous utilisons des données trimestrielles sur un échantillon de pays exportateurs de pétrole (Algérie, Argentine, Equateur, Gabon, Indonésie, Koweït, Libye, Malaisie, Nigeria, Oman, Russie, Arabie Saoudite, Emirats-Arabes-Unis, Mexique et Venezuela) pour la période de 1980 à 2010, sauf pour la Russie où la

série commence à partir de 1992. Afin de distinguer entre les pays fortement et faiblement dépendants au pétrole, nous utilisons deux indicateurs: le ratio exportations de pétrole sur le total des exportations et le ratio exportations de pétrole sur le PIB. Nous calculons ensuite une médiane pour chaque ratio et nous séparons l'échantillon de 16 pays en deux sous-échantillons en fonction de leur appartenance à la tranche supérieure (fortement dépendants) ou inférieure (faiblement dépendants). Nous vérifions enfin si chaque sous-échantillon est affecté ou non par le syndrome hollandais.

Dans cet essai, nous évaluons aussi le rôle de la politique monétaire pour les pays subissant un syndrome hollandais en estimant deux règles: taux de change et ciblage d'inflation. Le choix de ces deux règles est justifié pas le fait que le syndrome hollandais qui se réalise sous les deux effets ressource et dépense pourrait être évité suite à l'adoption de l'une des deux règles. Intuitivement, une règle de taux de change permet d'atténuer l'effet dépense en évitant l'appréciation du taux de change. De même, le ciblage d'inflation, via la maîtrise des prix, permet de stabiliser les salaires et éviter de ce fait l'effet ressource.

Nos principaux résultats montrent que le syndrome hollandais a lieu, essentiellement, dans les pays fortement dépendants de leurs exportations pétrolières. Plus précisément, après un choc sur le prix du pétrole, nous remarquons une baisse de la production manufacturière dans six pays fortement dépendants et dans seulement un pays faiblement dépendant. Aussi, la politique monétaire la plus appropriée ne semble pas être unique pour l'ensemble des pays souffrant du syndrome hollandais. Nos résultats sont plus performants en Algérie et Arabie Saoudite sous le ciblage d'inflation et sous la règle du taux de change au Gabon, Koweït, Oman, et le Vénezuela. Ces résultats dépendent de la taille et du degré d'ouverture de chaque économie. La règle la plus appropriée est donc le ciblage d'inflation losque l'économie est de grande taille (en terme de superficie) et d'un degré d'ouverture relativement bas et la rège de taux de change lorsque l'économie est de petite taille et à fort taux d'ouverture

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Introduction

For a long time, oil prices 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.

To investigate the dynamic effect of external shocks, in particular oil price shock, some of these studies have used econometric models, in particular VAR models, to decompose the direct effects of external shocks on output and other variables, from those generated by the endogenous monetary policy response as in Bernanke, Gertler et Watson (1997, 2004), Hamilton et Herrera, (2004), Harrera et Perseon (2007), and Kilian and Lewis (2011). All of these studies have investigated the effect of oil price shocks on output for the U.S. and the role played by monetary policy. Other contributions like Leduc and Sill (2004), Medina and Soto (2005), Carlstrom and Fuerst (2006), and Blanchard and Gali (2010) have developed Dynamic General Equilibrium models to study the macroeconomic implications of alternative monetary policy rules, after oil price shocks, for a small open economy. Medina and Soto (2005) analyzed the effects of oil price shocks under alternative monetary policy rules. The authors developed and estimated a DSGE model by Bayesian methods for Chilean economy. The main results show that an increase in the real price of oil leads to a fall in output and an increase in inflation. The contractionary effect of the oil shock is mainly due to the endogenous tightening of the monetary policy. Blanchard and Gali (2010) characterize the macroeconomic performances of a set of industrialized economies in the aftermath of the oil price shocks of the 1970s and the last decade, focusing on the differences across episodes. They examine four different hypotheses for the mild effects on inflation and economic

activity of the recent increase in the oil price: i) good luck; ii) smaller share of oil in production; iii) more flexible labor markets, and (iv) improvement in monetary policy. They conclude that the effects of oil price shocks have changed over time, with steadily smaller effects on prices and wages, as well as on output and employment. These changes have been attributed, partly, to the increase of the credibility of monetary policy.

However, even though the consequences of oil shocks have been investigated, to some extent, for developed economies, the fact remains that the effects of these shocks are less explored in emerging and developing countries. Indeed, this group of countries is especially vulnerable to external shocks. Many channels explain such vulnerability. First of all, these countries remain dependent from economic activity in industrialized countries (the trade channel) and from international capital markets -including international banking activity- to finance their investment (the financial channel). In addition, despite a declining trend since the last decade, domestic prices in emerging and developing countries remain influenced by exchange rates fluctuations (the pass-through channel). Within this group of economies, oil exporting countries are even more exposed to these shocks. Indeed, oil exporting economies rely heavily on oil for their exports earnings, and their growth portrays a strong dependence for imports. As a consequence, they tend to have more volatile business cycle and are more crisis prone than other small-open economies.

This thesis explains the role of monetary policy in an oil exporting economy in three essays. In each essay, we try to give an answer to our main question, related to the role of monetary policy in the aftermath of external shocks. To do this, we calibrate and estimate three DSGE models for some oil exporting countries. The DSGE modeling became, in recent years, widely used by academicians and practitioners. Indeed, over the last fifteen years, considerable progresses have been observed in the specification and the estimation of DSGE models. As a result, several institutions, in particular central banks, have adopted these models as a tool of their policy analysis[5].

[5]Its use is widespread by the most advanced country central banks like Bank of Canada (ToTEM), Bank of England (BEQM), ECB (NAWM), Norges Bank (NEMO), Sveriges Riksbank (RAMSES) ou the US Federal Reserve (SIGMA).

This growing interest for the DSGE modeling is due especially to its performances in terms of forecasting and macroeconomic policy analysis. It identifies the source of cyclical fluctuations, answer questions related to structural changes, predicts and plans the real effects of economic policies, and perform the counterfactual experiment. Also, the increasing use of DSGE models can be attributed to a significant extent to advances in estimation methods, notably the use of Bayesian estimation techniques. Indeed, as reported by Sungbae A and Schorfheide F (2007), Fernández-Villaverde (2010) and Del Negro and Schorfheide (2010) the Bayesian approach has some advantages which can be summarized in two main points: (i) the Bayesian method allows us to compute, directly, many objects of interests such as the posterior distribution of welfare gains and many other complicated functions of the underlying parameters, while capturing in these computed objects all the existing uncertainty regarding parameter values; (ii) the prior beliefs allow us to use other sources of information that do not directly enter the likelihood function. On the other hand, to prevent the flatness of the likelihood function the use of the prior density can introduce curvature into the objective function, making it possible to identify the values of different parameters. For these reasons, we adopted this approach as our empirical method to estimate the Algerian economy and a sample of oil exporting economies respectively in the second and the third essays.

In the first essay, we build a Multi-sector Dynamic Stochastic General Equilibrium (DSGE) model to investigate the impact of both windfall (an increase in oil price) and boom (an increase in oil resource) on an oil exporting economy. Our model is built to see if the two oil shocks (windfall and boom) generate a Dutch Disease effect and how monetary policy should be conducted to insulate the economy from the impacts of these shocks. For this, we calibrate the model under two monetary policy rules, namely fixed exchange rate rule (ER hereafter) and inflation targeting rule (IT hereafter).

The Dutch disease which mean the adverse effects of natural resource boom on the manufacturing sector (or the de-industrialization phenomenon), is the most cited impact of oil shocks in the oil exporting economy literature. It was modeled for the first time by Corden and Neary (1982) in a partial equilibrium framework. They assume a small open economy composed of three sectors: the energy sector, the manufacturing and the non-tradable goods (services) sectors. More precisely, the economy is composed

of: 1) the booming sector: after the discovery of a new resource or a technological progress in the commodity sector or a rise of natural resource price; 2) the lagging sector: generally refers to the manufacturing sector but can also refer to agriculture; 3) the non-tradable sector: includes services, utilities, transportation, etc. They, also, suggest two main mechanisms by which the oil shocks affect the economic activity: the spending effect and the resource-movement effect. These effects are the essential components of the Dutch disease theory. The spending effect is caused by higher domestic incomes due to the increased revenues coming from resource discovery or an increase in oil prices[6]. The higher incomes lead to increased expenditures on both tradable and non-tradable goods. The price of tradable goods is determined in international markets, so the increase in incomes in this small country has no effect on the tradable goods price. However, prices of non-tradable goods are established in the domestic market and consequently, would rise due to the increase in demand caused by the rise in income and expenditures. The higher relative prices of non-tradable goods increase the relative profitability of the non-tradable goods sector and, as a result, contract the tradable goods sector (not including the boom sector) (Neary and Van Wijnbergen 1986, p.2).

The resource movement effect, it occurs if the booming sector shares domestic factors of production with the other sectors of the economy. If so, then there is a tendency for the price of the factors to be bid up which would further squeeze the tradable goods sector. The boom increases the marginal product of factors initially employed in the booming sector, and so draws (mobile) resources out of other sectors. Consequently, there is a decline in the tradable goods sector whose producers would be unable to pay the higher prices for factors of production. These producers are unable to compete for the inputs, thereby preventing the manufacturers from purchasing all of the supplies needed to maintain production levels. As a result, these producers decrease their output, contracting the traded goods sector. To illustrate these two effects, we assume a small open oil exporting model with four sectors: tradable goods, oil, non-tradable goods and imports sectors. We also assume that the government subsidy domestic oil

[6]Several sources of Dutch disease effect have been cited in the literature, but in this work we focus only on oil price and oil resource fluctuations.

price is given, as in Bouakez et al (2008), by a convex combination of the current world price expressed in local currency and the last period's domestic price.

Our main findings show that the Dutch disease effect under its two main mechanisms, namely spending effect and resource-movement effect, occurs in the case of: flexible prices and wages and the flexible wages and sticky prices, when the exchange rate is fixed. In other words, the simulations suggest that Dutch disease effects do not arise in the case of sticky price model when the exchange rate is flexible. Also, the de-industrialization phenomenon is absent when prices and wages are sticky, whatever the objective of the central bank is. We also compare the source of fluctuations that leads to a strong effect in terms of de-industrialization. We conclude that the windfall leads to a stronger effect than a boom. Finally, the choice of flexible exchange rate regime helps to improve welfare compared to fixed exchange rate. Thus, it appears that the flexible exchange rate seems to be the best way to avoid the Dutch disease both in the cases of a windfall and a boom. In other words, it is preferable for a central bank, in an oil exporting economy, to adopt an inflation targeting regime to prevent the impact of oil shocks.

In the second essay, we estimate, by using the Bayesian approach, a DSGE model for the Algerian economy investigating the dynamic effect of four external shocks (oil price, real exchange rate, international interest rate and foreign inflation), and examining the appropriate monetary policy rule. To do so, we develop a Multisector Dynamic, Stochastic, General equilibrium (MDSGE) model with real and nominal rigidities. The aim is, first, to compare the importance of each shock as a source of fluctuations of the Algerian economy, and secondly, to define the appropriate monetary policy rule that insulates the economy from the impacts of these shocks. Our model is different from the existing literature in many aspects. First, given that in several oil exporting countries, government aims to smooth oil price changes, we assume as in previous essay, that the domestic oil price is defined by a convex combination of the current world price expressed in local currency and the last period's domestic price. This rule allows us to replicate the subsidy of oil price that is a common practice in Algeria. Second, in our model there are two exchange rates: US dollar/Algerian dinar and the euro/US dollar exchange rates. The first exchange rate is the exports' currency and the

second represents a part of the imports' currency. Third, our model is a small open oil exporting economy model for a number of reasons: (i) the model is a multisector DSGE model with an oil sector; (ii) oil resource is used in the production function of the oil firm; (iii) the refined oil is used as an input in non-oil production, and (iv) oil price is subsidized. In addition, we consider three alternative monetary policy rules: a fixed exchange rate rule, an headline inflation targeting rule, and a core inflation targeting rule. We adopt these rules for two main reasons: (i) they describe the conduct of monetary policy in a large number of developing and emerging market economies; and (ii) in the oil exporting economy, the presence of the oil component in headline CPI inflation engenders the question whether the measure of inflation in Algeria should be the headline inflation or the core inflation. In other words, does monetary policy in Algeria react to the headline inflation or the core inflation?

Our main findings show that, over the period 1990Q1-2010Q4, the core inflation target is the best monetary rule to stabilize both output and inflation. In other words, the current monetary policy -corresponding to our baseline model- followed by the Algerian central bank is not well-suited to oil shocks. These results are two main policy implications. First, they suggest that Algeria should modify its monetary policy in order to adopt a core inflation targeting framework. This implies to fulfill some preconditions such as the central bank independence. Second, Algerian authorities must strengthen the influence of the interest rate as a transmission channel of monetary policy. To this end, they must promote banking lending to the private sector and the development of the capital market. On these two points, Algeria lags relative to other upper middle income countries, especially in MENA region, preventing the use of the interest rate as the main instrument of the monetary policy.

In the third essay, we investigate, empirically, if an increase in oil price leads to a Dutch disease effect in oil exporting economies. More precisely, we try to compare the importance of this effect between high oil-dependent countries. For this, we estimate a Dynamic, Stochastic, General equilibrium (DSGE) model for some oil exporting countries using the Bayesian approach. We build a small open economy model with three production sectors. We add an oil sector, compared to the literature using DSGE

models, to better reflect the mechanisms of the Dutch disease described in the literature by Corden and Neary (1982).

We consider, in this essay, a sample of 16 oil exporting countries (Algeria, Argentina, Ecuador, Gabon, Indonesia, Kuwait, Libya, Malaysia, Mexico, Nigeria, Oman, Russia, Saudi Arabia, United Arab Emirates, and Venezuela) over the period from 1980 to 2010, except for Russia where our sample begins in 1992[7]. In order to distinguish between high-dependent and low-dependent countries, we use two indicators: the ratio of fuel exports to total merchandise exports and the ratio of oil exports to GDP. We estimate the median for each ratio on our 16 studied countries. Countries above (below) the median are considered as high (low) oil dependent economies. We verify if the first group is more sensitive to the Dutch disease effect. We also assess the role of monetary policy. For this, we evaluate the efficiency of two policy rules, namely exchange rate (ER) and inflation targeting (IT) rules. The choice of these rules is important in the case of a Dutch disease. Indeed, since the Dutch disease occurs under the spending and the resource movement effects, each monetary policy could play a central role to avoid this effect. Theoretically, in the case of an ER rule, the exchange rate will be fixed, which will lead to lock the spending effect channel. Similarly for the IT rule, the inflation rate will be stabilized. Knowing that wages are indexed to a price index, this rule will prevent the resource movement effect. Thus, it would be interesting to verify if, empirically, these rules could prevent the Dutch disease.

Our results suggest that in Algeria and Saudi Arabia, inflation targeting offers better performances. We observe the opposite in Gabon, Kuwait, Oman, and Venezuela. Such results are consistent with economic theory. Indeed, we see that in more open economies and smaller countries (in terms of economic size), the exchange rate rule is preferable to inflation rule. Venezuela seems an exception. Such country does not fulfill the traditional criteria favoring the choice of the exchange rule. In fact, this exception is only apparent. First, if we consider the volatility, we see that Venezuela is among the most volatile economy. Second, Venezuela suffers from a fiscal dominance effect: both inflation rate and fiscal deficit are the highest relative to other studied countries.

[7]We stress that the estimation of the DSGE models using a sample of countries is not a common practice because of the difficulties essentially related to the data availability for the emerging economies.

Chapter 1

Monetary Policy and the Dutch Disease in an Oil Exporting Economy

Introduction

The Dutch Disease theory was developed after the Netherlands found large sources of natural gas in the North Sea in the 1960's. Large capital inflows, from increased export revenues caused, demand for the Dutch florin to rise, which, in turn, led to an appreciation of the Dutch exchange rate. This appreciation made it difficult for the manufacturing sector to compete in international markets.

This theory has been the subject of abundant theoretical literature since the beginning of the 80's. It has been developed in a partial equilibrium framework and can be presented in two forms: the spending effect and the resource movement effect. Both effects lead to a decline of the manufacturing sector. This decline occurs because of the fall of output in this sector. Indeed, if the oil supply is inelastic, a rise of oil price leads to an increase of the demand of labor and capital in the oil sector and increases wages and capital return in this sector. If the production factors are mobile, capital and labor will move from the manufacturing sector to the oil and services sectors which will cause de-industrialization.

In their original work, Corden and Neary (1982) present the spending effect as the consequence of exchange rate appreciation on manufacturing sector production. According to these authors, the appreciation is due to an increase in the relative price stemming from increased demand in the service sector. Indeed, when manufacturing output falls, its price does not change because it is determined on the international market and the economy is considered as small. Demand for services will, therefore, increase along with its price. This leads to a rise in the price of non-tradables relative to tradables and to a real appreciation.

Regarding the resource movement effect, Corden and Neary (1982) explain that it is a consequence of perfect mobility of capital and labor from the manufacturing sector to the oil and services sectors. The resource movement effect occurs because an increase in oil prices generates a rise in wages and/or profits and generates a rise in aggregate demand in the economy. To the extent that a part of this demand will move toward the service sector, the price of non-tradable goods will rise. Consequently, the real exchange rate appreciates and generates a de-industrialization for the reasons explained above. Two types of external shocks generate these effects: windfall and boom. Although they are both positive external shocks, a windfall shock (a rise of price of natural resource) does not incur costs while a boom shock (an increase in the stock of oil resources) does incur costs[1].

Recent studies like Sosunov and Zamulin (2007), Lartey (2008), Batt et al (2008), Acosta et al (2009) and Lama and Medina (2010) have used DSGE models to assess the impact of a positive external shock in the case of a small open economy[2]. These articles discuss the impact of a positive external shock as an increase of capital inflow (Lartey (2008)), remittances (Acosta et al (2009)) or of commodity prices (Sosunov and Zamlin (2007), Batt et al (2008) and Lama and Medina (2010)). These shocks are defined in the literature of the Dutch disease as windfall shocks. A boom shock which requires costs has not been studied. Indeed, none of these papers is directly concerned with the effect of boom shocks and even less by a comparison between both sources of Dutch disease. In addition, none of them assesses the role of monetary policy in each

[1] The search for new resource and its extraction requires costs while the rise of price of oil not.

[2] Table 5 summarizes these papers focusing on the structure of models as well as the main assumptions and results.

case. Finally, none of these models directly analyze oil-exporting economies, which are the most vulnerable to this type of shocks.

In this context, we build a small open oil-exporting economy model with four sectors while the above-mentioned contributions build DSGE models with only tradable and non-tradable sectors. In this paper we add an oil sector to better reflect the mechanisms of the Dutch disease described in the literature by Corden and Neary (1982). The latter assume that the economy is composed of three sectors: i) the booming sector: after the discovery of a new resource or a technological progress in the commodity sector or a rise of natural resource price; ii) the lagging sector: generally refers to the manufacturing sector but can also refer to agriculture; iii) the non-tradable sector: includes services, utilities, transportation, etc.

To investigate the impact of the two main sources of Dutch Disease namely the windfall sector (an increase in oil prices) and the boom sector (an increase of oil resource) in a general equilibrium framework, we develop a Multisecor Dynamic Stochastic General equilibrium (MDSGE) model with microeconomic foundations and price and wage rigidities. The model is based on recent studies that have developed models for small open economies (Dib (2008), Bouakez, Rebei and Vencatachellum (2008), Acosta, Lartey and Mandelman (2009) and Lama and Medina (2010)). Drawing on these papers, we assume that the economy is inhabited by households, oil producing firms, non-tradable and tradable good producers, intermediate foreign goods importers, a central bank and a government. We also assume, as in Bouakez et al (2008), that the domestic oil price is given by a convex combination of the current world price expressed in local currency and the last period's domestic price. We adopt, finally, a Taylor-type monetary policy rule where it is assumed that the monetary authority adjusts the short-term nominal interest rate in response to fluctuations in CPI inflation and exchange rate.

The main finding is that the Dutch disease under both spending and resource movement effects occurs in the case of: flexible prices and wages and flexible wages and sticky prices, when exchange rate is fixed. In other cases, the simulations indicate that Dutch disease effects do not arise when prices are sticky, wages and the exchange rate are flexible; prices and wages are sticky whatever the objective of the central bank is. We

also compare the source of fluctuations that leads to a Dutch disease and we conclude that the windfall leads to a stronger de-industrialization compared to a boom.

In this essay, it appears that the flexible exchange rate seems to be the best way to avoid the Dutch disease both in the cases of a windfall and a boom, but also to improve welfare compared to fixed exchange rate. In other words, it is preferable for a central bank, in an oil exporting economy, to adopt inflation targeting regime to prevent the impact of oil shocks.

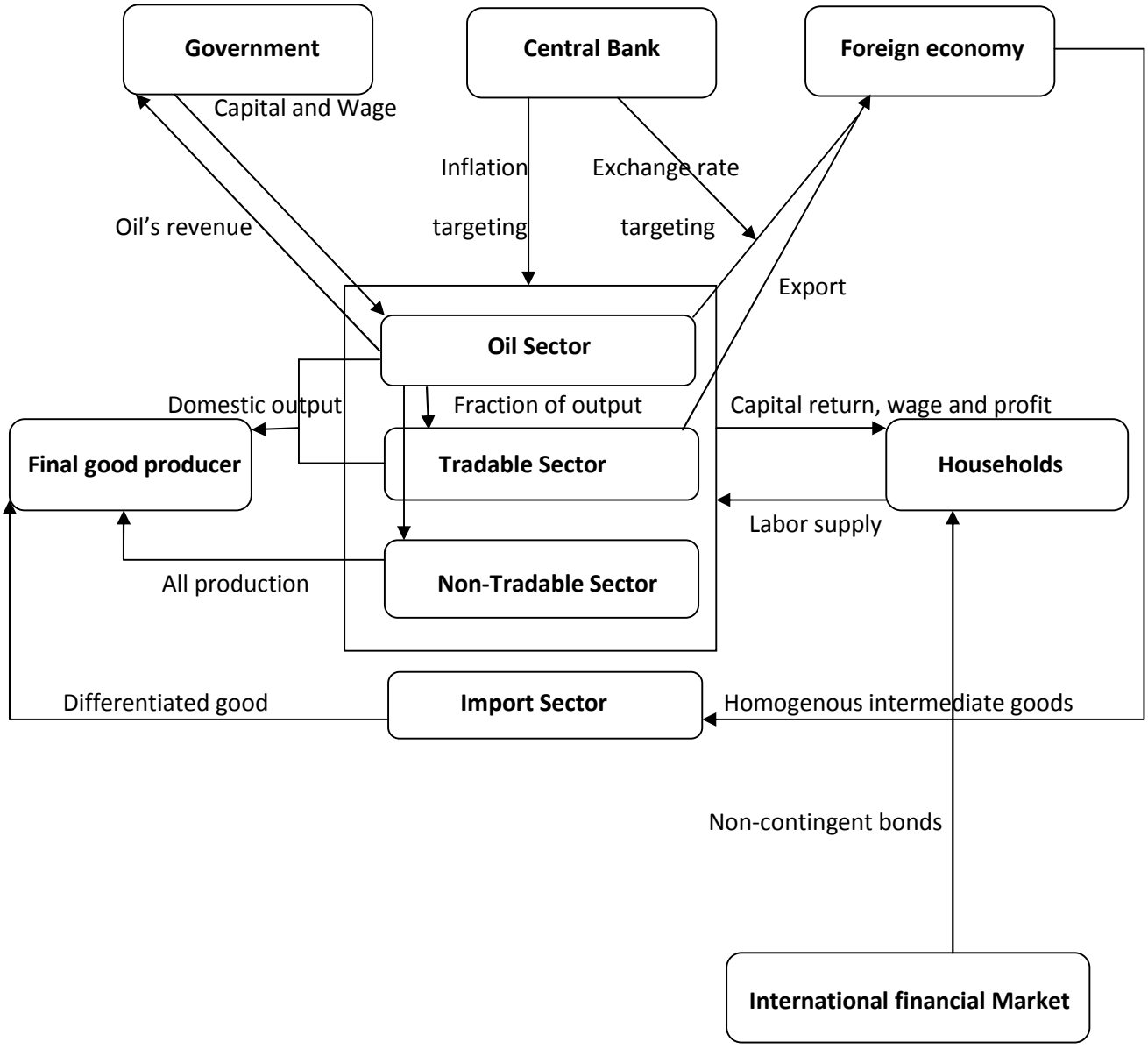
The rest of the chapter is organized as follows. In Section 2, we present the details of the model. Section 3 discusses the parameters calibration. Section 4 presents the results. Section 5 measures the welfare effect of both windfall and boom under alternative monetary policy rules. Section 6 concludes.

1.1 Small open oil exporting economy model

In this section, we model an oil exporting economy based on recent small open economy models (Dib (2008), Acosta, Lartey and Mandelman (2009) and Lama and Medina (2010)). We assume that the economy is inhabited by eight agents: households, oil producing firm, non-tradable and tradable goods producers, an intermediate foreign goods importer, a final good producer, a central bank and a government.

Households have access to international financial markets where they can buy or sell foreign non-state contingent bonds. They can also revise their nominal wages à la Calvo (1983) and Yun (1996). In both oil, tradable and final good sectors, each producer operates under perfect competition, while in the non-tradable good and imports sectors, there is a continuum of monopolistically-competitive firms. In these sectors, prices are sticky à la Calvo (1983) and Yun (1996). The central bank follows a Taylor-type rule, aimed at stabilizing the CPI inflation rate and changes in the nominal exchange rate.

Figure A : Flow chart for the economy



1.1.1 Households

To model the household's behavior, we assume that the economy contains a continuum of households indexed by $\iota \in (0,1)$. Each of them supplies differenciated labor services to the three production sectors, namely oil, tradable and non-tradable sectors. As in Erceg, Henderson and Levin (2000), a representative labor aggregator (or "employment agency") combines households' hours in the same proportions as firms would choose optimally. Thus, in each sector j, the demand curve for each type of labor is given by :

$$h_{j,t}(\iota) = \left(\frac{W_{j,t}(\iota)}{W_{j,t}}\right)^{-\theta} h_{j,t}. \tag{1.1}$$

with $j = [o, T, nT]$.
variables $h_{o,t}, h_{T,t}$ and $h_{nT,t}$ denote aggregate labor supplies to oil, tradable and non-tradable sectors, respectively. $\theta > 1$ denotes the constant elasticity of substitution between different types of labor services, $W_{j,t}(\iota)$ is the wage rate set by the household ι and $W_{o,t}, W_{T,t}$ and $W_{nT,t}$ are the aggregate wage index, or the unit cost of sales to the oil, tradable and non-tradable sectors, respectively.

The aggregate wage index $W_{j,t}$ in sector j is given by:

$$W_{j,t} = \left(\int_0^1 W_{j,t}(\iota)^{1-\theta} d\iota\right)^{\frac{1}{1-\theta}} \tag{1.2}$$

from (1.1) and (1.2), we consider $W_{j,t}$ and $h_{j,t}$ as given.

Each household ι derives utility from consumption $c_t(\iota)$ and disutility from labor $h_t(\iota)$:

$$U_0(\iota) = E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t(\iota), h_t(\iota)\right), \tag{1.3}$$

where β is the subjective discount factor ($0 < \beta < 1$), E_0 is the conditional expectation operator evaluated at time 0. The intantaneous utility function, $u(.)$, is:

$$u(.) = \frac{1}{1-\gamma} c_t(\iota)^{1-\gamma} - \frac{h_t(\iota)^{1+\sigma}}{1+\sigma}, \tag{1.4}$$

where the preference parameters are $\gamma > 1$ and $\sigma > 0$. The first parameter, γ, is the inverse of the elasticity of intertemporal substitution of consumption and the second parameter, σ, denotes the inverse of Frish labor supply elasticity. Aggregate labor supply, $h_t(\iota)$,depends on sector-specific labor supplies according to:

$$h_t(\iota) = h_{o,t}(\iota)^{\alpha_{ho}} h_{T,t}(\iota)^{\alpha_{hT}} h_{nT,t}(\iota)^{\alpha_{hnT}}, \tag{1.5}$$

where $h_{o,t}(\iota), h_{T,t}(\iota)$ and $h_{nT,t}(\iota)$ represent hours worked by the household ι at time t in oil, tradable and non-tradable sectors, respectively. The parameters α_{ho}, α_{hT} and α_{hnT} denote the elasticity of substitution of labor in the three sectors, where $\alpha_{ho} + \alpha_{hT} + \alpha_{hnT} = 1$.

Households have access to domestic and international financial markets. Each household enters period t with holdings of domestic bonds denominated in units of domestic currency, $B^d_{t-1}(\iota)$, and foreign bonds denominated in units of foreign currency, $B^f_{t-1}(\iota)$. These bonds are not state contingent. This assumption is crucial. In oil exporting economies, household's consumption is not smooth and there is no international risk sharing. Also, since the dynamics of exchange rate and the current account play a central role in explaning the spending effect, the assumption of incomplete international financial markets is necessary.[3][4]

During period t, household ι pays a lump-sum tax, $\Gamma_t(\iota)$, to finance government spendings, and sells or buys $B^f_t(\iota)$ for the price that depends on a country-specific risk-premium and the world interest rate. Buying foreign bonds entails paying a risk premium, κ_t, of which the functional form is borrowed from Dib (2008):

$$\kappa_t = \exp\left(-\phi \frac{e_t \widetilde{B^f_t} / P^f_t}{P_t Y_t}\right), \tag{1.6}$$

[3] In fact, one important implication of the incomplete markets framework is that it allows us to characterize the dynamics of the current account. See, among others, Chari, Kehoe and MacGrattan (2002), Benigno (2004) and Begnino and Theonissen (2006).

[4] See Kollmann (1996), Schmitt-Grohé and Uribe (2003) and Corsetti and Pesenti (2005) for more details about the implications of complete and incomplete international financial markets.

where ϕ measures the risk premium, e_t denotes the nominal exchange rate defined as the price of the foreign currency expressed in the domestic currency, $\widetilde{B_t^f}$ is the average stock of external nominal debt, which is positive if the domestic economy is a net borrower or negative if the domestic economy is a net lender. Finally, Y_t is the total real GDP and P_t^f is the foreign price index. This functional form ensures stationarity of the model.[5]

Household ι in period t earns nominal wages, $W_{o,t}(\iota), W_{T,t}(\iota)$ and $W_{nT,t}(\iota)$ for its labor supply, respectively to the oil, tradable and non-tradable good producers. It also receives dividend payments from both non-tradable, $D_{nT,t}(\iota)$, and import, $D_{I,t}(\iota)$, sectors so that $D_t(\iota) = D_{nT,t}(\iota) + D_{I,t}(\iota)$ and a factor payment of oil resources, $\varpi(\iota) P_{O,t} O_t$, where $P_{O,t}$ is the nominal price of oil resource input O_t and $\varpi(\iota)$ is the share of household ι in oil resource payments with $\int_0^1 \varpi(\iota)\, d\iota = 1$.

Finally, household ι accumulates $k_{o,t}(\iota), k_{T,t}(\iota)$ and $k_{nT,t}(\iota)$ units of capital stocks, used in the oil, tradable and non-tradable sectors and receives nominal rentals $Q_{o,t}, Q_{T,t}$ and $Q_{nT,t}$ respectively. The evolution of capital stock in each sector is given by:

$$k_{j,t+1}(\iota) = (1-\delta) k_{j,t}(\iota) + i_{j,t}(\iota) - \Psi_j\left(k_{j,t+1}(\iota), k_{j,t}(\iota)\right), \tag{1.7}$$

where δ is depreciation rate, common to all sectors $(0 < \delta < 1)$ and $\Psi_{j,t}(k_{j,t+1}(\iota), k_{j,t}(\iota))$ is an adjustment cost paid by households and satisfies $\psi_j(0) = 0, \psi_j'(.) > 0$ and $\psi_j''(.) < 0$. The functional form of $\Psi_j(.)$ is taken from Ireland (2003):

$$\Psi_{j,t}(.) = \frac{\psi_j}{2}\left(\frac{k_{j,t+1}(\iota)}{k_{j,t}(\iota)} - 1\right)^2 k_{j,t}(\iota). \tag{1.8}$$

The presence of the capital adjustment cost implies that, out of the steady state, the price of newly installed capital differs from the price of investment goods, i.e. Tobin's Q differs from 1. This form also allows to have both total and marginal costs of adjusting capital equal to zero in the steady state.

[5] See Schmitt-Grohé and Uribe (2003) for alternative ways of ensuring stationary paths in a small open economy.

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

$$P_t\left(c_t\left(\iota\right)+i_t\left(\iota\right)\right)+\frac{B_t^d\left(\iota\right)}{R_t}+\frac{e_tB_t^f\left(\iota\right)}{R_t^f\kappa_t}\preceq B_{t-1}^d\left(\iota\right)+e_tB_{t-1}^f\left(\iota\right)+$$
$$\sum_{j=o,T,nT}Q_{j,t}k_{j,t}\left(\iota\right)+\sum_{j=o,T,nT}W_{j,t}h_{j,t}\left(\iota\right)\ +\varpi\left(\iota\right)P_{O,t}O_t+D_t\left(\iota\right)-\Gamma_t\left(\iota\right), \tag{1.9}$$

where $P_ti_t\left(\iota\right)=P_{o,t}i_{o,t}\left(\iota\right)+P_{_{T,t}}i_{T,t}\left(\iota\right)+P_{nT,t}i_{nT,t}\left(\iota\right)$ denotes total investment. P_t is the consumption price index (CPI), defined below.

1.1.1.1 Consumption decision

Given initial values, household ι chooses $\{\mathrm{c}_t\left(\iota\right),\ \mathrm{k}_{o,t+1}\left(\iota\right),\ \mathrm{k}_{T,t+1}\left(\iota\right),\ \mathrm{k}_{nT,t+1}\left(\iota\right),\ \mathrm{B}_t^d\left(\iota\right)$ and $\mathrm{B}_t^f\left(\iota\right)\}$ to maximize equation (1.4) subject to equations (1.7), (1.8) and (1.9) and the no-Ponzi game restriction.
First-order conditions of the household problem are:

$$\lambda_t\left(\iota\right)=c_t^{-\gamma}\left(\iota\right), \tag{1.10}$$

$$\lambda_t\left(\iota\right)=\frac{\beta E_t\left[\lambda_{t+1}\left(\iota\right)\left(\psi_j\left(\frac{k_{j,t+2}(\iota)}{k_{j,t+1}(\iota)}-1\right)\frac{k_{j,t+2}(\iota)}{k_{j,t+1}(\iota)}-\frac{\psi_j}{2}\left(\frac{k_{j,t+2}(\iota)}{k_{j,t+1}(\iota)}-1\right)^2+q_{j,t+1}+1-\delta\right)\right]}{\psi_j\left(\frac{k_{j,t+1}(\iota)}{k_{j,t(\iota)}}-1\right)+1}, \tag{1.11}$$

for $j=(o,T,nT)$

$$\lambda_t\left(\iota\right)=\beta E_t\left(\frac{\lambda_{t+1}\left(\iota\right)}{\pi_{t+1}}\right)R_t, \tag{1.12}$$

$$\frac{\lambda_t\left(\iota\right)s_t}{R_t^f\kappa_t}=\beta E_t\left(\frac{\lambda_{t+1}\left(\iota\right)s_{t+1}}{\pi_{t+1}^f}\right), \tag{1.13}$$

where $q_{j,t}=\frac{Q_{j,t}}{P_t}$, $\pi_{t+1}=\frac{P_{t+1}}{P_t}$, $\pi_{t+1}^f=\frac{P_{t+1}^f}{P_t^f}$ and $s_t=\frac{e_tP_t^f}{P_t}$ represent the real capital return in each sector, the CPI inflation rate, the foreign inflation rate and the real exchange rate, respectively. In addition, $\lambda_t\left(\iota\right)$ denotes the budget multiplier associated with the budget constraint. Equation (1.11) corresponds to the optimal distribution of capital

between the three production sectors. By combining equations (1.12) and (1.13) we obtain equation (1.14) which represents a modified uncovered interest rate parity (UIP) condition:

$$\frac{R_t}{R_t^f \kappa_t} = \frac{e_{t+1}}{e_t}. \tag{1.14}$$

1.1.1.2 Wage Setting:

Following Erceg *et al.* (2000) and Dib (2008), we suppose that wages are sticky *à la* Calvo (1983) and Yun (1996). In each period, the constant probability of changing the nominal wages is given by $(1-\varphi_j)$. Therefore, in average, the wage remains unchanged for $\frac{1}{1-\varphi_j}$ periods. However, if household ι is not allowed to adjust its wage, it updates it according to the following rule:

$$W_{j,t} = \overline{\pi} W_{j,t-1},$$

where $\overline{\pi} > 1$ is the long run average gross rate inflation.

For the production sectors $j = o, T, nT$, household ι chooses $W_{j,t}(\iota)$ to maximize:

$$\max_{\widetilde{W}_{j,t}(\iota)} E_t \left[\sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \left(U\left(c_{t+s}(\iota), h_{t+s}(\iota)\right) + \lambda_{t+s} \pi^s W_{j,t+s}(\iota) h_{j,t+s}(\iota) / P_{t+s} \right) \right], \tag{1.15}$$

subject to:

$$h_{j,t+s}(\iota) = \left(\frac{\pi^s W_{j,t}(\iota)}{W_{j,t+s}} \right)^{-\theta} h_{j,t+s}. \tag{1.16}$$

The first-order condition gives:

$$\widetilde{w}_{j,t}(\iota) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} \Lambda_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{-\theta s} \pi_{t+k}^{\theta}}{E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{s(1-\theta)} \pi_{t+k}^{\theta-1}}. \tag{1.17}$$

Where $\widetilde{w}_{j,t}(\iota) = \frac{\widetilde{W}_{j,t}(\iota)}{P_t}$ and $w_{j,t+s} = \frac{W_{j,t+s}}{P_{t+s}}$ denote the real optimized wage and the real wage in sector j respectively, and for each sector j, $\Lambda_{j,t} = \alpha_{j,t}\frac{h_t^{1+\sigma}}{h_{j,t}\lambda_t}$.
The aggregate real wage index in sector j evolves according to:

$$(w_{j,t})^{1-\theta} = \varphi_j \left(\pi \frac{w_{j,t-1}}{\pi_t}\right)^{1-\theta} + \left(1-\varphi_j\right)\left(\widetilde{w}_{j,t}\right)^{1-\theta} \tag{1.18}$$

where π is the long run average gross rate of inflation.
Following Schmitt-Grohé and Uribe (2007), equation (1.17) is rewritten recursively. The real optimized wage, $\widetilde{w}_{j,t}$, in the sector j, is:

$$\widetilde{w}_{j,t} = \frac{\theta}{\theta-1}\frac{x_{j,t}^1}{x_{j,t}^2}, \tag{1.19}$$

where $x_{j,t}^1$ and $x_{j,t}^2$ are two auxiliary variables:

$$x_{j,t}^1 = \lambda_t h_{j,t}\Lambda_{j,t} w_{j,t}^{\theta} + \beta\varphi_j E_t\left[\left(\frac{\pi_{t+1}}{\pi}\right)^{\theta} x_{j,t+1}^1\right]. \tag{1.20}$$

and

$$x_{j,t}^2 = \lambda_t h_{j,t} w_{j,t}^{\theta} + \beta\varphi_j E_t\left[\left(\frac{\pi_{t+1}}{\pi}\right)^{\theta-1} x_{j,t+1}^2\right]. \tag{1.21}$$

Finally, R_t^f and π_t^f denoting respectively the foreign interest rate and the world inflation rate, evolve exogenously according to the following AR(1) process:

$$\log(R_t^f) = (1-\rho_{R^f})\log(R^f) + \rho_{R^f}\log(R_{t-1}^f) + \varepsilon_{R^f,t} \tag{1.22}$$

$$\log(\pi_t^f) = (1-\rho_{\pi^f})\log(\pi^f) + \rho_{\pi^f}\log(\pi_{t-1}^f) + \varepsilon_{\pi^f,t} \tag{1.23}$$

where removing the time index denotes steady state values and $\varepsilon_{R^f,t}$ and $\varepsilon_{\pi^f,t}$ are uncorrelated and normally distributed innovations with zero mean and standard deviations σ_{R^f} and σ_{π^f} respectively.

1.1.2 Oil sector

A single oil firm operates in a perfect competition market and combines capital, $k_{o,t} = \int_0^1 k_{o,t}(\iota)\, d\iota$, labor, $h_{o,t} = \int_0^1 h_{o,t}(\iota)\, d\iota$, and oil resource, O_t, to produce crude oil. Oil output is totally exported abroad for the international price $P^f_{o,t}$ denominated in the foreign currency.

The firm maximizes profits and solves the following problem:

$$\max_{k_{o,t},h_{o,t},O_t} \left[e_t P^f_{o,t} Y_{o,t} - Q_{o,t} k_{o,t} - W_{o,t} h_{o,t} - P_{O,t} O_t \right], \tag{1.24}$$

where $e_t P^f_{o,t} Y_{o,t}$ denotes total sale revenues in terms of domestic currency, subject to the following production function:

$$Y_{o,t} \preceq k^{\alpha_o}_{o,t} h^{\beta_o}_{o,t} O^{\theta_o}_t, \tag{1.25}$$

where α_o, β_o and $\theta_o \in (0,1)$ and $\alpha_o + \beta_o + \theta_o = 1$. Thus, given $e_t, P^f_{o,t}, P_{o,t}, Q_{o,t}, W_{o,t}$ and $P_{O,t}$, the oil producing firm chooses $\{k_{o,t}, h_{o,t}, O_t\}$ to maximize (1.24) subject to (1.25).
First-order conditions are:

$$q_{o,t} = \alpha_o s_t p^f_{o,t} \frac{Y_{o,t}}{k_{o,t}}, \tag{1.26}$$

$$w_{o,t} = \beta_o s_t p^f_{o,t} \frac{Y_{o,t}}{h_{o,t}}, \tag{1.27}$$

$$p_{O,t} = \theta_o s_t p^f_{o,t} \frac{Y_{o,t}}{O_t}, \tag{1.28}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p_{o,t} = \frac{P_{o,t}}{P_t}$, $p^f_{o,t} = \frac{P^f_{o,t}}{P^f_t}$ and $p_{O,t} = \frac{P_{O,t}}{P_t}$ denote respectively the real capital return, the real wage, the real domestic oil price, the real international oil price and the real price of the oil resource. Equations (1.26) – (1.28) represent the demand for $k_{o,t}, h_{o,t}$ and O_t respectively.

Note that foreign oil's price, $P^f_{o,t}$, and oil resource, O_t, evolutions are given by the following stochastic processes:

$$\log(P^f_{o,t}) = (1-\rho_{P^f_o})\log(P^f_o) + \rho_{P^f_o}\log(P^f_{o,t-1}) + \varepsilon_{P^f_o,t}, \tag{1.29}$$

$$\log(O_t) = (1-\rho_O)\log(O) + \rho_O\log(O_{t-1}) + \varepsilon_{O,t}, \tag{1.30}$$

where P^f_o and O are steady state values of $P^f_{o,t}$ and O_t, $\rho_{P^f_o}$ and ρ_O are the auto-correlation coefficients, and $\varepsilon_{P^f_o,t}$ and $\varepsilon_{O,t}$ are uncorrelated and normally distributed innovations with zero mean and standard deviations $\sigma_{P^f_o}$ and σ_O respectively.

1.1.3 Tradable sector

In this sector, the tradable good is a manufatured good. Again, tradable good producer operates on perfect competition markets. The firm produces its tradable good using capital, $k_{T,t}$, labor, $h_{T,t}$, and refined oil input[6], $Y^{I_T}_{o,t}$. Their production function is given by:

$$Y_{T,t} \preceq k^{\alpha_T}_{T,t} h^{\beta_T}_{T,t} Y^{I_T^{\theta_T}}_{o,t}, \tag{1.31}$$

where α_T, β_T and $\theta_T \in (0,1)$ and $\alpha_T + \beta_T + \theta_T = 1$.
Thus, given $e_t, P_{T,t}, P_{o,t}, Q_{T,t}$,and $W_{T,t}$, the tradable firm chooses $\{\mathrm{k}_{T,t}$,$\mathrm{h}_{T,t}$ and $\mathrm{Y}^{I_T}_{o,t}\}$ to solve its maximization problem. The first order conditions are:

$$q_{T,t} = \alpha_T s_t p_{T,t} \frac{Y_{T,t}}{k_{T,t}}, \tag{1.32}$$

$$w_{T,t} = \beta_T s_t p_{T,t} \frac{Y_{T,t}}{h_{T,t}}, \tag{1.33}$$

$$p_{o,t} = \theta_T s_t p_{T,t} \frac{Y_{T,t}}{Y^{I_T}_{o,t}}, \tag{1.34}$$

where $q_{T,t} = \frac{Q_{T,t}}{P_t}, w_{T,t} = \frac{W_{T,t}}{P_t}, p_{T,t} = \frac{P_{T,t}}{P^f_t}, s_t = e_t \frac{P^f_t}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real tradable price, the real exchange rate and the real domestic oil.
The price of tradable goods $p_{T,t}$, is given by $(1.32) - (1.34)$ and (1.31) :

[6] See section 5 for more details about refined oil.

$$s_t p_{T,t} = \frac{q_{T,t}^{\alpha_T} w_{T,t}^{\beta_T} p_{o,t}^{\theta_T}}{\alpha_T^{\alpha_T} \beta_T^{\beta_T} \theta_T^{\theta_T}}. \tag{1.35}$$

1.1.4 Non-tradable sector

In this sector, non-tradable good producers operate under monopolistic competition. There is a continuum of firms indexed by $i \in (0,1)$. Each firm i produces non-tradable goods using the following production function:

$$Y_{nT,t}(i) \preceq k_{nT,t}^{\alpha_{nT}}(i)\, h_{nT,t}^{\beta_{nT}}(i)\, Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i), \tag{1.36}$$

where $k_{nT,t}(i), h_{nT,t}(i)$ and $Y_{o,t}^{I_{nT}}(i)$ are used by firms to produce the non-tradable goods. Note also that α_{nT}, β_{nT} and $\theta_{nT} \in (0,1)$ and $\alpha_{nT} + \beta_{nT} + \theta_{nT} = 1$.

To maximize its profit, the producer i chooses $\left\{K_{nT,t}(i), h_{nT,t}(i) \text{ and } Y_{o,t}^{I_{nT}}(i)\right\}$ and sets its price, $\widetilde{P}_{nT,t}(i)$ à la Calvo (1983) and Yun (1996). Following a stochastic time dependent Calvo (1983) rule, the producer faces, in each period, a constant probability of changing its price. This probability is given by $(1-\phi_{nT})$ .Therefore, on average, the non-tradable price remains unchanged for $\frac{1}{1-\phi_{nT}}$ periods. As in Yun (1996), if non-tradable good producers are not able to change their price, they index them to the steady state CPI inflation rate.

The non-tradable firms' maximization problem can be written as follow:

$$\max_{k_{nT,t}(i), h_{nT,t}(i), P_{nT,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta\phi_{nT})^s \lambda_{t+s} D_{nT,t+s}(i)/P_{t+s}], \tag{1.37}$$

subject to (1.36) and the following demand function:

$$Y_{nT,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta} Y_{nT,t+s}, \tag{1.38}$$

with $D_{nT,t+s}(i)$ the profit function:

$$D_{nT,t+s}(i) = \pi^s \widetilde{P}_{nT,t}(i)\, Y_{nT,t+s}(i) - Q_{nT,t+s} k_{nT,t+s}(i) - W_{nT,t+s} h_{nT,t+s}(i) - P_{o,t} Y_{o,t}^{I_{nT}}(i),$$

where $\beta^s \lambda_{t+s}$ is the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$.

The first-order conditions of the maximization problem are:

$$q_{nT,t} = \alpha_{nT} \frac{Y_{nT,t}(i)}{k_{nT,t}(i)} mc_{nT,t}, \tag{1.39}$$

$$w_{nT,t} = \beta_{nT} \frac{Y_{nT,t}(i)}{h_{nT,t}(i)} mc_{nT,t}, \tag{1.40}$$

$$p_{o,t} = \theta_{nT} \frac{Y_{nT,t}(i)}{Y_{o,t}^{I_{nT}}(i)} mc_{nT,t}, \tag{1.41}$$

where $q_{nT,t} = \frac{Q_{nT,t}}{P_t}, w_{nT,t} = \frac{W_{nT,t}}{P_t}, mc_{nT,t} = \frac{MC_{nT,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real marginal cost and the real domestic oil price. We obtain the real marginal cost, $mc_{nT,t}$, by replacing $(1.39) - (1.41)$ in (1.36) :

$$mc_{nT,t} = \frac{q_{nT,t}^{\alpha_{nT}} w_{nT,t}^{\beta_{nT}} p_{o,t}^{\theta_{nT}}}{\alpha_{nT}^{\alpha_{nT}} \beta_{nT}^{\beta_{nT}} \theta_{nT}^{\theta_{nT}}}. \tag{1.42}$$

The optimal pricing condition is given by the maximization of (1.37):

$$\widetilde{p}_{nT,t}(i) = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta \phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} mc_{nT,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta \phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{1.43}$$

where $p_{nT,t+s} = \frac{P_{nT,t+s}}{P_{t+s}}, mc_{nT,t+s} = \frac{MC_{nT,t+s}}{P_{t+s}}, \widetilde{p}_{nT,t}(i) = \frac{\widetilde{P}_{nT,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ denote respectively the relative price of non-tradable goods, the real marginal cost in the non-tradable sector, the real optimized price for non-tradable goods and the CPI inflation rate.

We rewrite the optimal pricing condition as follows:

$$\widetilde{p}_{nT,t} = \frac{\vartheta}{\vartheta - 1} \frac{V_{nT,t}^1}{V_{nT,t}^2}, \tag{1.44}$$

where $V^1_{nT,t}$ and $V^2_{nT,t}$ are two auxiliary variables:

$$V^1_{nT,t} = \lambda_t Y_{nT,t} mc_{nT,t} p^{\theta}_{nT,t} + \beta \phi_{nT} E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta} V^1_{nT,t+1} \right], \tag{1.45}$$

and,

$$V^2_{nT,t} = \lambda_t Y_{nT,t} p^{\theta}_{nT,t} + \beta \phi_{nT} E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta-1} V^2_{nT,t+1} \right]. \tag{1.46}$$

Note finally that the aggregate real non-tradable price index evolves according to:

$$(p_{nT,t})^{1-\vartheta} = \phi_{nT} \left(\pi \frac{p_{nT,t-1}}{\pi_t} \right)^{1-\vartheta} + (1-\phi_{nT}) \left(\widetilde{p}_{nT,t} \right)^{1-\vartheta}. \tag{1.47}$$

1.1.5 Import sector

The final good producer uses an imported-composite good, $Y_{I,t}$, purchased in a domestic monopolistically competitive market. To produce $Y_{I,t}$, the firm uses differentiated goods, $Y_{I,t}(i)$, that are produced by a continuum of domestic importers, indexed by $i \in (0,1)$, using a homogeneous intermediate good produced abroad for the world price P^f_t. The differentiated goods are sold at price $P_{I,t}(i)$ subject to Calvo (1983) and Yun (1996) contracts.[7] Therefore, the importer faces, in each period, a constant probability $(1-\phi_I)$ of changing its price as in Calvo (1983). Following Yun (1996), we assume that if importers are not able to change their price, they index them to the steady state CPI inflation rate.

The maximization problem of importers can be written as follows:

$$\max_{\widetilde{P}_{I,t}(i)} E_0 \sum_{s=0}^{\infty} (\beta \phi_I)^s \lambda_{t+s} \left(\pi^s \widetilde{P}_{I,t}(i) - e_{t+s} P^f_{t+s} \right) Y_{I,t+s}(i), \tag{1.48}$$

where $Y_{I,t+s}(i)$ is chosen by firms to maximize their profit:

$$Y_{I,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{I,t}(i)}{P_{I,t+s}} \right)^{-\vartheta} Y_{I,t+s}. \tag{1.49}$$

[7] Introducing price rigidities allows the deviation from the law of one price in the import sector, leading to incomplete pass-through effects of exchange rate movements.

The zero−profit condition gives the importer price index:

$$P_{I,t+s} = \left(\int_0^1 \pi^s \widetilde{P}_{I,t}\left(i\right)^{1-\vartheta} di \right)^{\frac{1}{1-\vartheta}}. \tag{1.50}$$

Replacing (1.49) in (1.48), we get the optimal pricing condition:

$$\widetilde{p}_{I,t}\left(i\right) = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} \left(\beta\phi_I\right)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} mc_{I,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} \left(\beta\phi_I\right)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{1.51}$$

where $p_{I,t+s} = \frac{P_{I,t+s}}{P_{t+s}}$ is the relative price of imports, $mc_{I,t+s} = \frac{e_t P_{t+s}^f}{P_{t+s}} = s_t$ is the real marginal cost which is equal to the real exchange rate, $\widetilde{p}_{I,t}\left(i\right) = \frac{\widetilde{P}_{I,t}(i)}{p_t}$ is the optimized price in import sector and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ is the CPI inflation rate.

The aggregate real import price index evolves according to:

$$\left(p_{I,t}\right)^{1-\vartheta} = \phi_I \left(\pi \frac{p_{I,t-1}}{\pi_t} \right)^{1-\vartheta} + \left(1 - \phi_I\right) \left(\widetilde{p}_{I,t}\right)^{1-\vartheta}, \tag{1.52}$$

The non-linear recursive form of Eq(1.51) can be written as follow:

$$\widetilde{p}_{I,t} = \frac{\vartheta}{\vartheta - 1} \frac{V_{I,t}^1}{V_{I,t}^2}, \tag{1.53}$$

where $V_{I,t}^1$ and $V_{I,t}^2$ are two auxiliary variables that take the following form:

$$V_{I,t}^1 = \lambda_t Y_{I,t} mc_{I,t} p_{I,t}^{\theta} + \beta\phi_I E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta} V_{I,t+1}^1 \right], \tag{1.54}$$

$$V_{I,t}^2 = \lambda_t Y_{I,t} p_{I,t}^{\theta} + \beta\phi_I E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta-1} V_{I,t+1}^2 \right]. \tag{1.55}$$

1.1.6 Final good producer

We assume that the producer of the final good operates under perfect competition. It uses the following CES technology that includes a fraction of tradable output, $Y_{T,t}^d$, which is domestically-used, the non-tradable output, $Y_{nT,t}$, and imports, $Y_{I,t}$:

$$z_t = \left[\chi_T^{\frac{1}{\tau}} Y_T^{d\,\frac{\tau-1}{\tau}} + \chi_{nT}^{\frac{1}{\tau}} Y_{nT}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}} Y_I^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}}, \tag{1.56}$$

where $\tau > 0$ denotes the elasticity of substitution between the fraction of tradable output, the non-tradable output and imported goods and χ_T, χ_{nT}, χ_I represent the shares of tradable, non-tradable and imported goods in the total expenditure of final good, where $\chi_T + \chi_{nT} + \chi_I = 1$. To maximize its profit, the final good producer chooses $\left\{ Y_{I,t}, Y_{T,t}^d \text{ and } Y_{nT,t} \right\}$.

The maximization problem is:

$$\max_{Y_{I,t}, Y_{T,t}^d, Y_{nT,t}} P_t z_t - P_{I,t} Y_{I,t} - P_{T,t} Y_{T,t}^d - P_{nT,t} Y_{nT,t},$$

subject to (1.56). Solving this problem, we get the following demand functions:

$$Y_{I,t} = \chi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\tau} z_t, \quad Y_{T,t}^d = \chi_T \left(\frac{P_{T,t}}{P_t} \right)^{-\tau} z_t, \quad Y_{nT,t} = \chi_{nT} \left(\frac{P_{nT,t}}{P_t} \right)^{-\tau} z_t. \tag{1.57}$$

where $P_t, P_{I,t}, P_{T,t}, P_{nT,t}$ are given. Note also that the zero profit condition implies that the price of the final good is given by:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_T P_{T,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau} \right]^{\frac{1}{1-\tau}}, \tag{1.58}$$

Finally, the final good is split between total consumption and total investment so that $z_t = c_t + i_{o,t} + i_{T,t} + i_{nT,t}$.

1.1.7 Central Bank

It is assumed that the central bank adjusts the short-term nominal interest rate, R_t, in response to fluctuation in CPI inflation, π_t, and exchange rate changes Δe_t. As in Bouakez *et al* (2008), we use the following Taylor-type policy rule to close the model:

$$\log\left(\frac{R_t}{R}\right) = \zeta_\pi \log\left(\frac{\pi_t}{\pi}\right) + \zeta_e \log\left(\frac{\Delta e_t}{\Delta e}\right). \tag{1.59}$$

where $\pi, \Delta e$, and R are the steady state values of inflation (π_t) ,exchange rate (Δe_t) and nominal interest rate (R_t) respectively. The policy coefficients, ζ_π and ζ_e, measure the central bank responses to deviation of (π_t) and (Δe_t) from their steady state levels. When $\zeta_e = 0$ and $\zeta_\pi = \infty$, the central bank responds only to inflation movements (and the exchange rate regime is floating). When $\zeta_\pi = 0$ and $\zeta_e = \infty$ the central bank manages its rate to respond only to exchange rate fluctuation (and the exchange rate regime is fixed).

1.1.8 Government

In an oil exporting economy[8], the oil domestically used (refined oil), $Y^I_{o,t}$, is mostly produced abroad. For this, we assume that the government, which is the owner of the oil firm, buys it from the world market for the international price, $P^f_{o,t}$, denominated in the foreign currency. The refined oil is sold domestically to the tradable and non-tradable firms at price $P_{o,t}$ which can be considered as the domestic fuel prices. The latter is supposed to be subsidized by the government. For this purpose, we follow Bouakez *et al.* (2008) and assume that the domestic oil price $P_{o,t}$ is a convex combination of the current world price expressed in local currency and previous period domestic price. It is given by:

$$P_{o,t} = (1-\upsilon)P_{o,t-1} + \upsilon s_t P^f_{o,t}, \tag{1.60}$$

where $\upsilon \in (0,1)$,

[8]It's the case of Algeria and other countries as Iran for example.

Thus, when $\upsilon = 1$, there is no subsidy and the pass-through from the world oil price is complete. However, when $\upsilon = 0$, the domestic oil price is fully subsidized and there is no pass-through. Thus, all domestic firms will buy oil at price $P_{o,t}$.

Following this, the government's budget constraint can be written as follow:

$$P_{o,t}Y^I_{o,t} + e_t P^f_{o,t} Y_{o,t} + \Gamma_t = e_t P^f_{o,t} Y^I_{o,t} + W_{o,t}h_{o,t} + Q_{o,t}k_{o,t} + P_{O,t}O_t, \tag{1.61}$$

where the left-hand side represents the government's revenues that include lump-sum taxes, Γ_t, and receipts from selling oil to domestic, $P_{o,t}Y^I_{o,t}$, and foreign, $e_t P^f_{o,t} Y^{ex}_{o,t}$, firms. The right-hand side represents the government spending and include payments of both wages and capital returns ($W_{o,t}h_{o,t} + Q_{o,t}k_{o,t}$) in the oil sector and the amount of imported refined oil, $e_t P^f_{o,t} Y^I_{o,t}$.

1.1.9 Aggregation and Equilibrium

In a symmetric equilibrium, all households, importers and non-tradable good producers make the same decision so that: $c_t(\iota) = c_t, h_t(\iota) = h_t, h_{o,t}(\iota) = h_{o,t}, h_{T,t}(\iota) = h_{T,t}, h_{nT,t}(\iota) = h_{nT,t}, b_t(\iota) = b_t, b^f_t(\iota) = b^f_t, k_{o,t}(\iota) = k_{o,t}, k_{T,t}(\iota) = k_{T,t}, k_{nT,t}(\iota) = k_{nT,t}, w_{o,t}(\iota) = w_{o,t}$, $w_{T,t}(\iota) = w_{T,t}, w_{nT,t}(\iota) = w_{nT,t}, D_{nT,t}(\iota) = D_{nT,t}, D_{I,t}(\iota) = D_{I,t}, i(\iota) = i, Y_{nT,t}(i) = Y_{nT,t}, Y^{I_{nT}}_{o,t}(i) = Y^{I_{nT}}_{o,t}, \widetilde{p}_{nT,t}(i) = \widetilde{p}_{nT,t}$, $Y_{I,t}(i) = Y_{I,t}, \widetilde{p}_{I,t}(i) = \widetilde{p}_{I,t}$ for all ι and $i \in (0,1)$, where $b_t = \frac{B_t}{P_t}, b^f_t = \frac{B^f_t}{P^f_t}$ are the real net domestic and foreign currency bonds respectively. Thus, a symmetric equilibrium for this economy is composed of an allocation $\{\mathrm{c}_t, \mathrm{i}_t, \mathrm{i}_{o,t}, \mathrm{i}_{T,t}, \mathrm{i}_{nT,t}, \mathrm{Y}_{o,t}, \mathrm{Y}_{nT,t}, \mathrm{Y}_{T,t}, \mathrm{Y}^I_{o,t}, \mathrm{Y}^{I_T}_{o,t}, \mathrm{Y}^{I_{nT}}_{o,t}, \mathrm{Y}^d_T, \mathrm{Y}^{ex}_T, \mathrm{Y}_{I,t}, \mathrm{Y}_t, \mathrm{Y}^{va}_{nT,t}, \mathrm{Y}^{va}_{T,t}, \mathrm{z}_t, \mathrm{k}_{o,t}, \mathrm{k}_{T,t}, \mathrm{k}_{nT,t}, \mathrm{h}_t, \mathrm{h}_{o,t}, \mathrm{h}_{T,t}, \mathrm{h}_{nT,t}, \mathrm{b}^f_t, \kappa_t, \Lambda_{o,t}, \Lambda_{T,t}, \Lambda_{nT,t}\}^{\infty}_{t=0}$ and a sequence of prices and co-state variables $\{\mathrm{w}_{o,t}, \mathrm{w}_{T,t}, \mathrm{w}_{nT,t}, \widetilde{w}_{o,t}, \widetilde{w}_{T,t}, \widetilde{w}_{nT,t}, \mathrm{q}_{o,t}, \mathrm{q}_{T,t}, \mathrm{q}_{nT,t}, \mathrm{p}_{o,t}, \mathrm{p}_{T,t}, \mathrm{p}_{nT,t}, \widetilde{p}_{nT,t}, \mathrm{p}_{I,t}, \widetilde{p}_{I,t}, \mathrm{p}_{O,t}, \pi_t, \pi_{nT,t}, \pi_{I,t}, \mathrm{s}_t, \mathrm{e}_t, \mathrm{R}_t, \lambda_t, \mathrm{mc}_{nT,t}, \mathrm{mc}_{I,t}\}^{\infty}_{t=0}$ satisfying households, oil, tradable and non-tradable first-order conditions, the aggregate resources constraints, the monetary policy rules, the current account equation and the stochastic processes $\{\mathrm{p}^f_{o,t}, \mathrm{O}_t, \mathrm{R}^f_t, \mathrm{Y}^f_T, \pi^f_t\}^{\infty}_{t=0}$ of the shocks and the following market clearing conditions $b_t = b_{t-1} = 0$, $b^f_t = \widetilde{b}^f_t$ and:

$$Y^I_{o,t} = Y^{I_T}_{o,t} + Y^{I_{nT}}_{o,t} \tag{1.62}$$

$$Y_{T,t} = Y_{T,t}^{d} + Y_{T,t}^{ex} \tag{1.63}$$

Finally, the home economy exports part of its tradable output. According to McCallum and Nelson (1999) and Gertler, Gilchrist and Natalucci (2003), we assume that the foreign demand for the tradable goods, $Y_{T,t}^{ex}$, is given by :

$$Y_{T,t}^{ex} = \nu_T \left(\frac{e_t P_{T,t}}{P_t^f} \right)^{-\omega_T} Y_{T,t}^{f}. \tag{1.64}$$

where the foreign production of tradable goods, $Y_{T,t}^{f}$,is exogenous and evolves according to the following stochastic processes:

$$\log(Y_{T,t}^{f}) = (1 - \rho_{Y_T^f}) \log(Y_T^f) + \rho_{Y_T^f} \log(Y_{T,t-1}^{f}) + \varepsilon_{Y_T^f,t} \tag{1.65}$$

where $Y_T^f > 0$ is the steady-state values of $Y_{T,t}^{f}$ and $\rho_{Y_T^f}$ the autoregressive coefficients and $\varepsilon_{Y_T^f,t}$ the uncorrelated and normally distributed innovations with zero mean and standard deviation $\sigma_{Y_T^f}$.

As in McCallum and Nelson (1999), we assume that the domestic economy's exports from an insignificant franction of foreigners' consumption, and thus their weight in the foreign economy's aggregate price index is negligible.

The aggregate GDP is defined as:

$$Y_t = p_{T,t} Y_{T,t}^{va} + p_{nT,t} Y_{nT,t}^{va} + s_t p_{o,t}^{f} Y_{o,t}, \tag{1.66}$$

where $Y_{T,t}^{va}$, and $Y_{nT,t}^{va}$ are the value-added output in tradable and non-tradable sectors respectively. These variables are constructed by subtracting oil input as follows:[9]

$$Y_{T,t}^{va} = Y_{T,t} - p_{o,t} \frac{Y_{o,t}^{I_T}}{p_{T,t}}, \tag{1.67}$$

$$Y_{nT,t}^{va} = Y_{nT,t} - p_{o,t} \frac{Y_{o,t}^{I_{nT}}}{p_{nT,t}}. \tag{1.68}$$

[9] As in Dib (2008), our model suppose that tradable and non-tradable firms use refined oil as material inputs in their productions which is defined as gross output. Thus, value added output in each sector can be constructed by substracting commodity inputs.

Combining the households' budget constraint, the single period profit functions of non-tradable good producing firms and foreign good importers, the first-order conditions of the four sectors, and applying the market clearing conditions, we get the following current account equation:

$$\frac{b_t^f}{\kappa_t R_t^f} = \frac{b_{t-1}^f}{\pi_t^f} + p_{T,t} Y_{T,t}^{ex} + p_{o,t}^f Y_{o,t} - p_{o,t}^f Y_{o,t}^I - Y_{I,t}. \tag{1.69}$$

1.2 Calibration

The aim of this section is to assign values to the structural parameters of the model. The calibration exercise consists usually to either borrow the parameters from the literature on the economies of similar structure, or estimates them from time-series data for a specific economy, or, as in many studies, a mix of both. Our parameters values are taken, mostly, from the literature of DSGE models, and adapt them to characterize an oil exporting economy[10]. We also set the coefficients of correlation and standard deviation of the stochastic processes using OLS estimation.

There are 36 structural parameters in the model $\{\beta, \sigma, \gamma, \alpha_{h_o}, \alpha_{h_T}, \alpha_{h_{nT}}, \psi_o, \psi_T, \psi_{nT}, \theta, \phi, \delta, \upsilon, \alpha_o, \beta_o, \theta_o, \alpha_T, \beta_T, \theta_T, \alpha_{nT}, \beta_{nT}, \theta_{nT}, \vartheta, \phi_{nT}, \phi_I, \varphi_o, \varphi_T, \varphi_{nT}, \chi_T, \chi_{nT}, \chi_I, \tau, \nu_T, \omega_T, \zeta_\pi, \zeta_e\}$. The subjective discount factor, β, is set at 0.99 which implies an annual steady-state real interest rate of 4%. As in Bouakez *et al* (2008), Dib (2008) and Lartey (2008) the inverse of the elasticity of the intertemporal substitution of consumption γ is set at 2. Following Devereux et *al* (2006) among others, the inverse of the elasticity of the intertemporal substitution of labor σ is set at 1. The capital depreciation rate δ is set at 0.025. This value is common to the three sectors of production (oil, tradable and non-tradable sectors).

The parameters $(\alpha_o, \beta_o, \theta_o)$,$(\alpha_T, \beta_T, \theta_T)$, and $(\alpha_{nT}, \beta_{nT}, \theta_{nT})$, which are associated with the shares of capital, labor and a fraction of oil output in the output of each sector, are calibrated as in Macklem et al. (2000). We set the share of capital, α_o, labor, β_o, and oil resources, θ_o, in the production of oil to 0.41, 0.39 and 0.2 respectively. In

[10] We calibrate the model to match some features of oil exporting economies. Of these, Canadian and Algerian economies will be used to calibrate some parameters.

Table 1.1: Calibration of structural parameters.

Description	Parameters	Values
Structural Parameters		
Subject discount factor	β	0.99
Labor elasticity of substitution	ϑ	8
Intermediate good elasticity of substitution	θ	6
The inverse of the elasticity of intertemp substi of cons	γ	2
The inverse of the Frish wage elasticity of labour supply	σ	1
Labor elasticity of substitution in the oil sector	α_{h_o}	0.32
Labor elasticity of substitution in the tradable sector	α_{h_T}	0.13
Labor elasticity of substitution in the non-tradable sector	$\alpha_{h_{nT}}$	0.55
Parameter measuring the risk premium	ϕ	0.0015
The depreciation rate of capital	δ	0.025
Share of capital in the production of oil	α_o	0.41
Share of labor in the production of oil	β_o	0.39
Share of oil resource in the production of oil	θ_o	0.2
Share of capital in the production of tradable goods	α_T	0.26
Share of labor in the production of tradable goods	β_T	0.63
Share of oil input in the production of tradable goods	θ_T	0.11
Share of capital in the production of non-tradable goods	α_{nT}	0.28
Share of labor in the production of non-tradable goods	β_{nT}	0.66
Share of oil input in the production of non-tradable goods	θ_{nT}	0.06
Oil price rule parameter	υ	0.3
Calvo wage parameter for the oil sector	φ_o	0.65
Calvo wage parameter for the tradable sector	φ_T	0.65
Calvo wage parameter for the non-tradable sector	φ_{nT}	0.65
Capital adjustment cost parameter in oil sector	ψ_o	3
Capital adjustment cost parameter in tradable sector	ψ_T	3
Capital adjustment cost parameter in non-tradable sector	ψ_{nT}	3
Calvo price parameter in the non-tradable sector	ϕ_{nT}	0.65
Calvo price parameter in the import sector	ϕ_I	0.65
Elasticity of substitution between domestic and foreign goods	τ	0.8
Share of imported goods in the final good	χ_I	0.45
Share of tradable goods in the final good	χ_T	0.2
Share of non-tradable goods in the final good	χ_{nT}	0.35
Constant associated with the share of exports in home GDP	ν_T	0.2
Elasticity of substitution between home and foreign goods	ω_T	0.8
Inflation coefficient in the monetary policy rule	ζ_π	$0, \infty$
Exchange rate coefficient in the monetary policy rule	ζ_e	$\infty, 0$
Steady-state values		
Gross steady-state of domestic inflation	π	1.0085
Gross steady-state of the foreign inflation	π^f	1.0070
Steady state domestic interest rate	R	1.0185
Steady state foreign interest rate	R^f	1.0158

the sector of tradable goods, the share of capital, α_T, labor, β_T, and a fraction of oil output, θ_T, are assigned values to 0.26, 0.63 and 0.11 respectively. We also set to 0.28, 0.66 and 0.06 the share of capital, α_{nT}, labor, β_{nT}, and a fraction of oil output, θ_{nT}, in the production of non-tradable goods.

As in Dib (2008), we set the parameters that represent the degree of monopoly power in the intermediate good market, θ, and the labor market, ϑ, equal to 6 and 8 respectively. The steady-state price and wage markup are equal to 20% and 14% respectively. The price elasticity of demand for imported, domestic tradable and non-tradable goods, τ, is set at 0.8 as in Dib (2008). The share of imports, , χ_I, domestic tradable, χ_T, and non-tradable goods, χ_{nT}, in the production of final goods are set equal to 0.45, 0.2 and 0.35 respectively. These values are chosen given that the value of the average ratio of both imports and tradable good production[11] to GDP of Algerian economy. The share of non-tradable good is chosen by subtracting to the unit the previous values. We set values of the labor elasticity of substitution to match the shares of wages in the three sectors of the Algerian economy (oil, tradable and non-tradable), so that, $\alpha_{h_o}, \alpha_{h_T}$ and $\alpha_{h_{nT}}$ are equal to 0.32, 0.13 and 0.55 respectively.[12]

As in the standard literature of DSGE models, we set the parameter of Calvo price setting equal to 0.65 . Wage stickiness in the three sectors (oil, φ_o, tradable, φ_T, and non-tradable, φ_{nT}, goods sectors) are set at the same level. We assume that this value is the same across sectors (import, ϕ_I, and non-tradable sectors, ϕ_{nT}). This means that, on average, price adjustment occurs every 2.85 quarters. As in Lartey (2008) and Devereux, Lane and Xu (2006), we set the capital adjustment cost equal to 3 in the three sectors (oil, ψ_o, tradable, ψ_T, and non-tradable, ψ_{nT}, sectors). The parameter in the risk-premium terms ϕ is set equal to 0.0015. All of these parameters are listed in Table 1.1.

Finally, Table 1.2 reports the results of different OLS estimations of the exogenous stochastic processes. All parameters are statistically significant at the 5% level. Some of these stochastic processes are highly persistent while others are not.

[11] Since the Algerian economy exports an insignificant franction of tradable goods, the average ratio of total tradable production to GDP could be assimilated by the value of the domestic use. This is the case of many oil exporting countries.

[12] These values are chosen by using ONS (national office of statistics) data.

Table 1.2: Calibration of the stochastic parameters.

Shocks	Autocorrelations	Standard deviation
Foreign interest rate	ρ_{R^f} 0.9886	σ_{R^f} 0.1693
Foreign tradable output	$\rho_{Y_T^f}$ 0.9676	$\sigma_{Y_T^f}$ 0.1578
Foreign inflation	ρ_{π^f} 0.9549	σ_{π^f} 0.1999
Foreign oil output	$\rho_{Y_o^f}$ 0.2582	$\sigma_{Y_o^f}$ 0.0104
Foreign oil price	$\rho_{p_o^f}$ 0.2317	$\sigma_{p_o^f}$ 0.1975
Oil resources shock	ρ_O 0.9899	σ_O 0.2089

1.3 Simulation analysis

In this section, we analyze the effect of an increase of one percent in the price of oil (windfall) and oil resources (boom) on this economy. We attempt to verify if this increase generates a Dutch disease effect in both resource movement and spending effects and in which case the phenomenon of de-industrialization is the most important. Thus, we try to disentangle the source of fluctuation, between the windfall and the boom, which generates a Dutch disease effect. First, we conduct simulations under the hypothesis of perfect wage and price flexibility. Then, we consider the impact of an oil shock (price and resource) assuming that prices are sticky. Finally, we add the assumption of wage rigidity. In the two last cases, we analyse the response of some key variables under alternative monetary policy rules (fixed exchange rate rule (ER rule) and inflation targeting rule (IT rule)). 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) that will provide information on the occurrence of the Dutch disease effect.

1.3.1 Flexible prices and wages setting

In the case of flexible prices, monetary policy plays no role. Simulation results are shown in the figure 1.1 and 1.2 which present the reallocation process experienced in the economy in response to an increase of one standard deviation of oil price and oil resources. Figure 1.1 shows that an increase in the international price of oil leads to a

decline in the manufacturing sector.[13] Indeed, the results show a decline in all selected variables (production, capital, investment, wage and hours worked) in the tradable good sector. This decrease is accompanied by a boom in the oil and non-tradable sectors. Indeed, the impact on other sectors is quite large. As Figure 1.1 shows, all variables, capital, investment and wage, for instance, respond positively to oil price shock. This expansion in the oil sector is the result of the decline of manufacturing industry whose wages and capital decline. Hence, labor demand is much greater in the other sector (resource movement effect).

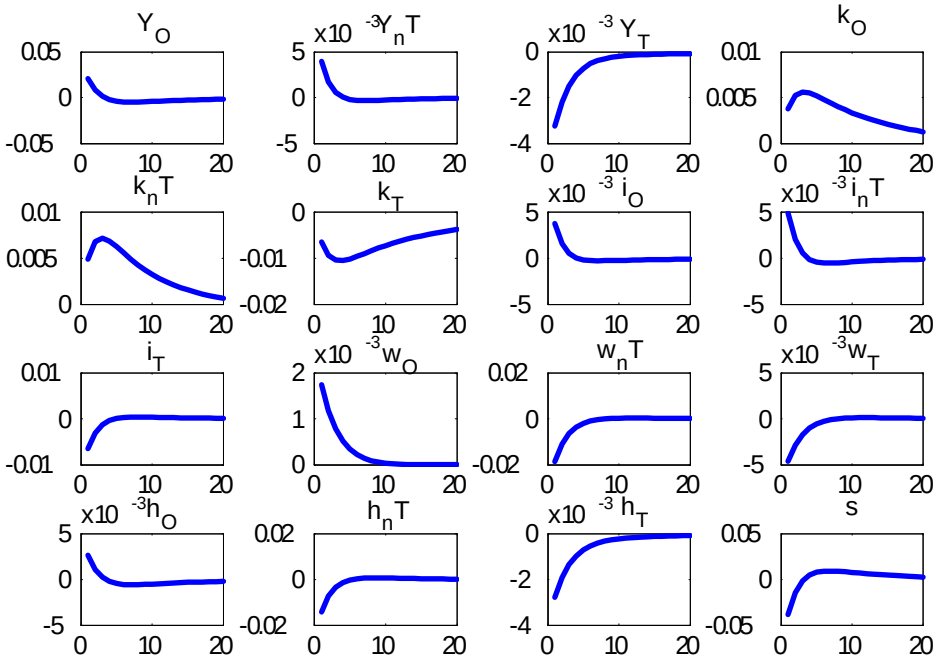


Figure 1.1: The effect of a 1% positive oil price shock (Baseline model)

Figure 1.1 also shows an appreciation of the real exchange rate after the windfall. This is due to currency inflows due to the rise in oil price. This appreciation of exchange rate seems to contribute partly to the decline of the manufacturing industry through a decline in price competitiveness of the sector and, therefore, the decline of its exports. This is similar to the spending effect.

[13] These results are similar to those of Lama and Medina (2010) and Lartey (2008).

After the boom (increase in oil resource), Figure 1.2 depicts an increase in wages, and marginal product in the oil sector which leads to an increase in labor demand and therefore a rise in the production of oil goods and a decline in the manufacturing production. This second effect is defined as the resource movement effect. On the other hand, Figure 1.2 shows an increase in the real exhange rate due to the rise of oil price. Through the spending effect, the appreciation of the exchange rate has probably contributed to the de-industrialization of the tradable goods sector.

Through these results, we can see that in both cases, windfall and boom, the economy undergoes de-industrialization because of both spending and resource movement effects.

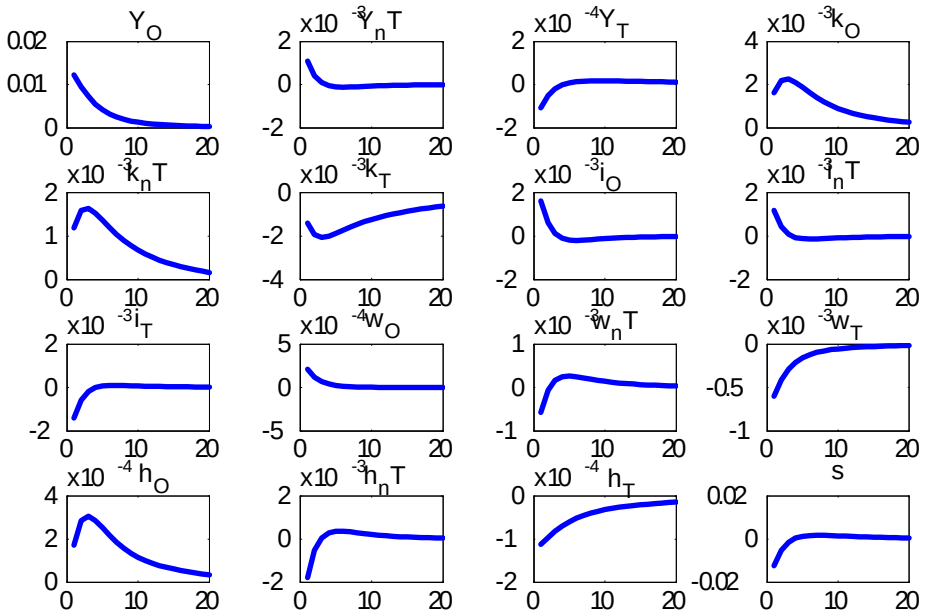


Figure 1.2: The effect of a 1% positive oil resource shock (Baseline model)

To compare the importance of de-industrialization in each case, boom and windfall, Figure 1.3 illustrates the impulse response functions of some key variables of the manufacturing sector facing an increase of one percent in oil prices and oil resources. Figure 1.3 shows that the decline in the manufacturing sector is much larger in the case of windfall (oil price shock). Indeed, key variables, such as investment, production and wage decrease more significantly in the case of a windfall than in the case of a

boom. Therefore, we conclude that, overall, Dutch disease effects are especially the consequence of a windfall rather than a boom. Thus, the question we answer is: what is the exchange rate regime that would avoid the consequences of a windfall and/or of a boom? To do so, we jointly consider price and wage rigidities.

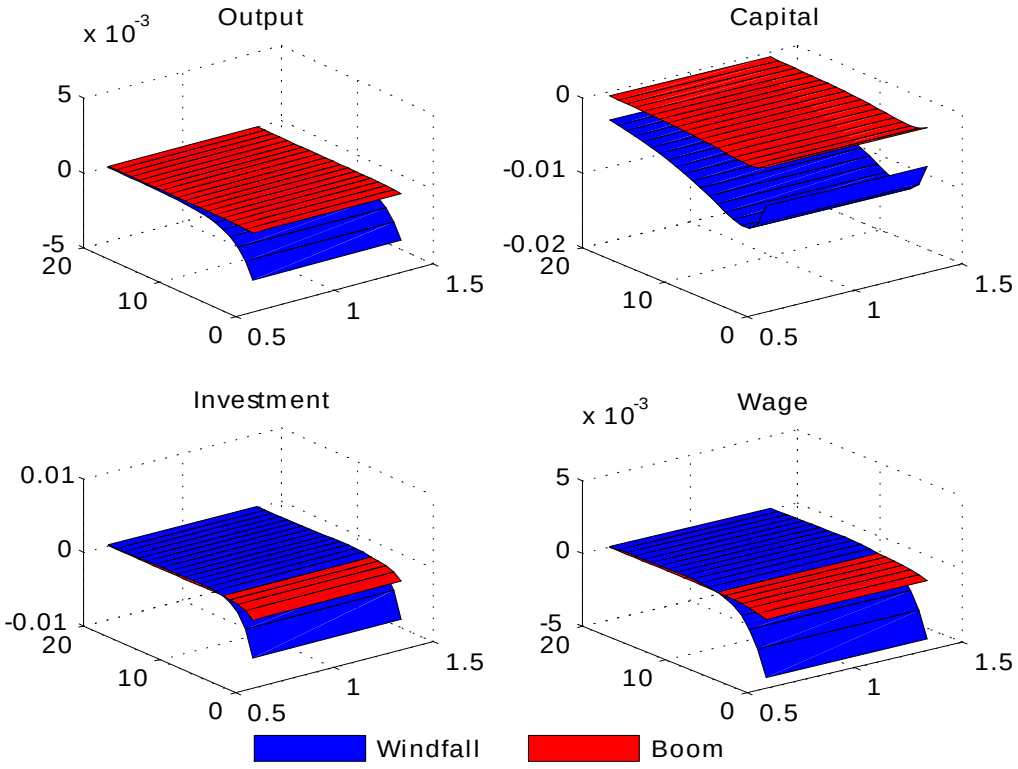


Figure 1.3: Comparison of the effect of a boom and windfall on the tradable sector

1.3.2 Sticky price model

In the case of sticky prices, the choice of the exchange rate regime plays a central role in the stabilization of the economy. We first simulate the impact of an increase in oil prices (and oil resource) in the case of a fixed exchange rate regime (ζ_e=∞), then we simulate the impact of an increase in oil prices in the case of a flexible exchange rate regime (ζ_e=0) (and oil resource).

1.3.2.1 Fixed exchange rate

As in the first case, Figure 1.4 shows a decline in the manufacturing sector compared to the other two sectors. Production of tradable goods, accumulation of capital and investment in this sector all experience a decline, comparatively to the baseline model, due to the increase in the oil price. In the two other sectors, the situation is different. This leads to an instantaneous increase in the production in the oil sector, which generates a large inflow of foreign currency. Unlike the baseline model, the windfall does not lead to an appreciation of the real exchange rate. This response can be interpreted as the result of the intervention of the central bank in the foreign exchange market to stabilize the exchange rate. Therefore, we conclude that (i) the spending effect has not occurred and (ii) the decline of the manufacturing sector only results from the resource movement effect.

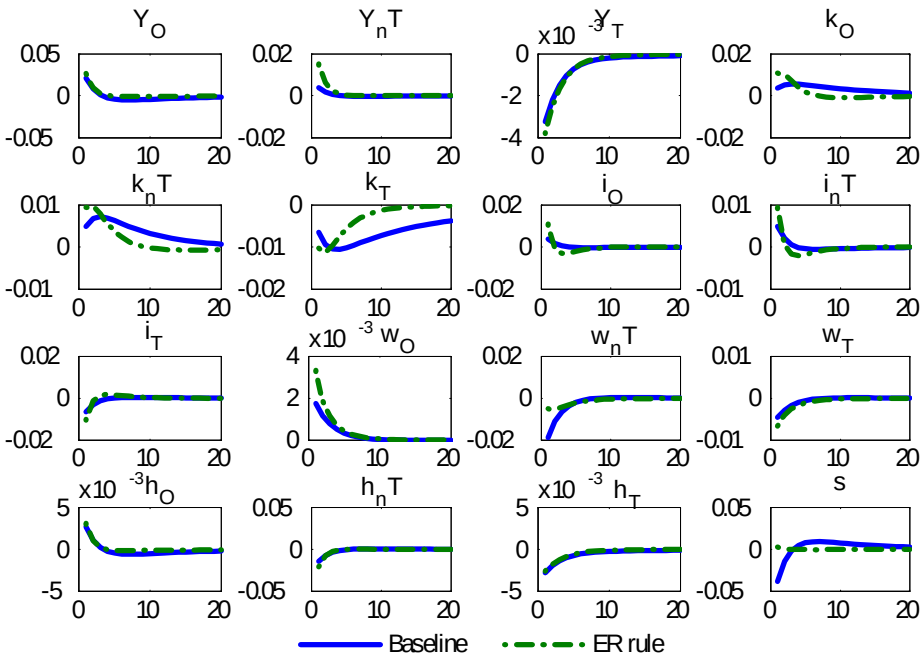


Figure 1.4: The effect of a 1% positive oil price shock (sticky price model)

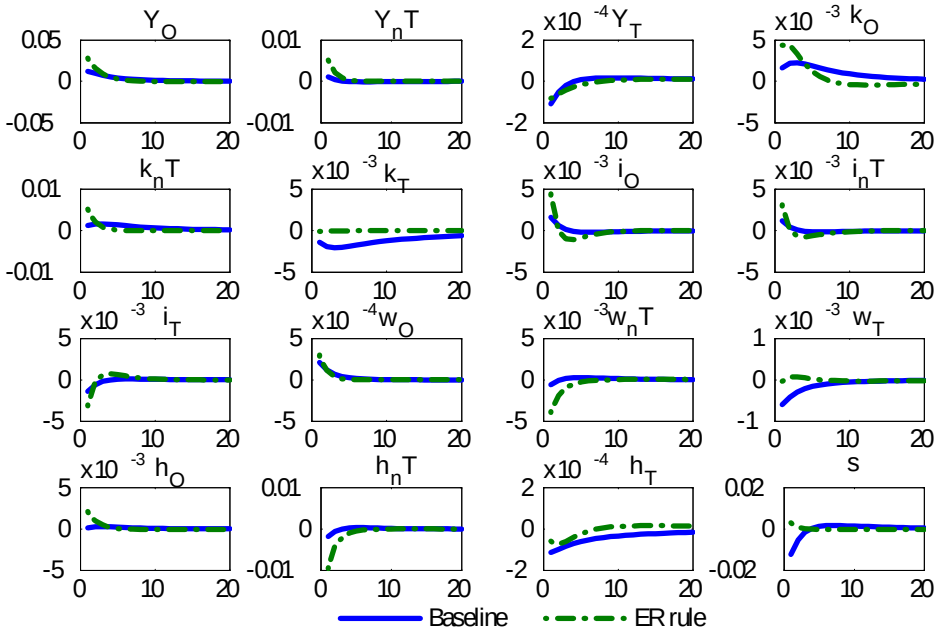


Figure 1.5: The effect of a 1% positive oil resource shock (sticky price model)

As Figure 1.4 shows, the de-industrialization of the economy seems to be the result of the labor shift from the tradable sector toward the oil sector.

Hours worked respond more after the shock in the oil sector relative to the manufacturing sector. This is due to rising wages in the oil sector that create a greater demand for labor in this sector. As a result, the production of the tradable sector declines.

In the case of a boom, Figure 1.5 also depicts a decline in the manufacturing sector due to an increase in oil resources. The oil and non-tradable sectors experience a rise in production and investment. As in the first case, the real exchange rate does not react to the shock. This is due to the fact that the appreciation is absorbed by the intervention of the monetary authority in the foreign exchange market. Therefore, the de-industrialization of the manufacturing sector can not be the result of the spending effect.

The resource movement effect is the most likely transmission channel. The increase in production in the oil sector leads to a significant increase in both wages and hours worked in this sector compared to the tradable sector.

Overall, we conclude that in the case of sticky prices and the fixed exchange rate, a boom or a windfall in the oil sector generates the Dutch disease effect driven by the resource movement effect.

1.3.2.2 Flexible exchange rate

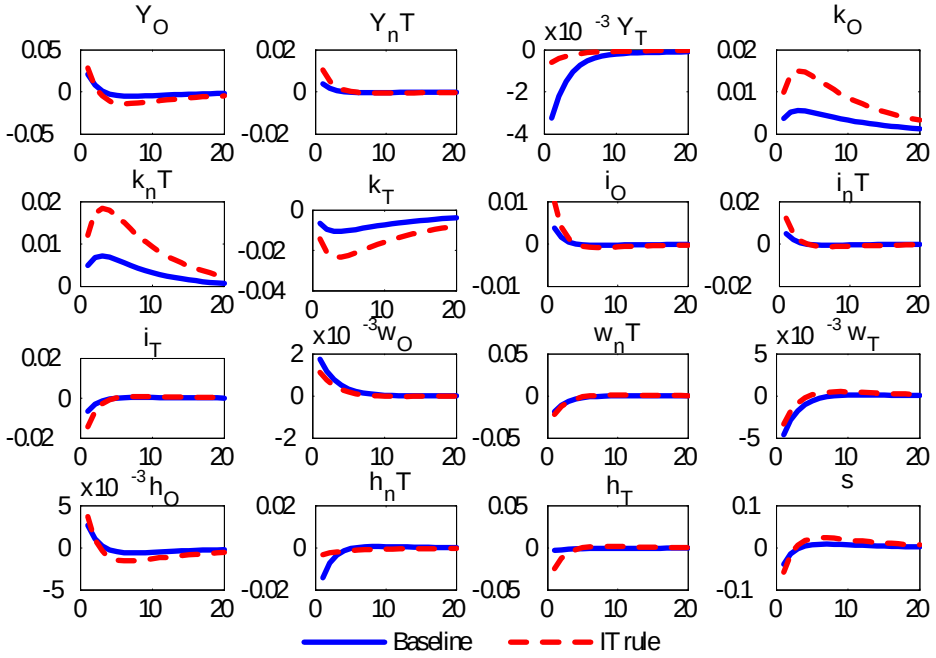


Figure 1.6: The effect of a 1% positive oil price shock (sticky price model)

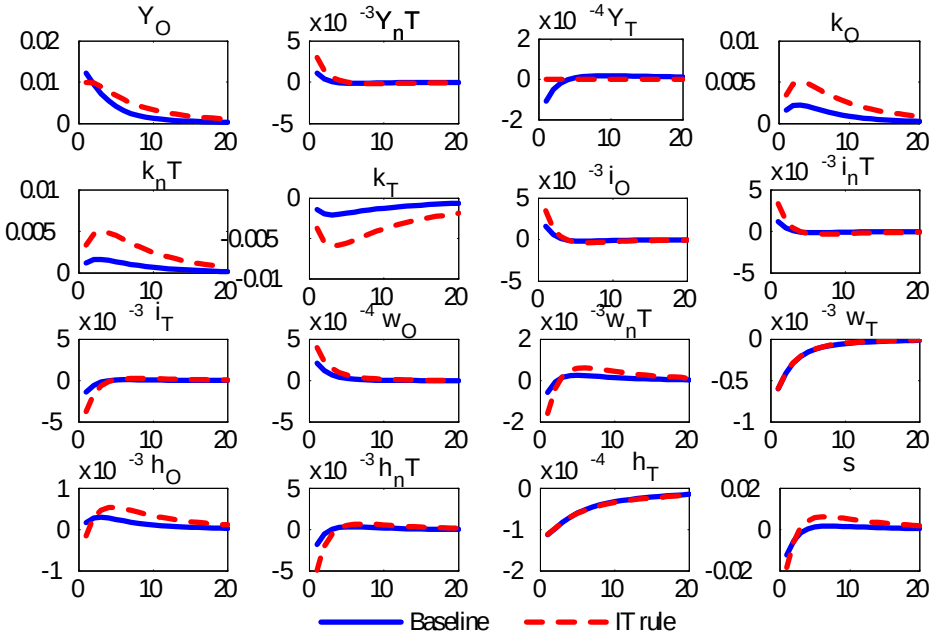


Figure 1.7: The effect of a 1% positive oil resource shock (sticky price model)

Figure 1.6 and 1.7 show that Dutch disease effect does not occur in the case of both windfall and boom under flexible exchange rate. Indeed, compared to the baseline model, the tradable good sector does not witness a decline, even if the oil and non-tradable sectors witness a boom following these two exogenous shocks.[14]

These results can be explained by the fact that inflation targeting prevents prices and wages increasert in both the oil and non-tradable sectors. Indeed, relatively to the baseline model, wages in all sectors experienced stability after the oil shock The resource movement effect is therefore avoided. So, flexibility of the exchange rate has not allowed the occurrence of the Dutch disease under its spending effect. Figure 1.6 and 1.7 show that the exchange rate appreciates in both cases (windfall and boom) but manufacturing output does not decline. This can be attributed to the structure of the oil exporting countries' manufacturing sector which is characterized by a low level of industrialization relative to developed countries. In other words, the spending effect

[14]This result seems to contradict the conclusion reached by Corden and Neary (1982) and Lartey (2008) who show that when monetary policy is designed to follow the flexible exchange rate rule, in the case of sticky price, the manufacturing output decline in response to the shock.

is not operational when the resource movement effect channel is locked. Therefore, exports of tradable goods are not affected by fluctuations of real exchange rate.

One of the findings is that, in the case of an exogenous boom (either an increase in oil prices or a rise in oil resources), the flexible exchange rate regime insulate from Dutch disease effect to the extent that fluctuations of the real exchange rate is insufficient to trigger the spending effect. This is, maybe, due to the structural characteristic of an oil exporting economy whose manufacturing sector is not sufficiently competitive.

1.3.3 Sticky price-wage model

In this section we assume that wages are sticky by setting $\varphi_j = 0.65$. In line with the work of Hausmann and Rigobon (2002) among others, we check the validity of the results obtained in the general equilibrium framework by comparing the results of a boom and windfall. As in the previous section, we assume, firstly, that the central bank targets the nominal exchange rate. Then, we compare the results to those obtained with a flexible exchange rate.

1.3.3.1 Fixed exchange rate

In the case of a fixed nominal exchange rate, Figues 1.8 and 1.9 show an increase of both oil prices and production in the oil sector. This increase is less important than in the case of the baseline model. Also, manufacturing production does not decline implying that Dutch disease effects are absent. Figure 1.9 shows that manufacturing production increases and then slightly declines. The non-tradable and oil sectors follow a similar pattern.

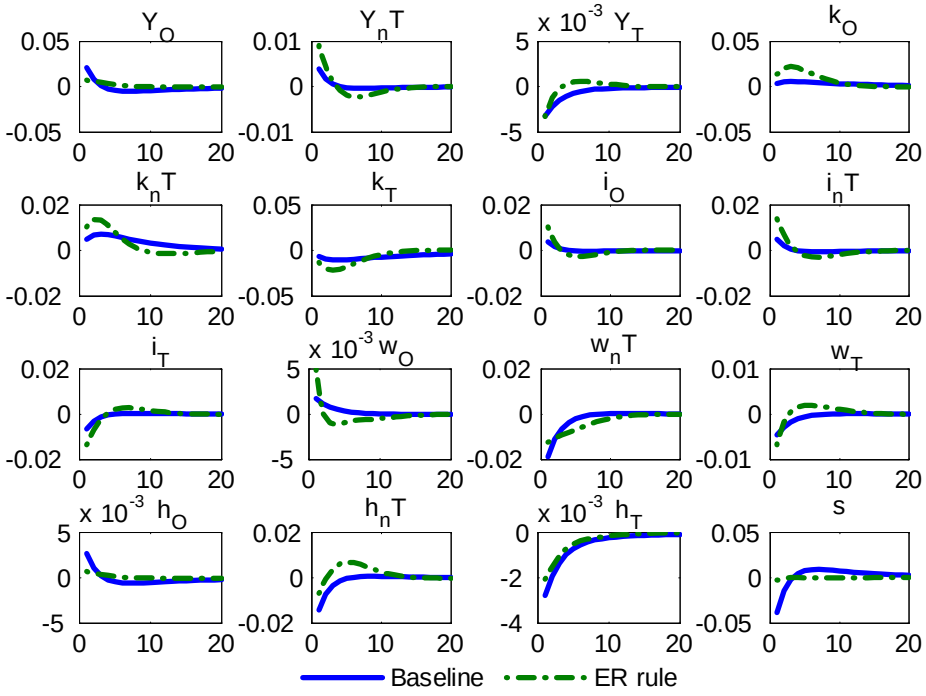


Figure 1.8: The effect of a 1% positive oil price shock (sticky price- wage model)

Thus, in the case where wages and prices are sticky and where the central bank targets the nominal exchange rate, Dutch disease effect does not rise. The main reason is that the spending effect channel neutralized by the monetary policy. Fluctuations of the nominal exchange rate are contained by the monetary authority from the third quarter in both cases (boom and windfall). Then, the resource movement effect, consisting in a shift of labor and capital from the manufacturing sector toward both oil and/or non-tradable sectors, is avoided because of sticky wages that does not allows the oil and non-tradable sectors to become more attractive. Therefore, wages and prices stickness together with fixed exchange rate completly offset Dutch disease effects.

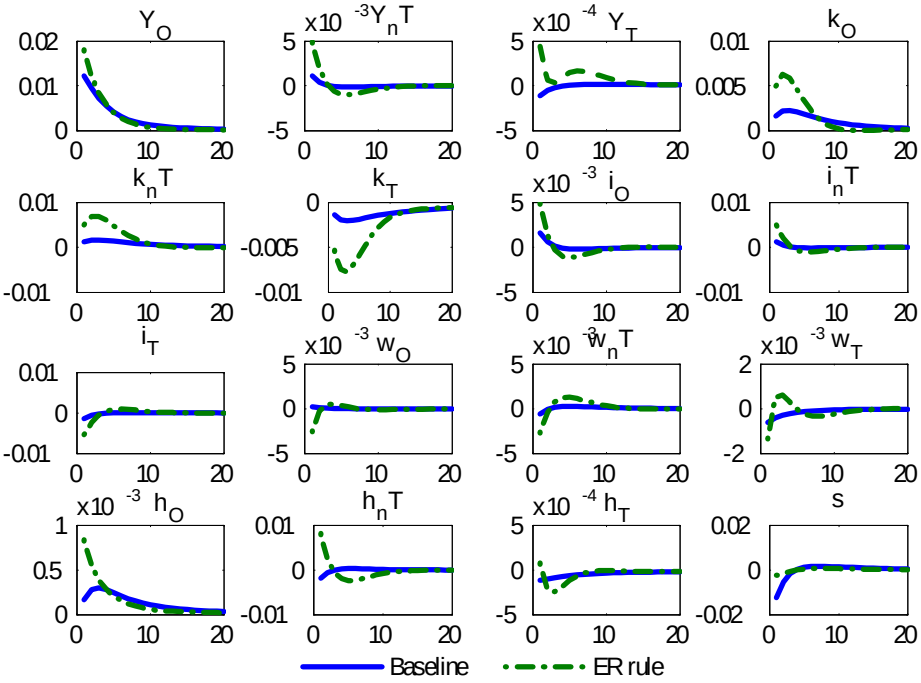


Figure 1.9: The effect of a 1% positive oil resource shock (sticky price- wage model)

1.3.3.2 Flexible exchange rate

In the last case where the exchange rate regime is flexible, Dutch disease effect does not occurs although the spending effect seems to be operational. The manufacturing sector does not decline both in the case of a windfall or a boom as shown by Figure 1.10 and 1.11.

Indeed, as in the case where only prices are sticky, exchange rate flexibility is not sufficient to allow the realization of the spending effect. Thus, in both cases (fixed exchange rates and flexible exchange rates) prices and wages rigidity insulate the economy from Dutch disease effects in the cases of either a windfall or a boom.

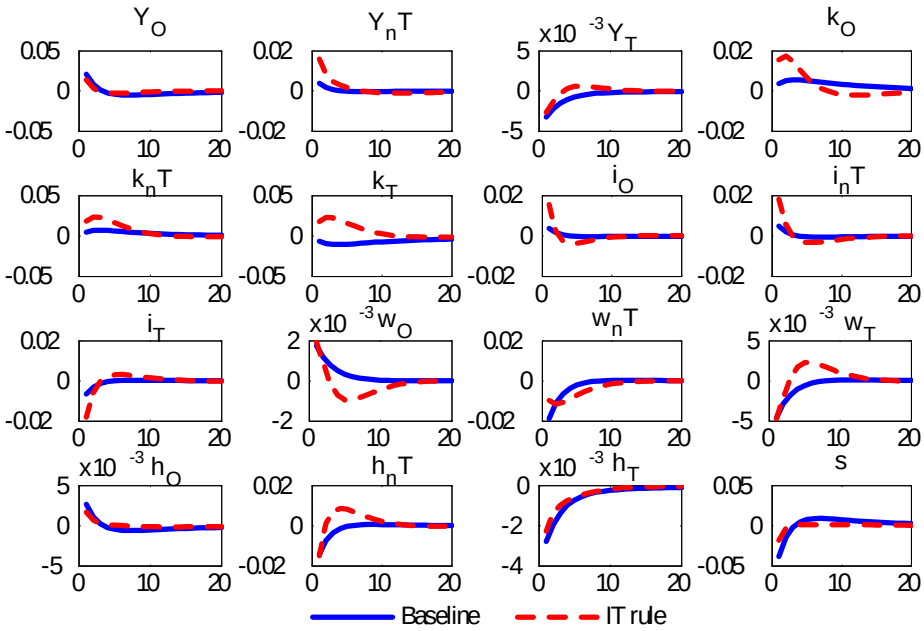


Figure 1.10: The effect of a 1% positive oil price shock (sticky price- wage model)

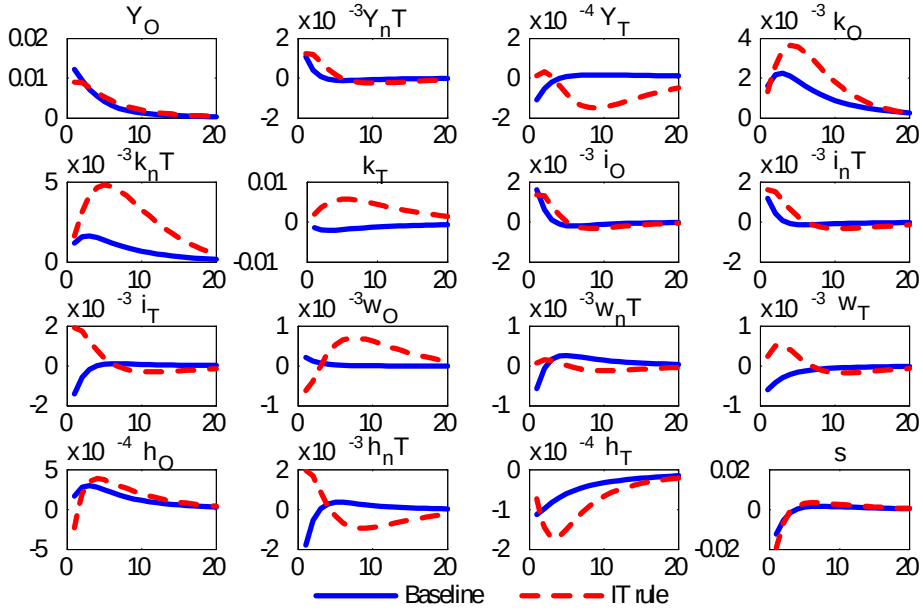


Figure 1.11: The effect of a 1% positive oil resource shock (sticky price- wage)

1.4 Welfare effects

In this section, we compare the impact of a windfall and a boom on the welfare under alternative exchange rate regimes. We compute the welfare using the unconditional expectation of the utility function. To do this, we use a second-order approximation of the utility function around the deterministic steady state[15].
Formally, the welfare criterion is derived from the following single-period utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U\left(c_t, h_t\right), \tag{1.70}$$

the second-order approximation result is given by:

$$\begin{aligned} \mu(.) \;\simeq\; & \overline{\mu} + \overline{c}^{1-\gamma} E(\widehat{c}_t) - \overline{h}^{1+\sigma} E\left(\widehat{h}_t\right) - \\ & \frac{\gamma}{2}\overline{c}^{1-\gamma} E\left(var\left(\widehat{c}_t\right) + \left[E\left(\widehat{c}_t\right)^2\right]\right) - \frac{\sigma}{2}\overline{h}^{1+\sigma} E\left(var\left(\widehat{h}_t\right) + \left[E\left(\widehat{h}_t\right)^2\right]\right) \end{aligned} \tag{1.71}$$

where bars denote steady-state values and hats represent percentage deviations from the steady-state. The welfare cost is measured by the compensating variation which allows us to measure the percentage changes in consumption in the deterministic steady state.

We calculate the welfare effects for the flexible price-and-wage model, sticky price and sticky wage models under alternative exchange rate regimes both in the case of windfall and boom.
Our main findings are summarized in Table 1.3.

Table 1.3: Welfare results (in percentage of the steady state of consumption).

	Windfall		**Boom**	
Flexible price and wage model	0.0192		0.0099	
Exchange rate regime	**Flexible**	**Fixed**	**Flexible**	**Fixed**
Sticky price model	0.0296	0.0226	0.0134	0.0173
Sticky price-wage model	0.0381	0.1563	0.0202	0.0334

[15] For similar method see Schmitt-Grohé and Uribe (2004)

Table 1.3 reports, in the flexible prices and wages model, that the welfare has a far greater impact on welfare cost than the boom. Indeed, welfare cost associated with a windfall is around 0.0192% of consumption in a deterministic steady-state, while with a boom it is around 0.099%. This is due to the fact that the windfall, as shown in section 3, leads to a strong effect of Dutch disease in terms of de-industrialization compared to a boom. Indeed, because of the fall of wages in the tradable sector (more important in the case of windfall), the households purchasing power is more important in the aftermath of a boom.
In the two other models (sticky price model and sticky price-wage model) the results remain unchanged such that, the welfare cost is more important following a windfall rather than a boom. Indeed, when the exchange rate regime is flexible, in the sticky price model, the welfare cost is equal to 0.0296% and 0.0134% in the case of windfall and boom respectively. In the case of sticky price-wage model, the welfare cost is equal to 0.0381% and 0.0202% respectively after a windfall and a boom. As shown by Table 1.3, the results are almost similar, under the fixed exchange rate rule in both windfall and boom.

The rest of the results shows that the flexible exchange rate regime helps to improve welfare compared to an ER rule. Indeed, after a windflall and a boom, an oil shock generates a more important welfare cost when the exchange regime is fixed[16]. Table 1.3 reports that after a boom, for the sticky price model, the welfare cost is estimated at 0.0134% and 0.0173% of consumption in a deterministic steady-state, under an IT rule (flexibe exchange rate regime) and a ER rule respectively. As for the sticky price-wage model, the welfare is around 0.0202% and 0.0334% in the cases of an IT rule and an ER rule respectively. After a windfall, the results show that, in the case of a sticky price-wage model, welfare cost is lower when the central bank targets the CPI inflation (IT rule). In other words, in the case of an ER rule, a rise in oil price leads to a greater welfare cost.

[16]Exept in the case of a sticky-price model after a winfall where the results are almost similar.

1.5 Conclusion

In this chapter, we have built a multisector DSGE model to model the Dutch disease phenomenon. To do so, the model takes into account the tradable good sector, the oil sector and the non-tradable good sector. The tradable good and oil sectors operate under perfect competition and the non-tradable goods sector operates under monopolistic competition. We have, thus, attempted to compare the response of the selected variables in the case of a windfall (increase in the oil price) and boom (increase in oil resources) and how monetary policy should be conducted to insulate the economy from the impacts of these shocks.

The main finding shows that the Dutch disease under both spending and resource movement effects seems to be realized in the following cases: flexible prices and wages both in the case of a windfall and in the case of a boom; flexible wages and sticky prices only in the case of fixed exchange rate. In others cases, simulations have shown that the Dutch disease could be avoided if: prices are sticky and wages are flexibles when the exchange rate is flexible; prices and wages are sticky whatever the objective of the central bank, in both cases: windfall and boom. Also, we compared the source of fluctuation that leads to a Dutch disease and we concluded that the windfall leads to a strong effect of Dutch disease in term of de-industrialization compared to a boom. The choice of flexible exchange rate regime also helps to improve welfare compared to an ER rule.

Finally, it appears that the flexible exchange rate seems to be the best way to avoid the Dutch disease both in the cases of a windfall and a boom. In other words, it is preferable for a central bank, in an oil exporting economy, to adopt inflation targeting regime to prevent the impact of oil shocks.

Chapter 2

External Shocks and Monetary Policy in an Oil Exporting Economy

Introduction

Emerging and developing economies are especially vulnerable to external shocks. Many channels explain such vulnerability. First of all, these countries remain dependent from economic activity in industrialized countries (the trade channel) and from international capital markets -including international banking activity- to finance their investment (the financial channel). In addition, despite a declining trend since the last decade, domestic prices in emerging and developing countries remain influenced by exchange rates fluctuations (the pass-through channel). Within this group of economies, oil exporting countries are even more exposed to these shocks. Indeed, oil exporting economies rely heavily on oil for their exports earnings, and their growth portrays a strong dependence for imports. As a consequence, they tend to have more volatile business cycle and are more crisis prone than other small-open economies. In this paper, we focus our attention on a specific oil exporter: Algeria. Relatively to other upper middle countries, Algeria is a relatively opened economy. In 2009, the exports of goods and services in terms of GDP amounted to 40.4 percent in Algeria while this ratio was 27.4 for upper middle countries (World dataBank website). Trade openness is

higher: 76.5 percent in Algeria against 52.6 percent in upper middle income countries[1]. In addition, as reported by Dib (2008b), this country has features that may intensify its responsiveness to external disturbances: (i) a managed exchange rate regime in which the dollar is the currency peg; (ii) a very strong concentration of its exports (oil accounts for more than 95% of its exports) with prices denominated in the U.S. dollar and set in the world markets; (iii) imports whose the major part (65%) is invoiced in euro; (iv) a net debtor position vis-à-vis the rest of the world; (v) a relatively diversified currency composition of its foreign debt since at least 60% of this debt has been issued in currencies other than the U.S. dollar; and (vi) a current account position highly dependent on oil-price fluctuations.

Over the period 2000-2010, despite significant oil revenues, economic performances in Algeria have been far from impressive. On the one hand, the average real GDP change amounted to 3.6 percent, consistently below growth performances in MENA region (5.6 percent)[2]. Interestingly, the activity rebound in 2010-relatively to the trough of 2009- has been significantly below in Algeria relative to MENA countries (0.8 percentage points and 2.6 respectively). On the other hand, in the aftermath of the 1994 stabilization program, Algerian inflation rate converged towards inflation levels in MENA region. Inflation has been stabilized in Algeria insofar as its inflation performances are close to the ones in other MENA countries (3.1 percent and 3.4 respectively over the period 2000-2010)[3]. Since 2006, despite a significant increase in the inflation rate -the consumption price index increased from 0.3 in 2006Q1 to 7.3 in 2008Q2 leading to a significant decrease in the inflation differential- Algeria remains one the best performers in MENA region. But this outcome is not striking if we take into account the unimpressive growth performance.

The previous structural characteristics of the Algerian economy and its economic performances raise the question of the appropriate monetary policy for this country. Focusing on the pattern of external shocks, it is the main purpose of this paper. To investigate

[1] If we consider the Middle East & North Africa (MENA) region as a whole, the exports of goods and services in percentage of GDP amounted to 41.4 in 2009 while the trade openness was 79.2 percent during the same year.

[2] For a sample included Egypt, Jordan, Kuwait, Lebanon, Libya, Morrocco, Oman, Qatar, Saudi Arabia, Tunisia, and United Arab Emirates. Data are extracted from IMF, World Economic Outlook Database, September 2011.

[3] IMF World Economic Outlook Database, September 2011.

the dynamic effect of external shocks, several studies have used econometric models, in particular VAR models, to decompose the direct effects of external shocks on output and other variables, from those generated by the endogenous monetary policy response as in Hamilton (1983); Bernanke *et al.* (1997); Hamilton and Herrera (2004), among others. All of these studies have investigated the effect of oil price shocks on output for the U.S. and the role played by the monetary policy. Other studies like Leduc and Sill (2001), Medina and Soto (2005) and Devereux *et al* (2006) have developed DSGE models to study the macroeconomic implications of alternative monetary policy rules, after external shocks, for a small open economy. Medina and Soto (2005) analyzed the effects of oil price shocks under alternative monetary policy rules. The authors developed and estimated a DSGE model by Bayesian methods for Chilean economy. The main results show that an increase in the real price of oil leads to a fall in output and an increase in inflation. The contractionary effect of the oil shock is mainly due to the endogenous tightening of the monetary policy. Devereux *et al.* (2006) compared alternative monetary policies for an emerging market economy that experienced external shocks to interest rates and terms of trade. They investigated, in particular, the importance of exchange rate flexibility in implementing such rules (a fixed exchange rate rule; and two types of inflation targeting rules). Their main finding is that degree of pass-through in import prices is crucial in determining the stabilization properties of an inflation targeting regime. Also, financial distortions amplify external shocks but have little impact on the ranking of alternative policy regimes.

In this chapter, we estimate, by using the Bayesian approach, a DSGE model for Algerian economy investigating the dynamic effect of four external shocks (oil price, real exchange rate, international interest rate and foreign inflation), and examining the appropriate monetary policy rule. To do so, we develop a Multisector Dynamic, Stochastic, General equilibrium (MDSGE) model with real and nominal rigidities. The aim is, first, to compare the importance of each shock as a source of fluctuations of the Algerian economy and secondly, to define the appropriate monetary policy rule that insulates the economy from the impacts of these shocks. Our model is different from the previous literature in many aspects. First, given that in several oil exporting countries, government aims to smooth oil price changes, we assume that the domestic oil price is defined by a convex combination of the current world price expressed in local currency

and the last period's domestic price. This rule allows us to replicate the subsidy of oil price that is a common practice in Algeria. Second, in our model there are two exchange rates: US dollar/Algerian dinar and the euro/US dollar real exchange rates. The first exchange rate is the exports' currency and the second represents a part of the imports' currency. Third, our model is a small open oil exporting economy model for a number of reasons: (i) the model is a multisector DSGE model with an oil sector; (ii) oil resource is used in the production function of the oil firm; (iii) the refined oil is used as an input in non-oil production, and (iv) oil price is subsidized.

In addition to these features, prices are sticky in the non-oil and import sectors. This allows monetary policy to play a role in our model. Indeed, this assumption is crucial in order to investigate the role of monetary policy in a DSGE model. We consider three alternative monetary policy rules: a fixed exchange rate rule, an headline inflation targeting rule, and a core inflation targeting rule. We adopt these rules for two main reasons: (i) they describe the conduct of monetary policy in a large number of developing and emerging market economies; and (ii) in the oil exporting economy, the presence of the oil component in headline CPI inflation engenders the question whether the measure of inflation in Algeria should be the headline inflation or the core inflation. In other words, does monetary policy in Algeria react to the headline inflation or the core inflation?

Our main findings show that, over the period 1990Q1-2010Q4, core inflation target is the best monetary rule to stabilize both output and inflation. In other words, the current monetary policy -corresponding to our baseline model- followed by the Algerian central bank is not well-suited to face to oil shocks.

The rest of the chapter is organized as follows. In section 2 we present the details of the model. Section 3 discusses the parameters calibration, data and priors. Section 4 presents the estimation results. Section 5 concludes.

2.1 The model

In this section we model an oil exporting economy based on the features of the Algerian economy. To do so, we assume that the economy is inhabited by seven agents: house-

hold, oil producing firm, non-oil good producers, intermediate foreign good imports, final good producer, a central bank and a government.

The household has access to international financial markets where it can buy or sell foreign non-state contingent bonds. In oil sector, there is a single perfectly competitive firm producing oil output, while in the non-oil good and imports sectors, there are a continuum of monopolistically-competitive firms. This firms set their prices à la Calvo (1983) and Yun (1996). As to the final good producer, it operates under perfect competition.

It is assumed that the central bank adjusts the short-term nominal interest rate in response to fluctuations in inflation in the non-oil good sector (core inflation), CPI inflation, and nominal exchange rate, using Taylor-type monetary policy rule. The government is considered as the owner of the oil firm.

2.1.1 Household

The representative household derives utility from consumption c_t and leisure $(1 - h_t)$.The preference of household is described by the following expected utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U\left(c_t, h_t\right), \tag{2.1}$$

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

$$u\left(.\right) = \frac{c_t^{1-\gamma}}{1-\gamma} - \frac{h_t^{1+\sigma}}{1+\sigma}, \tag{2.2}$$

where the preference parameters γ and σ are strictly positive. The first parameter, γ, is the inverse of the elasticity of intertemporal substitution of consumption and the second parameter, σ, denotes the inverse of the wage elasticity of labor supply. The single utility function, $u(.)$, is supposed to be strictly concave, strictly increasing in c_t and strictly decreasing in h_t. We also assume that h_t is defined by the following Cobb-Douglas technology:

$$h_t = h_{o,t}^{\alpha_{ho}} h_{no,t}^{\alpha_{hn_o}}, \tag{2.3}$$

where $h_{o,t}$ and $h_{no,t}$ represent hours worked by the household at time t in oil and non-oil sectors respectively. The parameters α_{ho} and α_{hno} denote the labor elasticity of substitution in the oil and non-oil sectors respectively, where $\alpha_{ho} + \alpha_{hno} = 1$.

The representative household has access to domestic and international financial markets. It enters in period t with holdings of domestic bonds denominated in units domestic currency (Algerian dinar), B^d_{t-1}, and foreign non-state contingent bonds, B^f_{t-1}, totally denominated in the Euro.

During period t, the household pays a lump-sum tax, ϖ, to finance government spending and sell or buy, B^f_t, at a price that depends on a country specific risk premium and the international interest rate. In other words, buying foreign bonds entails paying a risk premium, κ_t, whose the functional form is given by:

$$\kappa_t = \exp\left(-\phi \frac{e_t \xi_t \widetilde{B^f_t} / \widetilde{P^f_t}}{P_t Y_t}\right), \tag{2.4}$$

where ϕ denotes the parameter measuring the risk premium, e_t and ξ_t are two exchange rates[4]: the US dollar/ Algerian dinar (USD/DZD hereafter) and the euro/US dollar (EUR/USD hereafter) respectively and $\widetilde{B^f_t}$ is the average nominal stock of external debt which takes either a positive value if the domestic economy is a net borrower or negative value if the domestic economy is a net lender[5]. In our case, we assume that $B^f_t < 0$ to the extent that the Algerian economy is net borrower. Note finally that Y_t is the total real GDP and P^f_t is the foreign price index. By following this functional form, the model would not have a unit root because the holding bond would not follow a random walk[6]. The risk premium also ensures that the model has a unique steady state.

The representative household, in period t, earns nominal wages, $W_{o,t}$ and $W_{no,t}$ for their labor supply, respectively in the oil and non-oil sectors. It also receives dividend payments from both non-oil, $D_{no,t}$,and import, $D_{I,t}$,sectors so that $D_t = D_{no,t} + D_{I,t}$

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

[5] If the domestic economy is a net lender household receives a lower remuneration on their saving. If the economy is a net lender, household charges a premium on the foreign interest rate.

[6] See Schmitt-Grohé and Uribe (2003) for alternative ways of ensuring stationary paths in small open economy.

and a factor payment of oil resources, $\varpi(\iota) P_{O,t} O_t$, where $P_{O,t}$ is the nominal price of oil resource input O_t and $\varpi(\iota)$ is the share of household ι in oil resource payments with $\int_0^1 \varpi(\iota)\, d\iota = 1$.

At last, the household accumulates $k_{o,t}$ and $k_{no,t}$ units of capital stocks, used in the oil and non-oil sectors for nominal rental $Q_{o,t}$ and $Q_{no,t}$ respectively. The evolution of capital stock in each sector is given by:

$$k_{j,t+1} = (1-\delta)k_{j,t} + i_{j,t} - \Psi_j\left(k_{j,t+1}, k_{j,t}\right), \tag{2.5}$$

for $j = o, no$

where δ is the common depreciation rate to all sectors $(0 < \delta < 1)$ and $\Psi_{j,t}(k_{j,t+1},\, k_{j,t})$ is capital-adjustment cost[7] paid by household and satisfies $\psi_j(0) = 0, \psi_j^{'}(.) > 0$ and $\psi_j^{''}(.) < 0$.The functional form of $\Psi_j(.)$ is given, following Ireland (2003), by:

$$\Psi_{j,t}(.) = \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right)^2 k_{j,t}, \tag{2.6}$$

for $j = o, no$

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

$$\begin{aligned} P_t\left(c_t + i_t\right) + \frac{B_t^d}{R_t} + \frac{e_t \xi_t B_t^f}{R_t^f \kappa_t} \preceq B_{t-1}^d + e_t \xi_t B_{t-1}^f + \sum_{j=o,no} Q_{j,t} k_{j,t} \\ + (1-\varpi) \sum_{j=o,no} W_{j,t} h_{j,t} + D_t + P_{O,t} O_t, \end{aligned} \tag{2.7}$$

for $j = o, no$

where $P_t i_t = P_{o,t} i_{o,t} + P_{no,t} i_{no,t}$ is total investment in the oil and non-oil sectors respectively, and P_t is the consumption price index (CPI) that will be define bellow.

[7]The presence of the capital adjustment cost implies that, out of the steady state, the price of newly installed capital differs from the price of investment goods. In other words, the Tobin's Q is different from 1. This form allows to have both total and marginal costs of adjusting capital equal to zero in the steady state equilibrium.

Given initial value, the representative household chooses $\{c_t,\ k_{o,t+1},\ k_{no,t+1},\ \mathrm{h}_o,\ \mathrm{h}_{no},\ B_t^d$ and $B_t^f\}$ to maximize its lifetime utility function subject to capital accumulation equation, the budget constraint and the no-Ponzi game restriction.

The solution gives the following first order conditions:

$$\lambda_t = c_t^{-\gamma}, \tag{2.8}$$

$$\lambda_t = \alpha_{hj} \frac{h_t^{1+\sigma}}{h_{j,t}\left(1-\varpi\right) w_{j,t}}, \tag{2.9}$$

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)\frac{k_{j,t+2}}{k_{j,t+1}} - \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)^2 + q_{j,t+1} + 1 - \delta\right)\right]}{\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)+1}, \tag{2.10}$$

$$\lambda_t = \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right) R_t, \tag{2.11}$$

$$\frac{\lambda_t s_t \Xi_t}{R_t^f \kappa_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1} \Xi_{t+1}}{\widetilde{\pi}_{t+1}^f}\right), \tag{2.12}$$

for $j = o, no$

where $q_{j,t} = \frac{Q_{j,t}}{P_t}, \pi_{t+1} = \frac{P_{t+1}}{P_t}, \widetilde{\pi}_{t+1}^f = \frac{\widetilde{P}_{t+1}^f}{\widetilde{P}_t^f}$, $s_t = e_t \frac{P_t^f}{P_t}$ and $\Xi_t = \xi_t \frac{\widetilde{P}_t^f}{P_t^f}$ represent the real capital return in each sector, the CPI inflation rate, the world inflation rate, the USD/DZD real exchange rate and the EUR/USD real exchange rate respectively with P_t^f and $\widetilde{P}_t^f$ denoting the foreign GDP deflator expressed in U.S dollar and euro respectively. Also λ_t denotes the budget multiplier associated with the budget constraint.

By combining equations (2.11) and (2.12) we obtain equation (2.13) which represents the uncovered interest rate parity (UIP) condition:

$$\frac{R_t}{R_t^f \kappa_t} = \frac{s_{t+1}\Xi_{t+1}\pi_{t+1}}{s_t \Xi_t \pi_{t+1}^f}, \tag{2.13}$$

Finally, note that variables R_t^f, π_t^f and ξ_t which represent respectively the foreign interest rate, the world inflation rate and the EUR/USD exchange rate evolve exogenously according to the following AR(1) process:

$$\log(R_t^f) = (1-\rho_{R^f})\log(R^f) + \rho_{R^f}\log(R_{t-1}^f) + \varepsilon_{R^f,t} \tag{2.14}$$

$$\log(\pi_t^f) = (1-\rho_{\pi^f})\log(\pi^f) + \rho_{\pi^f}\log(\pi_{t-1}^f) + \varepsilon_{\pi^f,t} \tag{2.15}$$

$$\log(\xi_t) = (1-\rho_{\xi})\log(\xi) + \rho_{\xi}\log(\xi_{t-1}) + \varepsilon_{\xi,t} \tag{2.16}$$

where R^f, π^f and ξ are steady state values of R_t^f, π_t^f, and ξ_t. ρ_{R^f}, ρ_{π^f} and ρ_{ξ} are the autocorrelation coefficients, and $\varepsilon_{R^f,t}$, $\varepsilon_{\pi^f,t}$ and $\varepsilon_{\xi,t}$ are uncorrelated and normally distributed innovations with zero mean and standard deviations σ_{R^f}, σ_{π^f} and σ_{ξ} respectively.

2.1.2 Oil sector

To model oil production, we assume that oil firm operating in perfect competition uses technology, $A_{o,t}$,capital, $k_{o,t}$, labor, $h_{o,t}$, and oil factor, O_t, for the crude oil production. Oil output is totally exported abroad at the international price $P_{o,t}^f$ denominated in the US dollar.

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

$$\max_{k_{o,t},h_{o,t},O_t} \left[e_t P_{o,t}^f Y_{o,t} - Q_{o,t}k_{o,t} - W_{o,t}h_{o,t} - P_{O,t}O_t \right], \tag{2.17}$$

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

To resolve (2.17), firm must consider its function of production given by the following Cobb-Douglas technology:

$$Y_{o,t} \preceq A_{o,t} k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}, \tag{2.18}$$

where α_o, β_o and $\theta_o \in (0,1)$ and $\alpha_o + \beta_o + \theta_o = 1$. These coefficients denote respectively shares of capital, $k_{o,t}$, labor, $h_{o,t}$ and oil resource, O_t, in the production of oil.

Thus, given $e_t, P_{o,t}^f, Q_{o,t}, W_{o,t}$ and $P_{O,t}$,the oil producing firm chooses $\{k_{o,t},h_{o,t},O_t\}$ to maximize (2.17) subject to (2.18).

The first order conditions are:

$$q_{o,t} = \alpha_o s_t p_{o,t}^f \frac{Y_{o,t}}{k_{o,t}}, \tag{2.19}$$

$$w_{o,t} = \beta_o s_t p^f_{o,t} \frac{Y_{o,t}}{h_{o,t}}, \tag{2.20}$$

$$p_{O,t} = \theta_o s_t p^f_{o,t} \frac{Y_{o,t}}{O_t}, \tag{2.21}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p^f_{o,t} = \frac{P^f_{o,t}}{P_t}$ and $p_{O,t} = \frac{P_{O,t}}{P_t}$ denote respectively the real capital return, the real wage, the real oil price and the real price of the oil resource.

The equations (2.19)-(2.21) represent the demand for $k_{o,t}, h_{o,t}$ and O_t respectively. These results can be interpreted as the optimal choices of input that maximize oil producer's profit whose the value is equal to zero because of the perfect competition's assumption and the constant-return-to-scale production function.

Note, finally, that foreign oil's price, $P^f_{o,t}$, oil resource, O_t, and technology shock, $A_{o,t}$, evolutions are given by the following stochastic process:

$$\log(P^f_{o,t}) = (1 - \rho_{P^f_o}) \log(P^f_o) + \rho_{P^f_o} \log(P^f_{o,t-1}) + \varepsilon_{P^f_o,t}, \tag{2.22}$$

$$\log(O_t) = (1 - \rho_O) \log(O) + \rho_O \log(O_{t-1}) + \varepsilon_{O,t}, \tag{2.23}$$

$$\log(A_{o,t}) = (1 - \rho_{A_o}) \log(A_o) + \rho_{A_o} \log(A_{o,t-1}) + \varepsilon_{A_o,t}, \tag{2.24}$$

where P^f_o, O and A_o are steady state values of $P^f_{o,t}$, O_t and $A_{o,t}$. $\rho_{P^f_o}$, ρ_O and ρ_{A_o} are the autocorrelation coefficients, and $\varepsilon_{P^f_o,t}$, $\varepsilon_{O,t}$ and $\varepsilon_{A_o,t}$ are uncorrelated and normally distributed innovations with zero mean and standard deviations $\sigma_{P^f_o}, \sigma_O$ and σ_{A_o} respectively.

2.1.3 Non-oil sector

In this sector, we assume that the non-oil producers operate under monopolistic competition. Under this assumption, it's assumed that there is a continuum of firms indexed by $i \in (0, 1)$. Each firm i, produces non-oil goods using the following production function:

$$Y_{no,t}(i) \preceq A_{no,t} k^{\alpha_{no}}_{no,t}(i) h^{\beta_{no}}_{no,t}(i) Y^{I^{\theta_{no}}}_{o,t}(i), \tag{2.25}$$

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

process given by:

$$\log(A_{no,t}) = (1 - \rho_{A_{no}}) \log(A_{no}) + \rho_{A_{no}} \log(A_{no,t-1}) + \varepsilon_{A_{no,t}}, \tag{2.26}$$

Note also that α_{no}, β_{no} and $\theta_{no} \in (0,1)$ and $\alpha_{no} + \beta_{no} + \theta_{no} = 1$.These coefficients denote respectively a share of capital, $k_{no,t}$, labor, $h_{no,t}$ and refined oil, $Y^I_{o,t}$, used as an input in the production of non-oil goods.

To maximize its profit, the producer i chooses $\left\{K_{no,t}(i), h_{no,t}(i) \text{ and } Y^I_{o,t}(i)\right\}$ and sets its price, $\widetilde{P}_{no,t}(i)$ à la Calvo (1983) and Yun (1996). Following a stochastic time dependent rule of Calvo (1983), in each period, firm i can reset the price with a constant probability $(1 - \phi_{no})$ .Therefore, on average, the non-oil price remains unchanged for $\frac{1}{1-\phi_{no}}$ periods. As in Yun (1996), we assume that if non-oil goods producers are not able to change their price, they index them to the steady state CPI inflation rate according to the following rule:

$$P_{no,t} = \pi P_{no,t-1},$$

where π is the long run average gross rate of inflation.

The non-oil firms' maximization problem can be written as follow:

$$\max_{k_{no,t}(i), h_{no,t}(i), P_{no,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta\phi_{no})^s \lambda_{t+s} D_{no,t+s}(i)/P_{t+s}], \tag{2.27}$$

subject to (2.25) and the following demand function

$$Y_{no,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-\vartheta} Y_{no,t+s}, \tag{2.28}$$

where $D_{no,t+s}(i)$ is the profit function:

$$D_{no,t+s}(i) = \pi^s \widetilde{P}_{no,t}(i) Y_{no,t+s}(i) - Q_{no,t+s} k_{no,t+s}(i) - W_{no,t+s} h_{no,t+s}(i) - P_{o,t} Y^I_{o,t+s}(i),$$

with $(\beta^s \lambda_{t+s})$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t + s$.

The first order conditions of the maximization problem are:

$$q_{no,t} = \alpha_{no} \frac{Y_{no,t}(i)}{k_{no,t}(i)} mc_{no,t}, \tag{2.29}$$

$$w_{no,t} = \beta_{no} \frac{Y_{no,t}(i)}{h_{no,t}(i)} mc_{no,t}, \tag{2.30}$$

$$p_{o,t} = \theta_{no} \frac{Y_{no,t}(i)}{Y^I_{o,t}(i)} mc_{no,t}, \tag{2.31}$$

where $q_{no,t} = \frac{Q_{no,t}}{P_t}, w_{no,t} = \frac{W_{no,t}}{P_t}, mc_{no,t} = \frac{MC_{no,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real domestic oil price.

The real marginal cost, $mc_{no,t}$, can be obtain by replacing Eqs. (2.29)-(2.31) in (2.25):

$$mc_{no,t} = \frac{q_{no,t}^{\alpha_{no}} w_{no,t}^{\beta_{no}} p_{o,t}^{\theta_{no}}}{\alpha_{no}^{\alpha_{no}} \beta_{no}^{\beta_{no}} \theta_{no}^{\theta_{no}}}. \tag{2.32}$$

The optimal pricing condition is given by the maximization of (2.27):

$$\widetilde{p}_{no,t}(i) = \left(\frac{\vartheta}{\vartheta - 1}\right) \frac{E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} mc_{no,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{2.33}$$

where $p_{no,t+s} = \frac{P_{no,t+s}}{P_{t+s}}, mc_{no,t+s} = \frac{MC_{no,t+s}}{P_{t+s}}, \widetilde{p}_{no,t}(i) = \frac{\widetilde{P}_{no,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ denote respectively the relative price of non-oil goods, the real marginal cost in non-oil sector, the real optimized price for non-oil goods and the CPI inflation rate.

The aggregate nominal non-oil price index evolves according to the following recursive form:

$$(P_{no,t})^{1-\vartheta} = \phi_{no} (\pi P_{no,t-1})^{1-\vartheta} + (1 - \phi_{no}) \left(\widetilde{P}_{no,t}\right)^{1-\vartheta}, \tag{2.34}$$

Dividing (2.34) by P_t yields the following real non-tradable price index:

$$(p_{no,t})^{1-\vartheta} = \phi_{no}\left(\pi\frac{p_{no,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_{no})\left(\widetilde{p}_{no,t}\right)^{1-\vartheta}. \tag{2.35}$$

2.1.4 Import sector

The final good producer uses, for its production needs, an imported composite good, $Y_{I,t}$, purchased in a domestic monopolistically competitive market. To produce $Y_{I,t}$, the firm uses differentiated goods, $Y_{I,t}(i)$, that are produced by a continuum of domestic importers, indexed by $i \in (0,1)$, using a homogeneous intermediate good produced abroad and imported for the world price P_t^f. A part μ of these imported goods is denominated in euro, while another part $(1-\mu)$ is invoiced in U.S dollar. The differentiated goods are sold at price $P_{I,t}(i)$ which is supposed to be sticky *à la* Calvo (1983) and Yun (1996). Therefore, the importer faces, in each period, a constant probability, $(1-\phi_I)$, of changing its price as in Calvo (1983). Following Yun (1996), we assume that if importers are not able to change their price, they index them to the steady state CPI inflation rate.

The maximization problem of importers can be written as follows:

$$\max_{\widetilde{P}_{I,t}(i)} E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s}\left(\pi^s \widetilde{P}_{I,t}(i) - e_{t+s}\left(\mu + (1-\mu)\xi_t\right) P_{t+s}^f\right) Y_{I,t+s}(i), \tag{2.36}$$

where $Y_{I,t+s}(i)$ is chosen by firms to maximize their profit:

$$Y_{I,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{I,t}(i)}{P_{I,t+s}}\right)^{-\vartheta} Y_{I,t+s}, \tag{2.37}$$

The zero profit condition gives the importer price index:

$$P_{I,t+s} = \left(\int_0^1 \pi^s \widetilde{P}_{I,t}(i)^{1-\vartheta} di\right)^{\frac{1}{1-\vartheta}}, \tag{2.38}$$

replacing (2.37) in (2.36) and following the same steps than for the non-oil sector[8], we get the optimal pricing condition given by:

[8] See appendix B for more details.

$$\widetilde{p}_{I,t}(i) = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} mc_{I,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{2.39}$$

where $p_{I,t+s} = \frac{P_{I,t+s}}{P_{t+s}}$ is the relative price of imports, $mc_{I,t+s} = s_{t+s}(\mu + (1-\mu)\Xi_t)$ is the real marginal cost, $\widetilde{p}_{I,t}(i) = \frac{\widetilde{P}_{I,t}(i)}{p_t}$ is the optimized price in import sector and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ is the CPI inflation rate.

The aggregate nominal import price index evolves according to the following recursive form:

$$(P_{I,t})^{1-\vartheta} = \phi_I (\pi P_{I,t-1})^{1-\vartheta} + (1-\phi_I) \left(\widetilde{P}_{nT,t}\right)^{1-\vartheta}, \tag{2.40}$$

Dividing (2.40) by P_t yields the following real import price index:

$$(p_{I,t})^{1-\vartheta} = \phi_I \left(\pi \frac{p_{I,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_I)(\widetilde{p}_{I,t})^{1-\vartheta}. \tag{2.41}$$

2.1.5 Final good producer

We assume that the producer of final good operates under perfect competition. It uses the following CES technology that includes non-oil output, $Y_{no,t}$, which is domestically-produced, and imports, $Y_{I,t}$:

$$z_t = \left[\chi_{no}^{\frac{1}{\tau}} Y_{no}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}} Y_I^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}}, \tag{2.42}$$

where $\tau > 0$ denotes the elasticity of substitution between non-oil output and imported goods and χ_{no}, χ_I represent, respectively, the share of non-oil and imported goods in the final good, where $\chi_{no} + \chi_I = 1$. To maximize its profit, the final good producer chooses $\{Y_{I,t} \text{ and } Y_{no,t}\}$.

Resolving this problem, we get the following demand function:

$$Y_{I,t} = \chi_I \left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t, \quad \text{and} \quad Y_{no,t} = \chi_{no} \left(\frac{P_{no,t}}{P_t}\right)^{-\tau} z_t, \tag{2.43}$$

where $P_t, P_{I,t}, P_{no,t}$ are given. Note also that the zero profit condition implies that the price of final good is given by:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_{no} P_{no,t}^{1-\tau}\right]^{\frac{1}{1-\tau}}. \tag{2.44}$$

Note finally that the final good is divided between total consumption and total investment so that $z_t = c_t + i_{o,t} + i_{no,t}$.

2.1.6 Monetary policy

We assume that the central bank adjusts the short-term nominal interest rate, i_t, in response to fluctuation in inflation in the non-oil goods sector (core inflation), $\pi_{no,t}$, CPI inflation, π_t, and exchange rate, Δe_t according to the following Taylor-type monetary policy rule:

$$\frac{(1+R_{t+1})}{(1+\overline{R})} = \left(\frac{P_{no,t}}{P_{no,t-1}}\frac{1}{\overline{\pi}_{no}}\right)^{\mu_{\pi_{no}}} \left(\frac{P_t}{P_{t-1}}\frac{1}{\overline{\pi}}\right)^{\mu_\pi} \left(\frac{\Delta e_t}{\Delta \overline{e}}\right)^{\mu_e} \exp(\varepsilon_R), \tag{2.45}$$

where $\overline{R}, \overline{\pi}_{no}, \overline{\pi}$, and $\Delta\overline{e}$ are the steady state values of $R_t, \pi_{no,t}, \pi_t$,and Δe_t. The policy coefficient, $\mu_{\pi_{no}}, \mu_\pi$,and μ_e measuring central bank response to deviation of $\pi_{no,t}, \pi_t$,and Δe_t from their steady state levels.

2.1.7 Government

In an oil exporting economy[9], the oil domestically used (refined oil), $Y_{o,t}^I$, is mostly produced abroad. As a result, we assume that government, which is the owner of the oil firm, buys it from the world market for the international price, $P_{o,t}^f$, denominated in the foreign currency.

The refined oil is sold domestically to the non-oil firms at price $P_{o,t}$ which can be considered as the domestic fuel price. The latter is supposed to be subsidized by the

[9]It's the case of Algeria and other countries as Iran.

government. For this purpose, we assume according to Bouakez *et al.* (2008) and Benkhodja (2011), that the domestic oil price, $P_{o,t}$ is given by a convex combination of the current world price,$P_{o,t}^{f}$, expressed in local currency and last period's domestic price. It follows the following functional form:

$$P_{o,t} = (1-\upsilon)P_{o,t-1} + \upsilon e_t P_{o,t}^{f}, \tag{2.46}$$

where $\upsilon \in (0,1)$, and $P_{o,t}^{f}$ denotes the world price of oil that is determined in the world market and denominated in the foreign currency.

Following the oil price rule, when $\upsilon = 1$, there is no subsidy and the pass-through from the world oil price is complete. However, when $\upsilon = 0$, this means that the domestic oil price is fully subsidized and there is no pass-through. Thus, all domestic firms will buy the oil at a price $P_{o,t}$.

Finally, the government's budget constraint is given by:

$$\varpi \sum_{j=o,T,nT} W_{j,t}h_{j,t} + s_t p_{o,t}^{f} Y_{o,t} = \left(s_t p_{o,t}^{f} - p_{o,t}\right) Y_{o,t}^{I} + w_{o,t}h_{o,t} + q_{o,t}k_{o,t} + p_{O,t}O_t, \tag{2.47}$$

where the left hand side represents the government's revenue that includes a lump-sum tax, ϖ, and receipts from selling oil $\left(s_t p_{o,t}^{f} Y_{o,t}\right)$. The right hand side represents the government spending that include payment both wages and capital return $(w_{o,t}h_{o,t} + q_{o,t}k_{o,t})$ in the oil sector and the amount of oil's subsidies$\left(s_t p_{o,t}^{f} - p_{o,t}\right) Y_{o,t}^{I}$.

2.1.8 Aggregation and Equilibrium

In a symmetric equilibrium, all importers and non-oil goods producers make the same decision so that: $Y_{no,t}(i) = Y_{no,t}$, $Y_{o,t}^{I}(i) = Y_{o,t}^{I}$, $\widetilde{p}_{no,t}(i)=\widetilde{p}_{no,t}$, $Y_{I,t}(i)=Y_{I,t}$, $\widetilde{p}_{I,t}(i)=\widetilde{p}_{I,t}$ for all $i \in (0,1)$.Thus, a symmetric equilibrium for this economy is composed of an allocation $\{c_t,\ i_t,\ i_{o,t},\ i_{no,t},\ Y_{o,t},\ Y_{no,t},\ Y_{no,t}^{va},\ Y_{o,t}^{I},\ Y_{I,t},\ Y_t,\ z_t,\ k_{o,t},\ k_{no,t},\ h_t,\ h_{o,t},\ h_{no,t},\ b_t^{f},\ \kappa_t\}_{t=0}^{\infty}$ and a sequence of prices and co-state variables $\{w_{o,t},\ w_{no,t},\ q_{o,t},\ q_{no,t},\ p_{o,t},\ p_{no,t},\ \widetilde{p}_{no,t},\ \widetilde{p}_{I,t},\ p_{I,t},\ p_{O,t},\ \pi_t,\ \pi_{no,t},\ \pi_{I,t},\ s_t,\ e_t,\ R_t,\ \lambda_t,\ mc_{no,t},\ mc_{I,t}\}_{t=0}^{\infty}$ satisfying household, oil and non-oil first order conditions, the aggregate resources constraints, the monetary policy rules, the current account equation and the stochastic

processes $\{A_{o,t}, A_{no,t}, p^f_{o,t},\ O_t,\ \xi_t,\ R^f_t,\ \pi^f_t\}^{\infty}_{t=0}$ of the shocks and the following market clearing conditions $b_t{=}b_{t-1}{=}0$, $b^f_t{=}\widetilde{b}^f_t$ and:

$$Y_t = p_{no,t} Y^{va}_{no,t} + s_t p^f_{o,t} Y_{o,t}, \tag{2.48}$$

where Y_t, and $Y^{va}_{no,t}$ are the aggregate GDP and value-added output in non-oil goods sector respectively. The variable, $Y^{va}_{no,t}$, is constructed by subtracting oil input as follow[10]:

$$Y^{va}_{no,t} = Y_{no,t} - s_t p^f_{o,t} \frac{Y^T_{o,t}}{p_{no,t}}, \tag{2.49}$$

Combining the households' budget constraint, the single period profit functions of non-oil goods producing firms and foreign good importers and the first order conditions of the three sectors and applying the market clearing conditions yields the following current account equation:

$$\frac{b^f_t}{\kappa_t R^f_t} = \frac{b^f_{t-1}}{\pi^f_t} + p^f_{o,t} Y_{o,t}/\Xi_t - p^f_{o,t} Y^I_{o,t} - (\mu + (1-\mu)\,\Xi_t)\, Y_{I,t}/\Xi_t. \tag{2.50}$$

2.2 Model estimation

In this section, we estimate the model by using the Bayesian method. To do so, we will describe the methodology to use, data and prior distributions.

2.2.1 Bayesian approach:

The model is estimated by using the Bayesian method as in Sungbae and Schorfheide (2007), Fernández-Villaverde (2010) and Del Negro and Schorfheide (2008, 2010).

The Bayesian analysis is system-based and fits the solved DSGE model to a vector of aggregate time series. To incorporate additional information into the parameter estim-

[10] We suppose that non-oil firms use refined oil as material inputs in their productions which is defined as gross output. Thus, value added output in each sector can be constructed by substracting commodity inputs.

ation, we use prior distributions. The estimation is based on the likelihood function generated by the solution of the log-linear version of the model[11].

Since the model is too complex to be resolved analytically, we use a Taylor approximation around the steady state to replace all equations, in the symmetric equilibrium system, by approximations, which are linear functions in the log-deviation of the variables. Using the method described by Blanchard and Kahn (1980), we obtain the following state-space form which is used to estimate the model:

$$\begin{aligned} s_{t+1} &= \Pi s_t + W\varepsilon_t \\ f_t &= U s_t, \end{aligned} \tag{2.51}$$

where s_t is a state variables vector that includes predetermined and exogenous variables, f_t, the control variables vector, and, ε_t, the vector of random innovations and stochastic process.

We assume that the white noise innovations are normally distributed. Thus, we can compute the conditional likelihood function for the structural parameters using the Kalman filter $L(\Theta|\boldsymbol{F}^T)$, where $\boldsymbol{F}^T = \{f_1, ..., f_T\}$. This likelihood function can be used to transform a prior distribution $p(\Theta)$ for the structural parameters of the DSGE model into a posterior distribution. The letter, following the Bayes theorem, can be written as:

$$p\left(\Theta|\boldsymbol{F}^T\right) = \frac{L(\Theta|\boldsymbol{F}^T)p(\Theta)}{\int L(\Theta|\boldsymbol{F}^T)p(\Theta)d\Theta}. \tag{2.52}$$

The posterior distribution, $p\left(\Theta|\boldsymbol{F}^T\right)$, which represents a new set of beliefs, combine the prior beliefs, $p(\Theta)$, with the sample information embodied in the likelihood, $L(\Theta|\boldsymbol{F}^T)$. To find an approximation solution for the posterior distribution, we use the Metropolis-Hastings algorithm.

Following Sungbae A and Schorfheide F (2007), Fernández-Villaverde (2010) and Del Negro and Schorfheide (2010), among other, some advantages of the Bayesian approach can be cited: (i) the Bayesian method allows us to compute, directly, many objects of interests such as the posterior distribution of welfare gains and many other complicated

[11] Appendix B presents the log-linearized version of the model.

functions of the underlying parameters, while capturing in these computed objects all the existing uncertainty regarding parameter values; (ii) the prior beliefs allow us to use other sources of information that do not directly enter the likelihood function. On the other hand, to prevent the flatness of the likelihood function[12], we use the prior density which can introduce curvature into the objective function, making it possible to identify the values of different parameters.

There are 30 parameters to be estimated gathered in Θ=$\{\phi_{no}$, ϕ_I, ψ_o, ψ_{no}, ϑ, χ_I, χ_{no}, α_o, β_o, θ_o, α_{no}, β_{no}, θ_{no}, $\mu_{\pi_{no}}$, μ_π, μ_e, ρ_{R^f}, ρ_{a_o}, $\rho_{a_{no}}$, ρ_{π^f}, $\rho_{p_o^f}$, ρ_O, ρ_ξ, σ_{R^f}, σ_{a_o}, $\sigma_{a_{no}}$, σ_{π^f}, $\sigma_{p_o^f}$, σ_O, $\sigma_\xi\}$.
The rest of the parameters are calibrated, as commonly done in the DSGE literature. This procedure helps to cope with the problem of identification from which DSGE models commonly suffer, arising from the fact that the data used in the estimation may contain little information about some parameters.

Table 2.1: Calibration of structural parameters.

Description	Parameters	Values
Structural Parameters		
Subject discount factor	β	0.99
The inverse of the elasticity of intertemporal substitution of consumption	γ	2
The inverse of the Frish wage elasticity of labour supply	σ	1
Parameter measuring the risk premium	ϕ	0.0015
The depreciation rate of capital	δ	0.025
Lump-sum tax parameter	ϖ	0.2
Price elasticity of demand for imported and non-oil goods	τ	0.8
Share of import invoiced in the US dollar	μ	0.3
Oil price rule parameter	υ	0.3
Labor elasticity of substitution in the oil sector	α_{ho}	0.31
Labor elasticity of substitution in the non-oil sector	α_{hno}	0.69
Steady state values		
Gross steady-state domestic inflation rate	π	1.0085
Gross steady-state foreign inflation rate	π^f	1.0070
Steady state domestic interest rate	R	1.0185
Steady state foreign interest rate	R^f	1.0158

[12]This applies in particular if there is a lack of identification.

As in Almeida (2009) the parameters we chose to calibrate pertain mostly to three aspects: (i) those crucial to determine the steady-state; (ii) those for which we have reliable estimations from other sources; and (iii) those whose values are crucial to replicate the main steady-state key ratios. Table 2.1 reports the calibration values.

The subjective discount factor, β, is set at $0,99$ which implies an annual steady state real interest rate of 4%. As in Bouakez *et al.* (2008) and Dib (2008) the curvature parameter in the utility function, γ, is set at 2 implying an elasticity of intertemporal substitution of consumption of 0.5. Following Devereux *et al.* (2006) among others, the inverse of the elasticity of the intertemporal substitution of labor, σ, is set at 1. The capital depreciation rate, δ, is set at $0,025$. This value is common to the two sectors of production (oil and non-oil sectors).

The price elasticity of demand for imported, and non-oil goods, τ, is set at 0,8 as in Dib (2008). Lump-sum tax parameter, ϖ, and the share of import invoiced in the US dollar, μ, are set at 0.2 and 0.35 respectively. Indeed, following the annual economic reports of the Bank of Algeria (2009), the share of Algerian imports from the Euro Area is about 65% of total imports. Finally, we set values of the labor elasticity of substitution to match the shares of wages in the two sectors of Algerian economy (oil and non-tradable), so that, α_{h_o} and $\alpha_{h_{no}}$ are equal to $0,31$ and 0.69 respectively.[13] The parameter in the risk-premium terms, ϕ, is set equal to 0.0015.

2.2.2 Data

To estimate the model, we use seven series of quarterly Algerian and US data from 1990-Q1 to 2010-Q4: oil production, domestic inflation, the domestic real interest rate, USD/DZD real exchange rate, domestic GDP and real oil price. The oil price is the international price of WTI oil. The domestic interest rate is the discount rate computed by the Bank of Algeria to manage its monetary policy. All of these variables are deflated by an index of prices for the Algerian economy.

The model implies that all variables are stationary and fluctuate around constant means, but the series used in the estimation are non-stationary. Thus, to render them

[13] These values are chosen by using ONS (national office of statistics) data.

stationary, we applied an HP-filter and used the detrended series instead of the original ones.

2.2.3 Prior distributions

To reflect our beliefs about structural parameters, we specify prior distributions for the entire vector Θ. As studies on the Algerian economy are unavailable, we choose priors based on evidence from previous studies for oil exporting economies (like Medina and Soto (2005) and Dib (2008)), but for those for which we had no references we used common sense while trying to construct the least restrictive priors possible. These priors are summarized in Table 2.2.

We assume Beta distribution for those parameters that must lie in the [0 1] interval. This applies to the persistence parameters of the exogenous stochastic processes which are assumed to follow a beta distribution with a mean of 0.65 and a standard deviation of 0.03. The Beta distribution is also assigned to the parameters of price stickiness with a mean of 0.67 that corresponds to changing price every 3 quarters on average. We also assume that the mean of parameters $(\alpha_o, \beta_o, \theta_o)$ and $(\alpha_{no}, \beta_{no}, \theta_{no})$, which are associated with the shares of capital, labor and a fraction of oil output in the output of each sector, are set to match the average ratios observed in the Algerian data for the 1990-2010 period. We set the shares of capital, α_o, labor, β_o, and oil resources, θ_o, in the production of oil to $0,31$, $0,24$ and $0,45$ respectively. We also set to $0,23$, $0,52$ and $0,25$ the share of capital, α_{no}, labor, β_{no}, and a fraction of oil output, θ_{no},in the production of non-oil goods. The standard deviations of these parameters are assumed to follow Beta distribution and a standard error of 0.05.

We also assume Gamma and inverted Gamma distributions for the parameters that must be positive. This is the case of the standard errors of various innovations which are assumed to follow the inverse Gamma distribution, with a mean of 0.5 and a standard error of 2. The remaining parameters have a normal distribution. Thus, we use a normal distribution for the capital adjustment costs in each sector with a mean of 5 and a standard deviation of 2. Also, as in Rabanal and Rubio-Ramirez (2005) and Medina and Soto (2005) we do not impose non-negativity restrictions on the policy rule coefficients. Thus, we assume a normal distribution for all monetary policy coefficients

Table 2.2: Prior distributions.

				Priors	
Description	Coefficient	Domain	Density	Mean	Std.
Calvo-price-non-oil	ϕ_{no}	[0 1]	Beta	0.67	0.05
Calvo-price-import	ϕ_I	[0 1]	Beta	0.67	0.05
Cap-adjust-oil	ψ_o	$\mathbb{R}$	Normal	5	2.00
Cap-adjust-non-oil	ψ_{no}	$\mathbb{R}$	Normal	5	2.00
Inter-goods elast	ϑ	$\mathbb{R}^+$	Gamma	6	1.00
Share of imports	χ_I	[0 1]	Beta	0.7	0.10
Share of non-oil	χ_{no}	[0 1]	Beta	0.3	0.10
Share of cap-oil	α_o	[0 1]	Beta	0,31	0.05
Share of lab-oil	β_o	[0 1]	Beta	0,24	0.05
Share of oil-res	θ_o	[0 1]	Beta	0,45	0.05
Share cap-non-oil	α_{no}	[0 1]	Beta	0,23	0.05
Share lab-non-oil	β_{no}	[0 1]	Beta	0,52	0.05
Share oil-non-oil	θ_{no}	[0 1]	Beta	0,25	0.05
Core inf pol-rule	$\mu_{\pi_{no}}$	$\mathbb{R}$	Normal	0.70	0.30
Inflation pol-rule	μ_π	$\mathbb{R}$	Normal	0.50	0.30
Exch-rate pol-rule	μ_e	$\mathbb{R}$	Normal	0.60	0.30
AR inter-interest	ρ_{R^f}	[0 1]	Beta	0.65	0.20
AR oil produc	ρ_{a_o}	[0 1]	Beta	0.65	0.20
AR non-oil produc	$\rho_{a_{no}}$	[0 1]	Beta	0.65	0.20
AR world inflation	ρ_{π^f}	[0 1]	Beta	0.65	0.20
AR oil price	$\rho_{p_o^f}$	[0 1]	Beta	0.65	0.20
AR oil resource	ρ_O	[0 1]	Beta	0.65	0.20
AR EURO/USD	ρ_ξ	[0 1]	Beta	0.65	0.20
s.d inter-interest	σ_{R^f}	$\mathbb{R}^+$	InvGamma	0.5	inf
s.d oil produc	σ_{a_o}	$\mathbb{R}^+$	InvGamma	0.5	inf
s.d non-oil produc	$\sigma_{a_{no}}$	$\mathbb{R}^+$	InvGamma	0.5	inf
s.d world inflation	σ_{π^f}	$\mathbb{R}^+$	InvGamma	0.5	inf
s.d oil price	$\sigma_{p_o^f}$	$\mathbb{R}^+$	InvGamma	0.5	inf
s.d oil resource	σ_O	$\mathbb{R}^+$	InvGamma	0.5	inf
s.d EURO/USD	σ_ξ	$\mathbb{R}^+$	InvGamma	0.5	inf

with a mean of 0.50, 0.70 and 0.60 for core inflation, inflation and exchange rate coefficients respectively. A standard deviation of 0.3 is assigned to these parameters.

2.2.4 Estimation results

In order to study the robustness of our baseline model, we begin the analysis of our results by focusing on posterior means (Tables 2.3-2.4). Then we analyze the impulse response functions of the external shocks according to the alternative monetary policy rules. Finally, we study the business properties of our model, included variance decomposition.

2.2.4.1 The baseline model

Tables 2.3 and 2.4 report the bayesian estimation results of the structural parameters of the baseline model. As in several econometric studies of DSGE models, we estimate the model by computing the posterior mode and constructing the posterior distribution with the Metropolis-Hastings algorithm by generating 100.000 draws. Recall that prior means are mainly based on previous studies dedicated to oil exporters economies since few studies consider the case of Algeria.

Posterior means suggest a weaker price rigidity in the non-oil sector relatively to the import sector (Table 2.3). More precisely, the estimated Calvo probabilities of not resetting optimally prices are 0.64 and 0.76 respectively. That means that prices are adjusted every 2.77 quarters in the non-oil sector and every 4.16 quarters in the import sector suggesting the presence of nominal prices rigidities in the later sector. More precisely, price rigidities may be highest in Algeria relatively to other primary commodity exporters such as Chile owing to the greater influence of state concerning prices determination. In addition, it seems to us relevant to consider that the state exerts a stronger influence on the import sector than the non-oil one for two main reasons. Firstly, public and parapublic companies tend to own to the import sectors. Secondly, as stressed above, authorities subsidy the domestic price of oil, price that exert a direct influence on prices in the import sector. All this induces more rigidity in the former relative to the later. Finally, some import sectors-such as the food one-have monopolistic structures that favor prices rigidity.

Table 2.3: Estimation results.

Parameters	Prior mean	Post mode	S.D	Post mean	[5%	95%]
ϕ_{no}	0.67	0.7111	0.0095	0.6448	0.5957	0.6852
ϕ_I	0.67	0.7846	0.0139	0.7652	0.7346	0.7928
ψ_o	5	5.6835	0.9667	6.3242	4.4166	8.7259
ψ_{no}	5	4.3408	0.8590	5.8580	4.1968	7.3139
ϑ	6	3.4365	0.6977	4.0356	3.0584	4.9204
χ_I	0.7	0.5911	0.0282	0.6240	0.5347	0.7083
χ_{no}	0.3	0.4721	0.0165	0.4152	0.2254	0.6579
α_o	0.31	0.1909	0.0058	0.1568	0.1254	0.1908
β_o	0.24	0.0749	0.0249	0.0932	0.0339	0.1250
θ_o	0.45	0.4318	0.0313	0.4036	0.3454	0.4514
α_{no}	0.23	0.3755	0.0082	0.3848	0.3234	0.4541
β_{no}	0.52	0.3721	0.0201	0.3981	0.3355	0.4435
θ_{no}	0.25	0.1209	0.0162	0.1421	0.1139	0.1802
Mon policy coef						
μ_e	0.70	0.0246	0.0659	0.0352	0.0247	0.0433
μ_π	0.50	1.8579	0.1430	1.9179	1.7909	2.2799
$\mu_{\pi_{no}}$	0.60	-0.0516	0.0843	-0.0452	-0.0560	-0.0331
Log-marg data		-659.462				

The estimates of capital-adjustment cost parameters are 6.32 and 5.85 respectively in oil and non-oil sectors. Posterior means are significantly close to our prior means. High capital-adjustment costs means that the capital stock can not change quickly from period to period.

As in Dib (2008a and b), we assumed that the parameter representing the degree of monopoly power in the intermediate good market, ϑ, is equal to 6. In other words, at the steady state the price-markup is 20 percent. Our posterior mean is close to the prior value and its value is equal to 4.03.

The share of imported goods (0.625) in the final good is greater than the non-oil goods (0.415). Indeed, as low-diversified oil-exporting countries, Algeria remains heav-

ily dependent on imported capital goods, intermediate inputs, and also agricultural products[14].

The shares of capital, labor and oil resource in the oil and non-oil sectors exhibited by posterior mean are very close to prior mean. As this latter has been estimated by using Algerian date for the period $1990 - 2009$, the small gap between prior and posterior means shows the relevance of our baseline model to analyze the Algerian economy.

Table 2.4: Estimation results (continued).

	Prior mean	Post mode	S.D	Post mean	[5%	95%]
AR coefficients						
ρ_{R^f}	0.65	0.6027	0.0102	0.5776	0.6747	0.7210
ρ_{a_o}	0.65	0.6911	0.0107	0.6968	0.6628	0.7093
$\rho_{a_{no}}$	0.65	0.6532	0.0070	0.6800	0.5488	0.6068
ρ_{π^f}	0.65	0.6752	0.0102	0.6416	0.6036	0.6662
$\rho_{p_o^f}$	0.65	0.6078	0.0145	0.6240	0.5816	0.6520
ρ_O	0.65	0.6435	0.0153	0.6700	0.6488	0.6937
ρ_ξ	0.65	0.6483	0.0131	0.6581	0.6177	0.7213
S.d of shocks						
σ_{R^f}	0.5	3.7110	0.4480	3.6271	2.9458	4.2551
σ_{a_o}	0.5	0.0914	0.7638	0.1657	0.0504	0.2914
$\sigma_{a_{no}}$	0.5	0.7341	0.0561	0.4275	0.1523	0.7712
σ_{π^f}	0.5	0.1670	0.3170	0.1767	0.0463	0.3304
$\sigma_{p_o^f}$	0.5	0.2905	0.0185	0.3034	0.2670	0.3330
σ_O	0.5	4.6053	1.4088	4.6950	2.5819	7.2561
σ_ξ	0.5	9.1231	0.4013	9.0888	7.9347	10.4582
σ_r	0.5	0.1015	0.0445	0.0445	0.0458	0.0693
Log marg data		-659.462				

The lower part of Table 2.3 exhibits the monetary policy coefficients. Our baseline model suggests that the exchange rate does not play a major role in the monetary policy decisions. Indeed, we see that the posterior mean related to the parameter μ_e is significantly below prior mean, 0.035 and 0.70 respectively. Clearly, according to our baseline model, the Algerian central bank does not react to exchange rate disturbances.

[14] According to the World Trade Organization trade profiles, in 2009, agricultural products and manufactures account for 17.8% and 79.7% of total imports respectively.

This very low coefficient does not imply that Algerian authorities do not monitor exchange rate in their economic policy strategy. In fact, in the aftermath of the dramatic dinar devaluation in 1994 -included in the stabilization program- Algeria has adopted a *de facto* crawling band exchange rate regime.[15]

The main aim with this intermediate regime is to maintain the real effective exchange rate close to its equilibrium and to limit exchange rate volatility. Since 2002 this strategy has been successful: not only the real effective exchange rate is very stable, but also the gap between the real and the nominal effective exchange rates is very small. The low inflationary environment has favored such result. The inconvertibility of the dinar for financial transactions and the small size of the heavily regulated foreign exchange market allow the central bank to not respond directly, by manipulating the interest rate, to exchange rate swings. We see that headline inflation accounts for an important weight in the monetary policy (μ_π is equal to 1.918) while the coefficient associated to core inflation ($\mu_{\pi_{no}}$) is extremely low (-0.045). These coefficients are in line with the practice followed by numerous central banks. They tend to target total inflation instead of core inflation.

The lower part of Table 2.4 suggests that monetary policy in Algeria must face to a volatile environment. Interestingly, standard deviations show that international shocks-EUR/USD exchange rate, oil price, international interest rates and foreign inflation-are among the main disturbances that hit this economy. In addition, it appears from the higher part of Table 2.4 that shocks are also persistent. One of the main lesson of this Table is that many shocks affecting Algeria come from economic variables that are not under the control of the authorities. Considering the major importance of these external shocks for the Algerian economy, the impulse response functions of our baseline model focus on them (see Figure 2.1). Globally speaking, responses of domestic macroeconomic aggregates are consistent with the structural characteristics of the Algerian economy. In addition, as our variables return relatively rapidly to their steady state level after a shock, our model is stationary. Our analysis focuses on contemporaneous responses to shocks.

[15] Using the Reinhart and Rogoff's classification. According to the IMF, Algeria in classified in the category "other managed arrangement with no preannounced path for the exchange rate". See IMF Country Report n°11/39, February 2011.

As expected, GDP, investment and non-oil production increase after a positive oil price shock. Such response is consistent with the sensitiveness of the economy to oil sector. The negative response of oil output may rest on different factors. For this reason, the response is difficult to interpret. On the one hand, it may rest on the willingness of the authorities to limit the oil supply in order to maximize the oil rent. On the other hand, as an OPEC member, Algeria can not freely modify its oil supply according to oil prices changes. As a consequence, at least in the short-run, oil output can be relatively inelastic to prices fluctuations.

Oil price shock implies a positive wealth effect for consumers. Despite the fact that the oil used domestically is refined mostly in foreign countries and then imported, as the authorities subsidize domestic oil products, increase in oil price has few effects on the purchasing power of consumer. As a result, the main consequence of the increase in oil price is positive owing to the place of the oil sector in the economy. Sticky prices, in part due to the presence of subsidize and administrated prices explain the immediate responses of inflation: while the reaction is weak for headline inflation, we see a negative response for core inflation. The contemporaneous response of current account balance is negative but it improves significantly after two periods. This response rests on the strong elasticity of domestic demand to the economic activity. More precisely, the positive wealth effect triggers an increase in domestic spending, and so higher imports. Later, as the value of exports improved, a current account surplus appears. Neither inflation in the import sector nor the real exchange rate react to the oil price shock. Both prices stickiness and the state control explain this response in the import sector. If the real exchange rate reaction to the oil price shock contrasts with other studies on oil-exporting countries and primary commodity exporting-such studies show that the domestic currency tends to appreciate in real terms after a positive primary commodity prices shock- it is consistent with the real exchange rate stability target of the Algerian authorities.

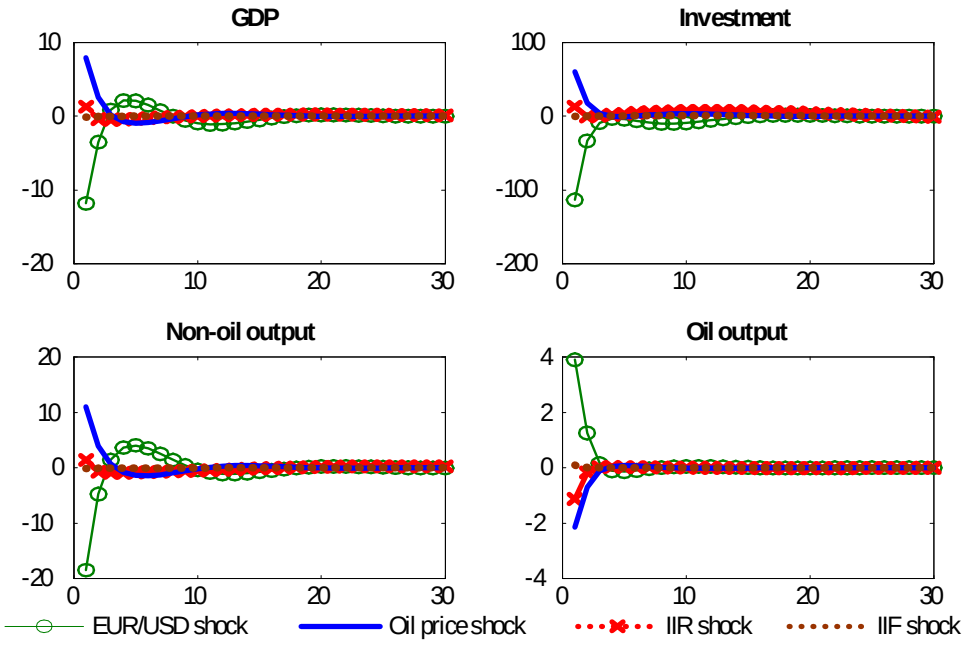


Figure 2.1: Responses to multiple shocks (baseline model)

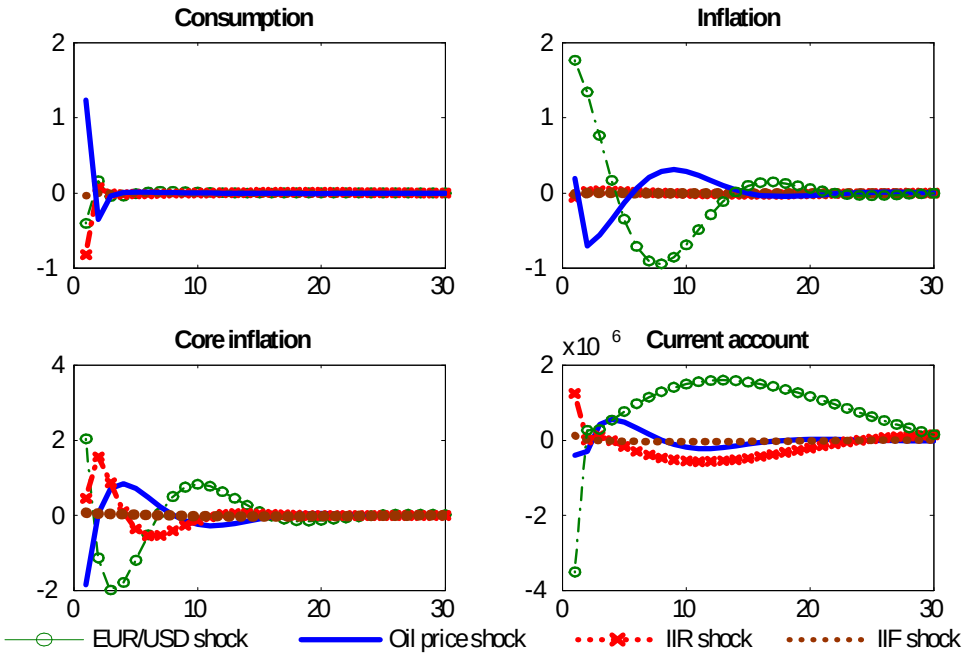


Figure 2.2: Responses to multiple shocks (baseline model)

Exchange rate shock exerts a significant influence on domestic macroeconomic variables. As exports are denominated in dollar and imports mainly in euro, it is important to keep in mind that nominal exchange rate shock is equivalent to terms of trade shock. We see that GDP, investment and non-oil production react negatively to a depreciation of the dollar against the euro. As oil prices are denominated in dollar, the very high share of the oil sector in the Algerian GDP explains the negative response of the latter. The exchange rate shock is equivalent to a negative wealth effect. In turn, the decrease in oil revenue leads to a fall in investment and non-oil output. Indeed, non-hydrocarbon sector is affected by the exchange rate shock *via* the fiscal expenditure policy which is dependent from oil revenue. The hydrocarbon stabilization fund established in 2000 has a limited impact on the pro-cyclicity of the fiscal policy. In other words, the volatility of the non-oil sector is significantly linked to the volatility of the oil sector. As the main trade partners of Algeria belong to the Euro area, the exchange rate shock leads to an increase in imported inflation that, in turn, induces a positive response of both headline and core inflation. As expected, consumption decreases on the impact of the exchange rate shock according to a negative wealth effect. The current account balance strongly deteriorates. Indeed, in accordance with a J-curve effect, the immediate effect of the exchange rate shock is a decrease in the value of exports with the depreciation of dollar while the value of imports tends to increase with the euro appreciation. After several periods, trade volumes adjust to the shock and the current account improves. Inflation in the import sector does not respond to the exchange rate shock. The real exchange rate appreciates on the impact of the shock, but the response is short-lived.

Both the international interest rate and the foreign inflation shocks tend to exert a weaker influence on domestic variables. The weak influence of the international interest rate rests on the relatively low level of financial openness of Algeria. Whatever the indicator of financial openness -the *de jure* Chinn and Ito's index or the *de facto* Lane and Milesi-Ferretti's estimate- it appears that the Algerian economy is among the least open one. Recall that the dinar remains inconvertible for capital transactions.
In 2008, according to the Chinn and Ito's index, Algeria has been ranked at the 113th position over 182 countries in terms of financial openness.[16] As suggested by the

[16]The *de facto* measure gives a similar picture. In 2007, the volume-based measure of financial integration -that is the sum of the stock of foreign assets and liabilities divided by the GDP- was

responses of domestic variables to the foreign inflation shock, the Algerian economy seems very few sensitive to external nominal foreign disturbances. The prevalence of real external shocks relative to nominal ones has important implications to assess the choice of the right monetary policy rule. Such a rule must favor both the stabilization of the inflation rate and the low volatility of production. In this perspective, a strict inflation targeting framework -in which the central bank targets only the deviation of the CPI inflation rate relative to its steady state equilibrium- may lead to excessive volatility of real macroeconomic variables (see the pioneer work by Svensson (2000)). Such a volatility when the economy is mainly hit by real shocks.

2.2.4.2 External shocks under alternative monetary policy rules

Figures 2.4 to 2.15 exhibit the responses of our domestic macroeconomic aggregates to four shocks: oil price, international interest rate, nominal exchange rate, and foreign inflation respectively. We show the results for the baseline model and the three monetary policy rules introduced in subsection 2.6: strict inflation targeting rule (IT rule), core inflation targeting rule (CIT rule) and exchange rate rule (ER rule). The importance of each monetary policy will be deduced from the gap of the responses of our selected variables shown in each figure. The aim is to determine the monetary policy rule that both minimizes the macroeconomic volatility and maintains the inflation rate at a low level once we take into account the main shocks that hit this country.

2.2.4.2.1 Effects of an oil price shock To analyze the effects of oil price shock, we distinguish the responses of real macroeconomic variables and inflation respectively under alternative monetary policy rules. Results on real variables show that, except for oil output, the alternative monetary policy rules provide better outcomes than the baseline model. This suggests that the current monetary policy followed by the central bank is not optimal to respond to oil price shocks. Both GDP, non-oil output, and consumption exhibit weaker contemporaneous responses under the core-inflation targeting rule. We find no significant differences for investment between the two inflation

104.1 per cent for Algeria against 182.1 percent for emerging countries. Authors' calculations using the updated and extended version of the External wealth of nations, Mark II database developed by Lane and Milesi-Ferretti (2007).

rules while the exchange rate rule does not allow a smooth response of this variable. Immediate responses are only one side to consider the monetary policy rule best adapted to shocks affecting the economy. The analysis of the adjustment is the other side. Adjustment refers to the speed at which a specific variable returns to its steady state level. Under the baseline model and the exchange rate rule, all real variables follow an unstable adjustment process. More precisely, our results shows that short-run fluctuations are sizeable under these two scenarios. Inflation targeting and core-inflation targeting rules do not exhibit significant different adjustment process.

Responses of headline inflation and core-inflation give more mixed results. On the impact of the shock, the weakest response for total inflation is obtained with the baseline model while the core-inflation targeting rule is the best one to limit the response of core-inflation. In the last cases, the worst monetary policy is the exchange rate rule. The analysis of the adjustment process confirms the latter result. Thus the exchange rate rule tends to be accompanied by sizeable short-run fluctuations. At the opposite, core-inflation targeting offers the most stable adjustment for both headline and core inflation.

After the oil price shock, inflation in the import sector exhibits the strongest response under the inflation targeting rule. Such result confirms findings in the previous literature on strict inflation targeting. This monetary regime induces wide fluctuations of the macroeconomic variables. Interestingly, as suggested by the adjustment process, this monetary rule does not allow a rapid adjustment of inflation in the import sector. The inflation targeting rule exerts a weaker influence on the contemporaneous response of the real exchange rate. We find the opposite for the core-inflation rule. But we need to be cautious to interpret these results as all alternative rules and the baseline model show only very short-lived responses of the real exchange rate to the oil price shock.

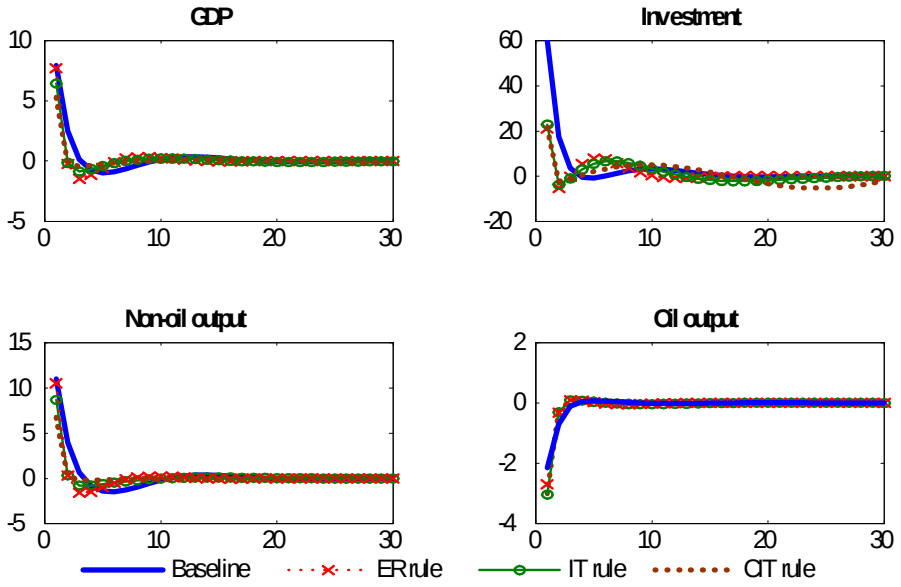


Figure 2.4: The effect of 1% positive oil price shock

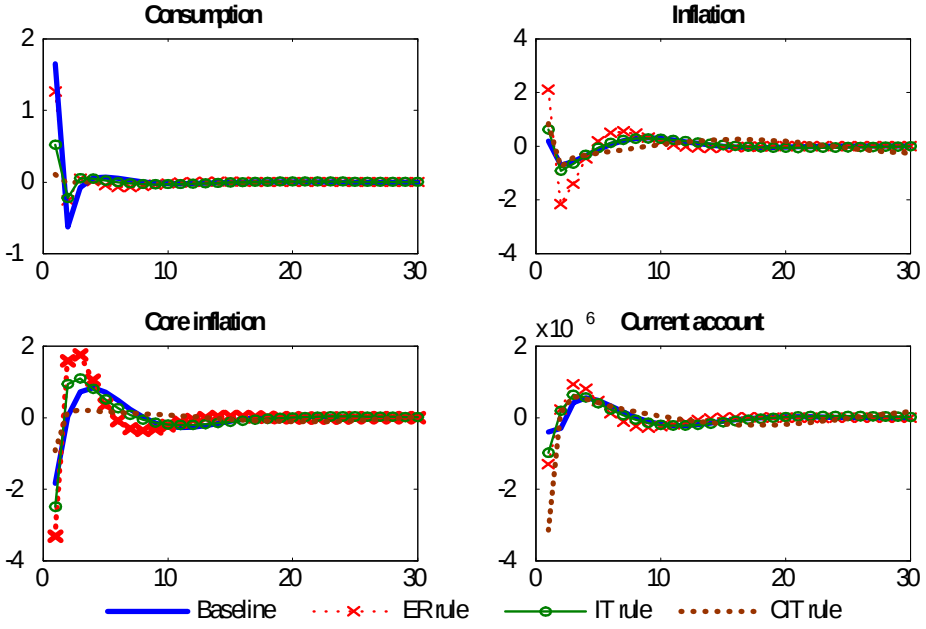


Figure 2.5: The effect of 1% positive oil price shock

To sum up, we see that the exchange rate rule is especially inefficient to respond to oil price shocks. Indeed, this rule implies a too reactive interest rate reaction to

any exchange rate deviation from its equilibrium state. Such reaction leads to a high volatility of macroeconomic variables.

Our results suggest at the same time that exchange rate rule is unable to stabilize inflation. From this perspective, if we consider the trade-off macroeconomic stabilization-low inflation environment, we find that the core-inflation targeting rule is superior to the inflation targeting rule.

Our results are in line with the recent literature on monetary policy in small open economies (Parrado (2004); Medina and Soto (2005) and Dhawan and Jeske (2007)). In the case of Algeria, targeting core-inflation instead of headline inflation allows to avoid the potential monetary policy overreaction due to oil prices fluctuations. Recall that this shock is one of the main affecting Algerian economy (see Table 2.4).

2.2.4.2.2 Effects of EUR/USD exchange rate shock In the case of exchange rate shock, all contemporaneous responses but one (the real exchange rate) are weaker under the CIT rule. At the same time, this monetary policy rule allows the smoother adjustment after the shock. Interestingly, both the baseline model and the exchange rate rule lead to higher macroeconomic volatility. More precisely, Figures 2.7-2.9 shows that real variables such as GDP, consumption, investment, oil and non-oil production, and the current account) have stronger short-run responses relatively to the core inflation targeting. This result suggests that the central bank overreacts if the exchange rate is targeted (as in the case of exchange rate rule) or if it targets both oil price and exchange rate (in the case of our baseline model). The exchange rate rule is especially effective to stabilize the real exchange rate in the aftermath of the shock. However, when assessing the pro and cons of alternative monetary rules, this effectiveness must not be overestimated, for two main reasons. Firstly, as exhibited in Figure 2.9, the responses of the real exchange rate are short-lived whatever the monetary rule. Secondly, as we stressed above, the Algerian foreign exchange market is very thin. The central bank is the sole seller of foreign exchange. More precisely, the central bank accumulates foreign exchange reserves by beneficing from the revenues due to hydrocarbon exports. Foreign exchange reserves are the main instrument used by the authorities to monitor the dinar exchange rate. In other words, the nominal interest rate is not constrained by the exchange rate target.

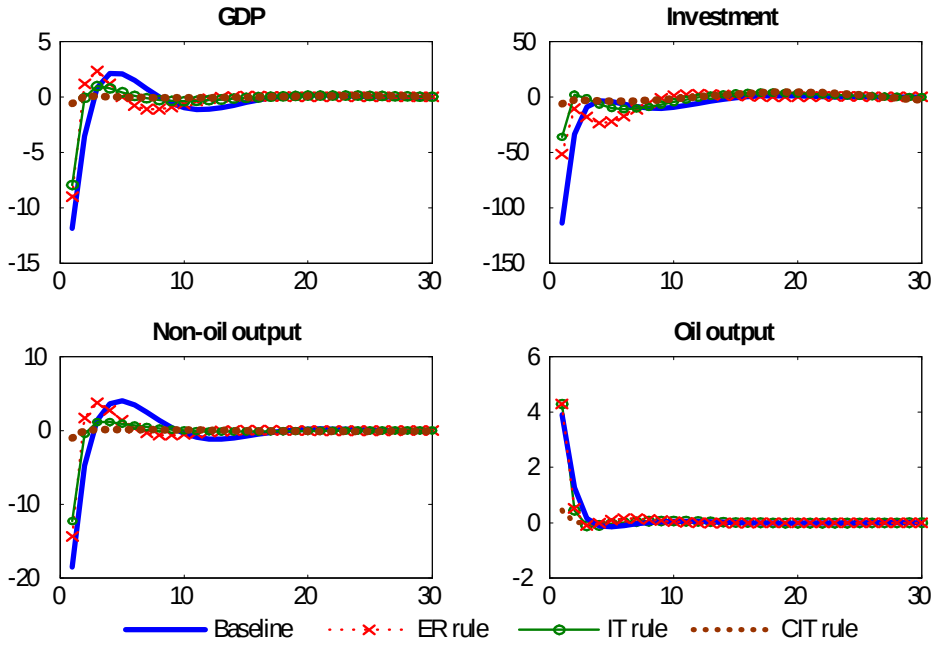


Figure 2.7: The effect of 1% positive EUR/USD shock

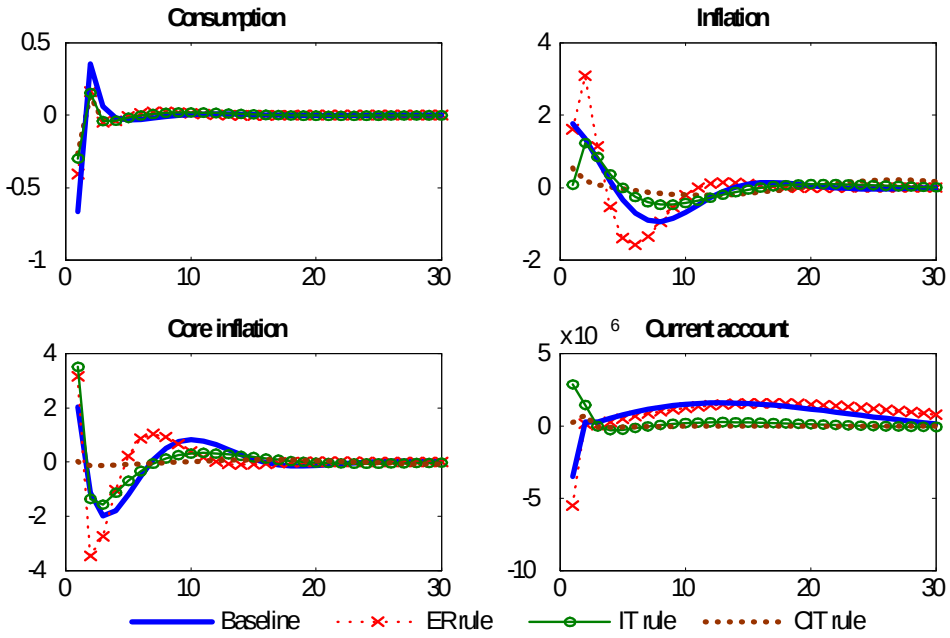


Figure 2.8: The effect of 1% positive EUR/USD shock

2.2.4.2.3 Effects of international interest rate and foreign inflations shocks

The responses and adjustment of our variables of interest exhibit a very low reaction in the case of core inflation targeting. Indeed, in the case of international interest rate and foreign inflation shocks, figure (2.10-2.15) show that the reaction of the most of selected variables (GDP, investment, non-oil and oil output and consumption, for example) is negligible in the case of CIT rule compared to the other two monetary policy rules, namely, IT and ER rules. This result is similar to the previous two shocks.

2.2.4.3 Business cycle properties

In this section, we compare the statistical properties of the model against those of the data. To do so, we estimate a Bayesian Vector Autoregression (BVAR) model using the same data set.

2.2.4.3.1 Volatility and correlation In what follows, we assess the performance of our DSGE model by considering the model implied volatilities (standard deviation) and correlation of some variables of interest in the data and from the model. Table 2.5 reports the results of the DSGE model and the BVAR model. The standard deviations are expressed in percentage terms.

Columns 2 and 3 display standard deviations of seven selected variables (GDP, consumption, oil output, inflation, international oil price, international interest rate and real exchange rate). The main striking lesson from Table 2.5 is the consistency of our results. Indeed, variables with the higher volatility relative to the GDP (Y) are also the most volatile ones in the DSGE model. The only exception is the international oil price (P_o^f) for which we find a lower volatility in the DSGE model. In the two specifications, the domestic headline inflation (π) exhibits the lowest volatility. The fact that the international oil price and the headline inflation have a low volatility is common feature in New-Keynesian models with price and/or wage rigidities (Dib (2008b)).
Columns 4 and 5 report the cross-correlation for our key variables. The results show that the correlation is positive between GDP and consumption, oil price and oil output in both BVAR and baseline models. The remaining variables, such as exchange rate, inflation, and international interest rate are negatively correlated with real GDP. Glob-

Table 2.5: Volatility and correlation.

Variables	Volatility		Correlation with GDP	
	VAR model	DSGE model	VAR model	DSGE model
Y	0.20	0.2570	–	–
c	0.569	0.4515	0.1283	0.7352
Y_o	0.303	0.2958	0.8129	0.8860
π	0.035	0.0435	−0.1602	−0.1831
P_o^f	0.758	0.1864	0.7585	0.0379
R^f	0.463	0.5479	−0.5418	−0.1530
s	0.332	0.4142	−0.8316	−0.7538

ally speaking, the baseline model succeeded well in reproducing the results obtained by the BVAR model.

2.2.4.3.2 Variance decomposition Our previous findings are confirmed by the variance decomposition: Algeria is especially sensitive to real shocks. Thus, technology shocks in both oil and non-oil sectors are the predominant source of macroeconomic fluctuations. This is common feature in New-Keynesian models, in which the main source of business cycle fluctuation is technology shocks. For instance, technological shocks in oil sector account for 56.21 percent of the variation in the GDP and 31.54 percent of the variation in the consumption. In the non-oil sector, the same shock explain 10.86 percent and 11.66 of the variance of GDP and consumption respectively.

Table 2.6: Variance decomposition.

	ε_{R^f}	$\varepsilon_{p_o^f}$	ε_{π}^{f}	ε_{ξ}	ε_{a_o}	$\varepsilon_{a_{no}}$	ε_{o}	ε_{R}
Y_t	4.65	6.41	0.14	1.33	56.21	10.86	19.30	1.11
c_t	1.71	42.62	0.40	2.83	31.54	11.66	6.09	3.14
i_t	1.79	36.36	0.57	2.18	18.95	29.91	5.78	4.46
$Y_{o,t}$	5.96	9.04	0.06	2.51	76.34	4.70	0.91	0.48
$Y_{no,t}$	3.32	4.39	0.09	1.30	28.02	52.11	10.07	0.71
π_t	2.12	9.21	0.77	0.80	40.34	34.11	6.59	6.06
$\pi_{no,t}$	2.39	6.37	0.15	0.91	43.65	38.03	7.35	1.16
$q_{o,t}$	0.43	14.55	0.13	0.88	72.98	8.41	1.63	0.99
$q_{no,t}$	0.52	15.07	0.19	0.86	9.96	69.96	1.92	1.51

Interestingly, prices and monetary shocks tend to exert a weaker influence on macroeconomic variables. For instance, international interest rate and foreign inflation shocks explain only a small share of the variance decomposition of our domestic variables. The low financial openness of Algeria explains this result. Similarly, the low degree of financial development explains the weak influence of domestic interest rate shocks, except for total inflation. More precisely, the main instrument used by the Algerian central bank is not the interest rate -despite the introduction of open market operations in 1996- but the control of banking liquidity. To this end, the central bank continues to use indirect instruments such as reserve requirements and credit auctions.

2.3 Conclusion

In this chapter, we estimated a multisector DSGE model for an oil exporting economy based on the features of the Algerian economy. To our knowledge, it's one of the first papers using an estimated DSGE model dedicated to this country. Building a three sectors model, we attempted to compare the response of some selected variables to external shocks and to evaluate three alternative monetary policy rules for Algerian economy. We try to shed some light to the following question: given the vulnerability of an oil exporting economy to external shocks, what is the appropriate monetary policy rule for Algerian economy? In a first step, we analyzed our results from our baseline model by focusing on posterior means and impulse response functions. In a second step, we compared different monetary rules.

Our main findings show that, over the period 1990Q1-2010Q4, core inflation target is the best monetary rule to stabilize both output and inflation. In other words, the current monetary policy -corresponding to our baseline model- followed by the Algerian central bank is not well-suited to face to oil shocks. These results are two main policy implications. Firstly, they suggest that Algeria should modify its monetary policy in order to adopt a core inflation targeting framework. This implies to fulfill some preconditions such as the central bank independence. Secondly, Algerian authorities must strengthen the influence of interest rate as a transmission channel of the monetary policy. To this end, they must promote banking lending to the private sector and the development of the capital market. On these two points, Algeria lags relative to other

upper middle income countries, especially in MENA region, preventing the use of the interest rate as the main instrument of the monetary policy.

Chapter 3

The Dutch Disease Effect in a High vs Low Oil dependent countries

Introduction

Since the early 2000's, oil price has risen dramatically. This increase is similar to the two oil shocks of 1973 and 1979. The price of Brent increased fivefold, exceeding for the first time 100 US Dollars (see figure 3.1). High oil price has an important impact on macroeconomic performances in importing and exporting oil countries. Indeed, the raise of commodity prices (particularly oil prices), may have, as stressed in the literature, three major consequences: high inflation, economic volatility and the Dutch disease.

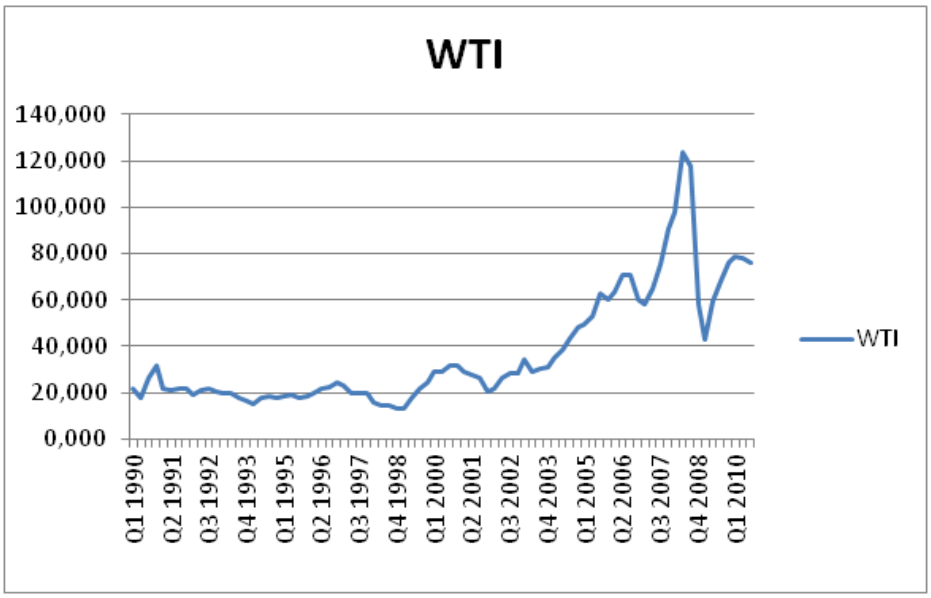


Figure 3.1: Evolution of oil price (WTI) between 1990 and 2010

Regarding importing countries, as the United-States and the Euro Area, studies such as Bernanke, Gertler and Watson (1997, 2004), Hamilton and Herrera (2004), and Blanchard and Gali (2010) show that the increase in oil prices has not only a negative effect on both inflation and growth, but also on economic volatility.

Regarding oil-exporting countries, the most cited impact in the literature is that of Dutch disease. Following Corden and Neary (1982) and Corden (1984), the Dutch disease shows that an exogenous increase in resource prices or in resource output results in real exchange rate appreciation and a decline in the manufacturing sector. This effect occurs mainly in two forms: the spending effect and the resource movement effect. The spending effect can be defined as the negative consequence of real exchange rate appreciation on manufacturing sector production. The resource movement effect results from the perfect mobility of capital and labor from the manufacturing sector to the oil and services sectors. This effect occurs because an increase in oil prices generates a rise in wages and/or profits and generates a rise in aggregate demand in the economy. To the extent that a part of this demand will move toward the service sector, the price of non-tradable goods will rise. Consequently, the real exchange rate appreciates and lead to a de-industrialization process.

Since the studies of Corden and Neary (1982) and Corden (1984), the Dutch disease theory has been the object of an extensive literature. Indeed, the Dutch disease effect has been studied theoretically and empirically for oil exporting economies but also for emerging and developed economies. Theoretical models used were developed, first, in a partial equilibrium framework as in Corden and Neary (1982) and Corden (1984). General equilibrium framework has been elaborated in more recent studies as Sosunov and Zamulin (2007), Lartey (2008), Batt et al (2008), Acosta, Lartey and Mandelman (2009), Lama and Medina (2010) and Benkhodja (2011). Indeed, these papers use Dynamic Stochastic General Equilibrium (DSGE) models to assess the impact of external shocks in the case of a small open economy.

Empirically, the Dutch disease has been tested using cointegration models to capture the impact of oil prices shocks as in Oomes and Kalcheva (2007) and Jahan-Parvar and Mohammadi (2011). The main drawback of these studies is to consider the Dutch disease in oil exporting economies whatever their oil dependence. However, all oil exporting countries are not identical in terms of their dependence on oil. In other words, in some countries, exports of oil may exceed 70% of total exports, while in other countries, oil exports account for, only, a small part of total exports. This difference is crucial because the most dependent countries to their oil exports are more vulnerable to oil price shock compared to the other countries. From this perspective, the main aim of this paper is twofold: first, to determine to what extent the degree of dependence on oil exports matters to induce the Dutch disease effect; and second, to identify the best monetary policy rule to face to the Dutch disease.

To investigate the impact of the recent increase of oil price on a small open oil exporting economy, we estimate a Dynamic, Stochastic, General equilibrium (DSGE) model for some oil producing countries using the Bayesian approach. We build a small open economy model with four sectors while the above mentioned contributions build DSGE models with only tradable and non-tradable sectors. In this paper we add an oil sector to better reflect the mechanisms of the Dutch disease described in the literature by Corden and Neary (1982). The latter assume that the economy is composed of three sectors: 1) *the booming sector*: after the discovery of a new resource or a technological progress in the commodity sector or a rise of natural resource price; 2) *the lagging*

sector: generally refers to the manufacturing sector but can also refer to agriculture; 3) *the non-tradable sector*: includes services, utilities, transportation, etc.

Table 3.1: Oil Exporting Countries Ranked According to their Dependence Degree to Oil Sector.

	$\frac{X_o}{X}$*	$\frac{X_o}{GDP}$**
Algeria	97,70	35,59
Venezuela	95,90	21,25
Kuwait	93,21	46,54
Libya***	92,61	59,31
Nigeria	90,36	34,36
Saudi Arabia	87,58	48,07
Gabon	85,61	50,98
Oman	79,04	43,62
Russia	66,69	13,94
United Arab Emirates	64,81	25,66
Ecuador	50,32	16,68
Egypt	43,98	3,68
Indonesia	28,42	2,22
Malaysia	14,81	7,44
Mexico	13,51	4,03
Argentina	10,34	1,71
Median	72,865	23,455

* Fuel exports in % of merchandise exports in 2009. World Bank, World dataBank

** Oil exports in % of GDP (2010). International Monetary Fund, World Economic Outlook Database, October 2011

*** Last available data: 1998.

Our model is based on recent studies that have developed models for small open oil exporting economies (Dib (2008) and Benkhodja (2011)). We assume that the economy is inhabited by eight agents: households, oil producing firms, non-tradable and manufacturing goods producers, an intermediate foreign goods importer, a final good producer, a central bank and a government. Households have access to international financial markets where they can buy or sell foreign non-state contingent bonds. In both oil, manufacturing and final goods sectors, each producer operates under perfect

competition, while in the non-tradable goods and imports sectors, there is a continuum of monopolistically-competitive firms. These firms set their prices à la Calvo (1983) and Yun (1996). The central bank sets the short-term nominal interest rate following a Taylor rule, aimed at stabilizing the CPI inflation rate, changes in the nominal exchange rate and the output gap.

Empirically, we consider a sample of 16 oil exporting countries (Algeria, Argentina, Ecuador, Gabon, Indonesia, Kuwait, Libya, Malaysia, Mexico, Nigeria, Oman, Russia, Saudi Arabia, United Arab Emirates, and Venezuela) over the period from 1980 to 2010, except for Russia where our sample begins in 1992. We use quarterly detrended data extracted from the International Financial Statistics provided by the IMF. In order to distinguish between high-dependent and low-dependent countries, we use two indicators: the ratio of fuel exports to total merchandise exports and the ratio of oil exports to GDP. We estimate the median for each ratio on our 16 studied countries. Countries above (below) the median are considered as high (low) oil dependent economies (see Table 3.1). We verify if the first group is more sensitive to the Dutch disease effect.

In this chapter, we also assess the role of monetary policy. For this, we evaluate the efficiency of two policy rules, namely exchange rate (ER) and inflation targeting (IT) rules. The choice of these rules is important in the case of a Dutch disease. Indeed, since the Dutch disease occurs under the spending and the resource movement effects, each monetary policy could play a central role to avoid this effect. Theoretically, in the case of an ER rule, the exchange rate will be fixed, which will lead to lock the spending effect channel. Similarly for the IT rule, the inflation rate will be stabilized. Knowing that wages are indexed to price index, this rule will prevent the resource movement effect. Thus, It would be interesting to verify if, empirically, these rules could prevent the Dutch disease.

Our main findings show that in the first sample, namely high oil dependant economies, 6 countries are affected by the Dutch disease (decrease in the manufacturing production). The other sample, low oil dependant countries, are less affected by the fluctuation of oil price. Indeed, only one country has suffered a Dutch disease effect after the shock. In this paper, it also appears that the flexible exchange rate seems to be the best way to avoid the Dutch disease under its both spending and resource movement effects. In

other words, it is preferable for a central bank, in a high oil dependant countries, to adopt inflation targeting regime to prevent the impact of oil shocks.

The remainder of the chapter is organized as follows. Section 2, presents the model. Section 3, describes solving and calibration methods. Section 4, discusses the data and the estimation results. Section 5 determines the best monetary policy rule. Section 6 concludes.

3.1 The model

As in previous studies (Dib (2008) and Benkhodja (2011)), we assume that the economy is inhabited by eight agents: households, oil producing firms, non-tradable and manufacturing goods producers, an intermediate foreign goods importer, a final good producer, a central bank and a government.

Households have access to international financial markets where they can buy or sell foreign non-state contingent bonds. In both oil, manufacturing and final goods sectors, each producer operates under perfect competition, while in the non-tradable goods and imports sectors, there is a continuum of monopolistically-competitive firms. These firms set their prices à la Clavo (1983) and Yun (1996). The central bank sets the short-term nominal interest rate following a Taylor rule, aimed at stabilizing the CPI inflation rate, changes in the nominal exchange rate and the output gap.

3.1.1 Households

There is a continuum of households indexed by $\iota \in (0,1)$. Each household ι derives utility from consumption, $c_t(\iota)$, and disutility from labor, $h_t(\iota)$:

$$U_0(\iota) = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\gamma} \eta_t \left(\frac{c_t(\iota)}{c_{t-1}(\iota)^{\varpi}} \right)^{1-\gamma} - \varsigma_t \frac{h_t(\iota)^{1+\sigma}}{1+\sigma} \right\}, \tag{3.1}$$

where E_0 is the conditional expectation operator, $(0 < \beta < 1)$ is the subjective discount factor and $\gamma > 1$ and $\sigma > 0$ are the inverse of the elasticity of intertemporal substitution of consumption and the inverse of the wage elasticity of labor supply, respectively;

$\varpi \in (0,1)$ is a habit formation parameter and η_t and ς_t denote respectively a taste shock and the labor supply shock.

We assume that the aggregate labor supply, $h_t(\iota)$, depends on sector-specific labor supplies according to:

$$h_t(\iota) = h_{o,t}(\iota)^{\alpha_{ho}} h_{nT,t}(\iota)^{\alpha_{hnT}} h_{M,t}(\iota)^{\alpha_{hM}}, \tag{3.2}$$

where $h_{o,t}(\iota)$, $h_{nT,t}(\iota)$ and $h_{M,t}(\iota)$ represent hours worked by the household ι at time t in oil, non-tradable and manufacturing sectors, respectively. The parameters $\alpha_{ho}, \alpha_{hnT}$ and α_{hM} denote the elasticity of substitution of the labor in the three sectors, where $\alpha_{ho} + \alpha_{hnT} + \alpha_{hM} = 1$. The household's budget constraint in period t is:

$$P_t(c_t(\iota) + i_t(\iota)) + \frac{B_t^d(\iota)}{R_t} + \frac{e_t B_t^f(\iota)}{R_t^f \kappa_t} \preceq B_{t-1}^d(\iota) + e_t B_{t-1}^f(\iota) + \sum_{j=o,M,nT} Q_{j,t} k_{j,t}(\iota) + (1-\varkappa) \sum_{j=o,M,nT} W_{j,t} h_{j,t}(\iota) + \varrho(\iota) P_{O,t} O_t + D_t, \tag{3.3}$$

where c_t denotes total consumption and $P_t i_t = P_{o,t} i_{o,t} + P_{M,t} i_{M,t} + P_{nT,t} i_{nT,t}$ denotes total investment, P_t is the consumption price index (CPI), R_t is the gross nominal interest rate on domestic debt, B_t^d, between t and $t+1$, $W_{o,t}, W_{M,t}$ and $W_{nT,t}$ are the nominal wages received by the household, in period t, for its labor supply in the oil, manufacturing, and non-tradable sectors respectively, $D_t = D_{nT,t} + D_{I,t}$ is the dividend payment received from non-tradable and import firms, $\varrho(\iota) P_{O,t} O_t$ is the factor payment of oil resources, where $P_{O,t}$ is the nominal price of oil resource input O_t and $\varrho(\iota)$ is the share of the household ι in oil resource payment with $\int_0^1 \varrho(\iota)\, d\iota = 1$, $B_{t-1}^d(\iota)$ and $B_{t-1}^f(\iota)$ denote, respectively, domestic non-state-contingent bonds denominated in units of domestic currency and foreign bonds denominated in units of foreign currency. We assume that the representative household enter period t with holdings of domestic and foreign non-state contingent bonds because in oil exporting economies, household's consumption is not smooth and there is no international risk sharing. Also, since the dynamics of exchange rate and the current account play a central role in explaning the spending effect, the assumption of the incomplete international financial markets

is necessary. The parameter, $\varkappa$, denotes a lump-sum tax paid by the representative household to finance government spending. At time t, B_t^f is bought or sold by household for the price that depends on the world interest rate R_t^f and a country-specific risk-premium, κ_t. The latter has the following functional form:

$$\kappa_t = \exp\left(-\phi \frac{e_t \widetilde{B_t^f} / P_t^f}{P_t Y_t}\right), \tag{3.4}$$

where ϕ denotes the parameter measuring the risk premium, e_t is the nominal exchange rate and $\widetilde{B_t^f}$ is the average nominal stock of external debt which take either a positive value if the domestic economy is a net borrower or negative value if the domestic economy is a net lender[1]. Note finally that, Y_t, is the total real GDP, and P_t^f is the foreign price index. By following this functional form, the model would not have a unit root because the holding bond would not follow a random walk[2]. The risk premium also ensures that the model has a unique steady state.

Note finally that the representative household accumulates $k_{o,t}, k_{M,t}$ and $k_{nT,t}$ units of capital stocks, used in the oil, manufacturing and non-tradable sectors and receives nominal rentals $Q_{o,t}, Q_{M,t}$ and $Q_{nT,t}$ respectively. The law of motion of capital stock in each sector is given by:

$$k_{j,t+1}(\iota) = (1-\delta)k_{j,t}(\iota) + i_{j,t}(\iota) - \Psi_j\left(k_{j,t+1}(\iota), k_{j,t}(\iota)\right), \tag{3.5}$$

where δ is depreciation rate, common to all sectors $(0 < \delta < 1)$ and $\Psi_{j,t}(\mathrm{k}_{j,t+1}(\iota), \mathrm{k}_{j,t}(\iota))$ is an adjustment cost paid by households and satisfy $\psi_j(0) = 0, \psi_j^{'}(.) > 0$ and $\psi_j^{''}(.) < 0$. The functional form of $\Psi_j(.)$ is:

$$\Psi_{j,t}(.) = \frac{\psi_j}{2}\left(\frac{k_{j,t+1}(\iota)}{k_{j,t}(\iota)} - 1\right)^2 k_{j,t}(\iota). \tag{3.6}$$

[1] If the domestic economy is a net lender households receive a lower remuneration on their saving. If the economy is a net lender, households charge a premium on the foreign interest rate. In our case, we assume that $B_t^f < 0$ to the extent that several oil exporting economies are net borrower.

[2] The risk premium associated with asset transactions is an increasing function of a monotonic transformation of the external debt to output ratio. This feature has the additional positive externality of making the model stationary à la Schmitt-Grohé and Uribe (2003).

3.1.1.1 Consumption decision

Given initial values, each household ι chooses $\{\mathrm{c}_t(\iota),\ \mathrm{h}_t(\iota),\ \mathrm{k}_{o,t+1}(\iota),\ \mathrm{k}_{M,t+1}(\iota),\ \mathrm{k}_{nT,t+1}(\iota),\ \mathrm{B}_t^d(\iota)$ and $\mathrm{B}_t^f(\iota)\}$ to maximize equation (3.1) subject to equations (3.3),(3.5) and (3.6) and the no-Ponzi game restriction. This latter take the following form:

$$\lim_{T\to\infty}\left(\prod_{t=0}^{T}\frac{1}{\kappa_t R_t^f}\right)B_T^f(\iota)=0. \tag{3.7}$$

Equation (3.7) implies that households are unable to finance consumption indefinitely by borrowing, i.e, by having negative financial asset.

The first order conditions of the household's optimization problem are:

$$\eta_t\left(\frac{c_t(\iota)}{c_{t-1}(\iota)^{\varpi}}\right)^{1-\gamma}-\varpi\beta E_t\left(\eta_t\frac{c_{t+1}(\iota)}{c_{t-1}(\iota)^{\varpi}}\right)^{1-\gamma}=c_t(\iota)\lambda_t \tag{3.8}$$

$$\begin{aligned}\beta E_t\left[\lambda_{t+1}(\iota)\left(\psi_j\left(\frac{k_{j,t+2}(\iota)}{k_{j,t+1}(\iota)}-1\right)\left(\frac{k_{j,t+2}(\iota)}{k_{j,t+1}(\iota)}\right)-\frac{\psi_j}{2}\left(\frac{k_{j,t+2}(\iota)}{k_{j,t+1}(\iota)}-1\right)^2+1-\delta+q_{j,t+1}\right)\right]\\ =\lambda_t(\iota)\left[\psi_j\left(\frac{k_{j,t+1}(\iota)}{k_{j,t}(\iota)}-1\right)+1\right],\quad \text{for } j=o,M,nT\end{aligned} \tag{3.9}$$

$$\lambda_t(\iota)=\beta E_t\left(\frac{\lambda_{t+1}(\iota)}{\pi_{t+1}(\iota)}\right)R_t, \tag{3.10}$$

$$\frac{\lambda_t(\iota)s_t}{R_t^f\kappa_t}=\beta E_t\left(\frac{\lambda_{t+1}(\iota)s_{t+1}}{\pi_{t+1}^f}\right), \tag{3.11}$$

where $q_{j,t}=\frac{Q_{j,t}}{P_t}$, $\pi_{t+1}=\frac{P_{t+1}}{P_t}$, $\pi_{t+1}^f=\frac{P_{t+1}^f}{P_t^f}$ and $s_t=\frac{e_tP_t^f}{P_t}$ represent the real capital return in each sector, the CPI inflation rate, the world inflation rate and the real exchange rate respectively. In addition, $\lambda_t(\iota)$ denotes the budget multiplier associated with the budget constraint.

By combining equations (3.10) and (3.11) we obtain equation (3.12) which represents a modified uncovered interest rate parity (UIP) condition:

$$\frac{R_t}{R_t^f \kappa_t} = \frac{e_{t+1}}{e_t}. \tag{3.12}$$

3.1.1.2 Wage setting

As in Erceg, Henderson and Levin (2000), we assume that households are monopolistic suppliers of differenciated labor services to the three production sectors, namely oil, manufacturing and non-tradable sectors. Following these authors, a representative labor aggregator combines households' hours in the same proportions as firms would choose optimally. Thus, in each sector j, the demand curve for each type of labor is:

$$h_{j,t}(\iota) = \left(\frac{W_{j,t}(\iota)}{W_{j,t}} \right)^{-\theta} h_{j,t}. \tag{3.13}$$

variables $h_{o,t}, h_{M,t}$ and $h_{nT,t}$ denote aggregate labor supplies to oil, manufacturing and non-tradable sectors respectively, $\theta > 1$ denotes the constant elasticity of substitution between different types of labor services, $W_{j,t}(\iota)$ is the wage rate set by the household ι and $W_{o,t}, W_{M,t}$ and $W_{nT,t}$ are the aggregate wage index, or the unit cost of sales to the oil, manufacturing and non-tradable sectors, respectively.

The aggregate wage index $W_{j,t}$ in sector j is given by:

$$W_{j,t} = \left(\int_0^1 W_{j,t}(\iota)^{1-\theta} \, d\iota \right)^{\frac{1}{1-\theta}}, \tag{3.14}$$

where $W_{j,t}$ and $h_{j,t}$ are considered as given.

Households set nominal wages according to a stochastic time dependent rule as in Calvo (1983) and Yun (1996). In each period, the constant probability of changing the nominal wages is given by $(1-\varphi_j)$. Therefore, in average, the wage remains unchanged for $\frac{1}{1-\varphi_j}$ periods. However, if household ι is not allowed to adjust its wage, it updates it according to the following rule:

$$W_{j,t} = \overline{\pi} W_{j,t-1},$$

where $\overline{\pi} > 1$ is the long run average gross rate inflation. Thus, the aggregate real wage index in sector j, evolves over time according to:

$$(w_{j,t})^{1-\theta} = \varphi_j \left(\pi \frac{w_{j,t-1}}{\pi_t} \right)^{1-\theta} + (1-\varphi_j) (\widetilde{w}_{j,t})^{1-\theta}, \tag{3.15}$$

where $\widetilde{w}_{j,t}(\iota) = \frac{\widetilde{W}_{j,t}(\iota)}{P_t}$ and $w_{j,t+s} = \frac{W_{j,t+s}}{P_{t+s}}$ denote the real optimized wage and the real wage in sector j respectively.

In the case where re-optimization is possible, household ι chooses $\widetilde{W}_{j,t}(\iota)$, for the production sectors $j = o, M, nT$, to maximize:

$$\max_{\widetilde{W}_{j,t}(\iota)} E_t \left[\sum_{s=0}^{\infty} (\beta\varphi_j)^s \left(U(c_{t+s}(\iota), h_{t+s}(\iota)) + \lambda_{t+s} \pi^s \widetilde{W}_{j,t+s}(\iota) h_{j,t+s}(\iota) / P_{t+s} \right) \right], \tag{3.16}$$

subject to (3.13). The first order condition for $\widetilde{W}_{j,t}(\iota)$, gives:

$$\widetilde{w}_{j,t}(\iota) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta\varphi_j)^s \lambda_{t+s} h_{j,t+s} \Lambda_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{-\theta s} \pi_{t+k}^{\theta}}{E_t \sum_{s=0}^{\infty} (\beta\varphi_j)^s \lambda_{t+s} h_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{s(1-\theta)} \pi_{t+k}^{\theta-1}}. \tag{3.17}$$

for each sector j, $\Lambda_{j,t} = \alpha_{j,t} \frac{h_t^{1+\sigma}}{h_{j,t} \lambda_t}$.

Following Schmitt-Grohé and Uribe (2007), equation (**??**) is rewritten recursively. The real optimized wage, $\widetilde{w}_{j,t}$, in the sector j, is:

$$\widetilde{w}_{j,t} = \frac{\theta}{\theta - 1} \frac{x_{j,t}^1}{x_{j,t}^2}, \tag{3.18}$$

where $x_{j,t}^1$ and $x_{j,t}^2$ are two auxiliary variables:

$$x_{j,t}^1 = \lambda_t h_{j,t} \Lambda_{j,t} w_{j,t}^{\theta} + \beta\varphi_j E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\theta} x_{j,t+1}^1 \right], \tag{3.19}$$

and

$$x_{j,t}^{2} = \lambda_t h_{j,t} w_{j,t}^{\theta} + \beta \varphi_j E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\theta-1} x_{j,t+1}^{2} \right]. \tag{3.20}$$

3.1.2 Tradable sector

In this sector, we assume that there are two types of tradable goods[3]: oil and manufacturing goods. It's assumed that oil firm operates under perfect competition, while manufactured intermediate goods producing firms operate in a monopolistic competitive market indexed by $i \in (0, 1)$.

3.1.2.1 Oil firm

There is a single oil firm which combines capital, $k_{o,t}$, labor, $h_{o,t}$, and an oil resource, O_t, to produce crude oil, $Y_{o,t}$. Its production function is given by:

$$Y_{o,t} = Y_{o,t}^{d} + Y_{o,t}^{ex} = A_{o,t} k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}, \tag{3.21}$$

where α_o, β_o and $\theta_o \in (0, 1)$ and $\alpha_o + \beta_o + \theta_o = 1$. $A_{o,t}$ is a technology shock specific to the oil sector and evolves exogenously according to a stochastic process.
Thus, given $e_t, P_{o,t}, Q_{o,t}, W_{o,t}$ and $P_{O,t}$, the oil goods producing firm chooses $\{k_{o,t}, h_{o,t}, O_t\}$ to maximize its profit given by:

$$\max_{k_{o,t}, h_{o,t}, O_t} \left[e_t P_{o,t} Y_{o,t} - Q_{o,t} k_{o,t} - W_{o,t} h_{o,t} - P_{O,t} O_t \right] / P_t, \tag{3.22}$$

subject to (3.21). $e_t P_{o,t} Y_{o,t}$ denotes total sales revenues in terms of domestic currency, and $P_{O,t}$ is the oil resource price.
First order conditions are:

$$q_{o,t} = \alpha_o s_t p_{o,t} \frac{Y_{o,t}}{k_{o,t}}, \tag{3.23}$$

$$w_{o,t} = \beta_o s_t p_{o,t} \frac{Y_{o,t}}{h_{o,t}}, \tag{3.24}$$

[3]In our model, tradable goods are defined as intermediate goods that have export or import potential.

$$p_{O,t} = \theta_o s_t p_{o,t} \frac{Y_{o,t}}{O_t}, \tag{3.25}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p_{O,t} = \frac{P_{O,t}}{P_t}$ and $s_t = e_t \frac{P_t^f}{P_t}$ denote respectively the real capital return, the real wage, the real oil resource price, and the real exchange rate.

3.1.2.2 Manufacturing firms

There are a continuum of monopolistic competitive manufactured intermediate goods producing firms indexed by $i \in (0,1)$. The manufacured goods are produced by firm i by using capital, $k_{M,t} = \int_0^1 k_{M,t}(\iota)\, d\iota$, labor, $h_{M,t} = \int_0^1 h_{M,t}(\iota)\, d\iota$, and oil input, $Y_{o,t}^M$. Its production function is given by the following Cobb-Douglas function:

$$Y_{M,t}(i) = Y_{M,t}^d(i) + Y_{M,t}^{ex}(i) = A_{M,t} k_{M,t}^{\alpha_M}(i) h_{M,t}^{\beta_M}(i) Y_{o,t}^{M^{\theta_M}}(i), \tag{3.26}$$

where α_M, β_M and $\theta_M \in (0,1)$ and $\alpha_M + \beta_M + \theta_M = 1$.These coefficients denote, respectively, a share of capital, labor, and oil input, in the production of manufactured goods. $A_{M,t}$ is a technology shock specific to the manufacturing sector and evolves exogenously according to a stochastic process.

The nominal profit of firm i in period $t+s$ is:

$$D_{M,t+s}(i) = \pi^s \widetilde{P}_{M,t}(i)\, Y_{M,t+s}(i) - Q_{M,t+s} k_{M,t+s}(i) - W_{M,t+s} h_{M,t+s}(i) - e_t P_{o,t} Y_{o,t}^M(i),$$

To maximize its profit, the manufactured goods producer i chooses $K_{M,t}(i), h_{M,t}(i)$ and $Y_{o,t}^M(i)$ and sets its price, $\widetilde{P}_{M,t}(i)$. As in Calvo (1983), after each period, firm i faces an exogenous and constant probability of changing the nominal prices $(1-\phi_M)$. Therefore, in average, the price remains unchanged for $\frac{1}{1-\phi_M}$ periods. However, as in Yun (1996), if manufacturing firm is not allowed to adjust its price, it updates it according to the following rule:

$$P_{M,t} = \overline{\pi} P_{M,t-1},$$

where $\overline{\pi} > 1$ is the long run average gross rate inflation. Thus, the aggregate real price index in sector j, evolves over time according to:

$$(p_{M,t})^{1-\vartheta} = \phi_M \left(\pi \frac{p_{M,t-1}}{\pi_t} \right)^{1-\vartheta} + (1-\phi_M) \left(\widetilde{p}_{M,t} \right)^{1-\vartheta} \tag{3.27}$$

The maximization problem of the domestic manufactured-good producer can be written as follow:

$$\max_{k_{M,t}(i), h_{M,t}(i), Y^M_{o,t}(i), P_{M,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta \phi_M)^s \lambda_{t+s} D_{M,t+s}(i)/P_{t+s}], \tag{3.28}$$

subject to (3.26) and the following demand function:

$$Y_{M,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{M,t}(i)}{P_{M,t+s}} \right)^{-\vartheta} Y_{M,t+s}, \tag{3.29}$$

where $\beta^s \lambda_{t+s}$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$. The first order conditions in real terms are:

$$q_{M,t} = \alpha_M \frac{Y_{M,t}(i)}{k_{M,t}(i)} mc_{M,t} \tag{3.30}$$

$$w_{M,t} = \beta_M \frac{Y_{M,t}(i)}{h_{M,t}(i)} mc_{M,t} \tag{3.31}$$

$$s_t p_{o,t} = \theta_M \frac{Y_{M,t}(i)}{Y^M_{o,t}(i)} mc_{M,t} \tag{3.32}$$

where $q_{M,t} = \frac{Q_{M,t}}{P_t}, w_{M,t} = \frac{W_{M,t}}{P_t}, mc_{M,t} = \frac{MC_{M,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P^f_t}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real oil price. The real marginal cost, $mc_{M,t}$, is obatined by replacing (3.30)−(3.32) in (3.26):

$$mc_{M,t} = \frac{q^{\alpha_M}_{M,t} w^{\beta_M}_{M,t} p^{\theta_M}_{o,t}}{\alpha^{\alpha_M}_M \beta^{\beta_M}_M \theta^{\theta_M}_M}. \tag{3.33}$$

If producer i is allowed to change its price, it sets, $P_{M,t}$, for both domestic and foreign markets. The optimal pricing condition is given by the maximization of (3.28):

$$\widetilde{p}_{M,t}(i) = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_M)^s \lambda_{t+s} Y_{M,t+s} p_{M,t+s}^{\vartheta} mc_{M,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_M)^s \lambda_{t+s} Y_{M,t+s} p_{M,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{3.34}$$

where $p_{M,t+s} = \frac{P_{M,t+s}}{P_{t+s}}, mc_{M,t+s} = \frac{MC_{M,t+s}}{P_{t+s}}, \widetilde{p}_{M,t}(i) = \frac{\widetilde{P}_{M,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ denote respectively the relative price of manufactured goods, the real marginal cost in manufacturing sector, the real optimized price for manufactured goods and the CPI inflation rate.

We rewrite the optimal pricing condition as follows:

$$\widetilde{p}_{M,t} = \frac{\vartheta}{\vartheta - 1} \frac{V_{M,t}^1}{V_{M,t}^2}, \tag{3.35}$$

where $V_{M,t}^1$ and $V_{M,t}^2$ are two auxiliary variables:

$$V_{M,t}^1 = \lambda_t Y_{M,t} mc_{M,t} p_{M,t}^{\vartheta} + \beta\phi_M E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta} V_{M,t+1}^1 \right], \tag{3.36}$$

and,

$$V_{M,t}^2 = \lambda_t Y_{M,t} p_{M,t}^{\vartheta} + \beta\phi_M E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta-1} V_{M,t+1}^2 \right]. \tag{3.37}$$

3.1.3 Non-tradable sector

We assume that in the non-tradable sector, there is a continuum of services producing firms indexed by $i \in (0,1)$. Each firm i, produces non-tradable goods,$Y_{nT,t}(i)$, by using capital, $k_{nT,t}(i)$, labor, $h_{nT,t}(i)$, and a part of oil output, $Y_{o,t}^{I_{nT}}(i)$, with the following constant returns to scale production function:

$$Y_{nT,t}(i) = A_{nT,t} k_{nT,t}^{\alpha_{nT}}(i) h_{nT,t}^{\beta_{nT}}(i) Y_{o,t}^{nT^{\theta_{nT}}}(i), \tag{3.38}$$

where α_{nT}, β_{nT} and $\theta_{nT} \in (0,1)$ are the share of capital, labor and oil input in output respectively, and $\alpha_{nT} + \beta_{nT} + \theta_{nT} = 1$. $A_{nT,t}$ is a technology shock specific to the non-tradable sector and evolves exogenously according to a stochastic process.

To maximize its profit, the producer i chooses $\{K_{nT,t}(i), h_{nT,t}(i)$ and $Y_{o,t}^{I_{nT}}(i)\}$ and sets its price, $\widetilde{P}_{nT,t}(i)$ .The non-tradable firms' maximization problem can be written as follow:

$$\max_{k_{nT,t}(i),h_{nT,t}(i),Y_{o,t}^{I_{nT}}(i),P_{nT,t}(i)} E_0 \sum_{s=0}^{\infty}[(\beta\phi_{nT})^s \lambda_{t+s} D_{nT,t+s}(i)/P_{t+s}], \tag{3.39}$$

subject to (3.38) and the following demand function:

$$Y_{nT,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta} Y_{nT,t+s}, \tag{3.40}$$

where $D_{nT,t+s}(i)$ is the profit function:

$$D_{nT,t+s}(i) = \pi^s \widetilde{P}_{nT,t}(i) Y_{nT,t+s}(i) - Q_{nT,t+s} k_{nT,t+s}(i) - W_{nT,t+s} h_{nT,t+s}(i) - e_t P_{o,t}^f Y_{o,t}^{nT}(i),$$

where $\beta^s \lambda_{t+s}$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$.

The first order conditions of the maximization problem are:

$$q_{nT,t} = \alpha_{nT} \frac{Y_{nT,t}(i)}{k_{nT,t}(i)} mc_{nT,t} \tag{3.41}$$

$$w_{nT,t} = \beta_{nT} \frac{Y_{nT,t}(i)}{h_{nT,t}(i)} mc_{nT,t} \tag{3.42}$$

$$s_t p_{o,t} = \theta_{nT} \frac{Y_{nT,t}(i)}{Y_{o,t}^{nT}(i)} mc_{nT,t} \tag{3.43}$$

where $q_{nT,t} = \frac{Q_{nT,t}}{P_t}, w_{nT,t} = \frac{W_{nT,t}}{P_t}, mc_{nT,t} = \frac{MC_{nT,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t^f}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real oil price. The real marginal cost, $mc_{nT,t}$, is obatined by replacing (3.41)−(3.43) in (3.38):

$$mc_{nT,t} = \frac{q_{nT,t}^{\alpha_{nT}} w_{nT,t}^{\beta_{nT}} p_{o,t}^{\theta_{nT}}}{\alpha_{nT}^{\alpha_{nT}} \beta_{nT}^{\beta_{nT}} \theta_{nT}^{\theta_{nT}}}. \tag{3.44}$$

The non-tradable firm sets its price, $\widetilde{P}_{nT,t}(i)$, à la Calvo (1983) and Yun (1996). In each period, firm i faces an exogenous and constant probability of changing the nominal prices $(1-\phi_{nT})$. Therefore, in average, the price remains unchanged for $\frac{1}{1-\phi_{nT}}$ periods. However, if non-tradable firm is not allowed to adjust its price, it updates it according to the following rule:

$$P_{nT,t} = \overline{\pi} P_{nT,t-1},$$

where $\overline{\pi} > 1$ is the long run average gross rate inflation. Thus, the aggregate real price index in sector j, evolves over time according to:

$$(p_{nT,t})^{1-\vartheta} = \phi_{nT}\left(\pi \frac{p_{nT,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_{nT})\left(\widetilde{p}_{nT,t}\right)^{1-\vartheta} \tag{3.45}$$

where $\widetilde{p}_{nT,t}(\iota) = \frac{\widetilde{P}_{nT,t}(\iota)}{P_t}$ and $p_{nT,t+s} = \frac{P_{nT,t+s}}{P_{t+s}}$ denote the real optimized price and the real price.

The optimal pricing condition is given by the maximization of (3.39):

$$\widetilde{p}_{nT,t}(i) = \frac{\vartheta}{\vartheta-1} \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} mc_{nT,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}, \tag{3.46}$$

where $p_{nT,t+s} = \frac{P_{nT,t+s}}{P_{t+s}}, mc_{nT,t+s} = \frac{MC_{nT,t+s}}{P_{t+s}}, \widetilde{p}_{nT,t}(i) = \frac{\widetilde{P}_{nT,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ denote respectively the relative price of non-tradable goods, the real marginal cost in non-tradable sector, the real optimized price for non-tradable goods and the CPI inflation rate.

We rewrite the optimal pricing condition as follows:

$$\widetilde{p}_{nT,t} = \frac{\vartheta}{\vartheta-1} \frac{V_{nT,t}^1}{V_{nT,t}^2}, \tag{3.47}$$

where $V^1_{nT,t}$ and $V^2_{nT,t}$ are two auxiliary variables:

$$V^1_{nT,t} = \lambda_t Y_{nT,t} mc_{nT,t} p^{\vartheta}_{nT,t} + \beta \phi_{nT} E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta} V^1_{nT,t+1} \right], \tag{3.48}$$

and,

$$V^2_{nT,t} = \lambda_t Y_{nT,t} p^{\vartheta}_{nT,t} + \beta \phi_{nT} E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta-1} V^2_{nT,t+1} \right]. \tag{3.49}$$

3.1.4 Import goods producer

In our model, we assume that an imported-composite good, $Y_{I,t}$, purchased in a domestic monopolistically competitive market, is used by the final good producer. To produce $Y_{I,t}$, the firm uses differentiated goods, $Y_{I,t}(i)$, that are produced by a continuum of domestic importers, indexed by $i \in (0,1)$, using a homogeneous intermediate good produced abroad for the world price P^f_t. The differentiated goods are sold at price $P_{I,t}(i)$ subject to Calvo (1983) and Yun (1996) contracts[4]. In each period, importer faces an exogenous and constant probability of changing the nominal prices $(1-\phi_I)$. Therefore, in average, the price remains unchanged for $\frac{1}{1-\phi_I}$ periods. However, if nontradable firm is not allowed to adjust its price, it updates it according to the following rule:

$$P_{I,t} = \overline{\pi} P_{I,t-1},$$

where $\overline{\pi} > 1$ is the long run average gross rate inflation. Thus, the aggregate real price index in import sector, evolves over time according to:

$$(p_{I,t})^{1-\vartheta} = \phi_I \left(\pi \frac{p_{I,t-1}}{\pi_t} \right)^{1-\vartheta} + (1-\phi_I) (\widetilde{p}_{I,t})^{1-\vartheta}, \tag{3.50}$$

where $\widetilde{p}_{I,t}(\iota) = \frac{\widetilde{P}_{I,t}(\iota)}{P_t}$ and $p_{I,t+s} = \frac{P_{I,t+s}}{P_{t+s}}$ denote the real optimized price and the real price.

[4]Introducing price rigidities allows the deviation from the law of one price in the import sector, leading to incomplete pass-through effects of exchange rate movements.

The maximization problem of importers can be written as follows:

$$\max_{\widetilde{P}_{I,t}(i)} E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} \left(\pi^s \widetilde{P}_{I,t}(i) - e_{t+s} P^f_{t+s} \right) Y_{I,t+s}(i), \tag{3.51}$$

where $Y_{I,t+s}(i)$ is chosen by firms to maximize their profit :

$$Y_{I,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{I,t}(i)}{P_{I,t+s}} \right)^{-\vartheta} Y_{I,t+s}. \tag{3.52}$$

Replacing (3.52) in (3.51), we get the optimal pricing condition:

$$\widetilde{p}_{I,t}(i) = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} Y_{I,t+s} p^{\vartheta}_{I,t+s} mc_{I,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi^{\vartheta}_{t+k}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} Y_{I,t+s} p^{\vartheta}_{I,t+s} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi^{\vartheta-1}_{t+k}}, \tag{3.53}$$

where $p_{I,t+s} = \frac{P_{I,t+s}}{P_{t+s}}$ is the relative price of imports, $mc_{I,t+s} = \frac{e_t P^f_{t+s}}{P_{t+s}} = s_t$ is the real marginal cost which is equal to the real exchange rate, $\widetilde{p}_{I,t}(i) = \frac{\widetilde{P}_{I,t}(i)}{p_t}$ is the optimized price in import sector and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$ is the CPI inflation rate.

The non-linear recursive form of Eq(3.53) can be written as follow:

$$\widetilde{p}_{I,t} = \frac{\vartheta}{\vartheta - 1} \frac{V^1_{I,t}}{V^2_{I,t}}, \tag{3.54}$$

where $V^1_{I,t}$ and $V^2_{I,t}$ are two auxiliary variables that take the following form:

$$V^1_{I,t} = \lambda_t Y_{I,t} mc_{I,t} p^{\vartheta}_{I,t} + \beta\phi_I E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta} V^1_{I,t+1} \right], \tag{3.55}$$

$$V^2_{I,t} = \lambda_t Y_{I,t} p^{\vartheta}_{I,t} + \beta\phi_I E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\vartheta-1} V^2_{I,t+1} \right]. \tag{3.56}$$

3.1.5 Final good producer

Firm in the final-good sector is perfectly competitive. It combines a fraction of tradable output, $Y_{M,t}^{d}$, which is domestically-produced, the non-tradable output, $Y_{nT,t}$, and imports, $Y_{I,t}$: Its production function is:

$$z_t = \left[\chi_M^{\frac{1}{\tau}} Y_M^{d\,\frac{\tau-1}{\tau}} + \chi_{nT}^{\frac{1}{\tau}} Y_{nT}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}} Y_I^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}}, \tag{3.57}$$

where $Y_{M,t} = \left(\int_0^1 Y_{M,t}(i)^{\frac{1-\vartheta}{\vartheta}} di \right)^{\frac{\vartheta}{1-\vartheta}}$,$Y_{nT,t+s} = \left(\int_0^1 Y_{nT,t}(i)^{\frac{1-\vartheta}{\vartheta}} di \right)^{\frac{\vartheta}{1-\vartheta}}$ and $Y_{I,t+s} = \left(\int_0^1 Y_{I,t}(i)^{\frac{1-\vartheta}{\vartheta}} di \right)^{\frac{\vartheta}{1-\vartheta}}$ are aggregate of domestic tradable good, non-tradable goods and import goods; and $\vartheta > 1$ is the constant elasticity of substitution between intermediate goods in composite goods aggregate; $\tau > 0$ is the elasticity of substitution between the fraction of manufacturing output, the non-tradable output and imported goods and χ_M, χ_{nT}, $\chi_I \in (0,1)$ represent the share of manufactured, non-tradable and imported goods in the final good. Note that $P_{M,t+s} = \left(\int_0^1 \pi^s \widetilde{P}_{M,t}(i)^{1-\vartheta} di \right)^{\frac{1}{1-\vartheta}}$, $P_{nT,t+s} = \left(\int_0^1 \pi^s \widetilde{P}_{nT,t}(i)^{1-\vartheta} di \right)^{\frac{1}{1-\vartheta}}$ and $P_{I,t+s} = \left(\int_0^1 \pi^s \widetilde{P}_{I,t}(i)^{1-\vartheta} di \right)^{\frac{1}{1-\vartheta}}$ are the price index associated with the aggregators $Y_{M,t}^{d}$, $Y_{nT,t}$ and $Y_{I,t}$ respectively.

To maximize its profit, the final good producer chooses $Y_{I,t}, Y_{M,t}^{d}$ and $Y_{nT,t}$. Given the final-good price, P_t, and $P_{M,t}, P_{nT,t}$ and $P_{I,t}$, the demands functions for manufactured, non-tradable and imported goods are:

$$Y_{I,t} = \chi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\tau} z_t, \quad Y_{M,t}^{d} = \chi_M \left(\frac{P_{M,t}}{P_t} \right)^{-\tau} z_t, \quad Y_{nT,t} = \chi_{nT} \left(\frac{P_{nT,t}}{P_t} \right)^{-\tau} z_t \tag{3.58}$$

The zero profit condition implies that the price of final good, P_t, is given by:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_M P_{M,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau} \right]^{\frac{1}{1-\tau}} \tag{3.59}$$

Note finally that the final good is divided between total consumption and total investment so that $z_t = c_t + i_{o,t} + i_{M,t} + i_{nT,t}$.

3.1.6 Monetary policy

We assume that the central bank manages its nominal interest rate, R_t, in response to fluctuation in CPI inflation,π_t, nominal exchange rate changes, Δe_t, and output, Y_t. We use in this exercice, the following Taylor rule:

$$\log\left(\frac{R_t}{R}\right) = \rho_R \log\left(\frac{R_{t-1}}{R}\right) + (1-\rho_R)\left[\upsilon_\pi \log\left(\frac{\pi_t}{\pi}\right) + \upsilon_e \log\left(\frac{\Delta e_t}{\Delta e}\right) + \upsilon_y \log\left(\frac{Y_t}{Y}\right)\right] + \varepsilon_{R,t}. \tag{3.60}$$

Variables without time subscripts denote deterministic steady state values. This rule implies that the steady state inflation rate is interpreted as the target level of inflation. The parameter ρ_R is the degree of interest rate smoothing which reflects the central bank's preference for interest rate stability. υ_π, υ_e and υ_y are the policy coefficients measuring central bank's responses to deviation of inflation rate, exchange rate and output respectively, and $\varepsilon_{R,t}$ is an iid monetary policy shock.

3.1.7 The government

It's assumed that the government is the owner of the oil firm. Its budget constraint is:

$$s_t p_{o,t}\left(Y^d_{o,t} + Y^{ex}_{o,t}\right) + \varkappa \sum_{j=o,M,nT} W_{j,t} h_{j,t} = w_{o,t} h_{o,t} + q_{o,t} k_{o,t} + p_{O,t} O_t, \tag{3.61}$$

where the left hand side represents the government's revenu that include lump-sum taxes $\left(\varkappa \sum_{j=o,M,nT} W_{j,t} h_{j,t}\right)$ and receipts from selling oil to domestic $\left(s_t p_{o,t} Y^d_{o,t}\right)$ and foreign $\left(s_t p_{o,t} Y^{ex}_{o,t}\right)$ firms. The right hand side represents the government spending that include payment of wages, capital return and a factor payment of oil resource $(w_{o,t} h_{o,t} + q_{o,t} k_{o,t} + p_{O,t} O_t)$ in the oil sector.

3.1.8 Symmetric equilibrium

In a symmetric equilibrium, all housholds, importers, manufactured and non-tradable goods producers make the same decision so that: $\mathrm{c}_t(\iota)=\mathrm{c}_t$, $\mathrm{h}_t(\iota)=\mathrm{h}_t$, $\mathrm{h}_{o,t}(\iota)=\mathrm{h}_{o,t}$, $\mathrm{h}_{M,t}(\iota)=\mathrm{h}_{M,t}$, $\mathrm{h}_{nT,t}(\iota)=\mathrm{h}_{nT,t}$, $\mathrm{b}_t(\iota)=\mathrm{b}_t$, $\mathrm{b}^f_t(\iota)=\mathrm{b}^f_t$, $\mathrm{k}_{o,t}(\iota)=\mathrm{k}_{o,t}$, $\mathrm{k}_{M,t}(\iota)=\mathrm{k}_{M,t}$,

$k_{nT,t}(\iota)=k_{nT,t}$, $w_{o,t}(\iota)=w_{o,t}$, $w_{M,t}(\iota)=w_{M,t}$, $w_{nT,t}(\iota)=w_{nT,t}$, $D_{M,t+s}(\iota)=D_{M,t+s}$, $D_{nT,t}(\iota)=D_{nT,t}$, $D_{I,t}(\iota)=D_{I,t}$, $i(\iota)=i$, $Y_{nT,t}(i)=Y_{nT,t}$, $Y^{nT}_{o,t}(i)=Y^{nT}_{o,t}$, $\widetilde{p}_{nT,t}(i)=\widetilde{p}_{nT,t}$, $\widetilde{p}_{I,t}(i)=\widetilde{p}_{I,t}$, $Y_{I,t}(i)=Y_{I,t}$, $Y_{M,t}(i)=Y_{M,t}$, $\widetilde{p}_{M,t}(i)=\widetilde{p}_{M,t}$, $Y^{d}_{M,t}(i)=Y^{d}_{M,t}$, $Y^{ex}_{M,t}(i)=Y^{ex}_{M,t}$, $Y^{M}_{o,t}(i)=Y^{M}_{o,t}$ for all ι and $i \in (0,1)$.Thus, a symmetric equilibrium for this economy is composed of an allocation $\{c_t, i_t, i_{o,t}, i_{M,t}, i_{nT,t}, Y_{o,t}, Y_{nT,t}, Y^{d}_{o,t}, Y^{M}_{o,t}, Y^{nT}_{o,t}, Y^{ex}_{o,t}, Y_M, Y^{d}_{M}, Y^{ex}_{M}, Y_{I,t}, Y_t, Y^{va}_{nT,t}, Y^{va}_{M}, z_t, k_{o,t}, k_{M,t}, k_{nT,t}, h_t, h_{o,t}, h_{M,t}, h_{nT,t}, b^{f}_{t}, \kappa\}^{\infty}_{t=0}$ and a sequences of price and co-state variables $\{w_{o,t}, w_{M,t}, w_{nT,t}, \widetilde{w}_{o,t}, \widetilde{w}_{M,t}, \widetilde{w}_{nT,t}, q_{o,t}, q_{M,t}, q_{nT,t}, p_{M,t}, \widetilde{p}_{M,t}, p_{nT,t}, \widetilde{p}_{nT,t}, p_{I,t}, \widetilde{p}_{I,t}, p_{O,t}, \pi_t, \pi_{nT,t}, \pi_{I,t}, s_t, e_t, R_t, \lambda_t, \Lambda_{o,t}, \Lambda_{M,t}, \Lambda_{nT,t}, mc_{M,t}, mc_{nT,t}, mc_{I,t}\}^{\infty}_{t=0}$ satisfying households, oil, tradable and non-tradable first order conditions, the aggregate resources constraints, the monetary policy rules, the current account equation and the stochastic processes $\{\eta_t, \varsigma_t, R^{f}_{t}, \pi^{f}_{t}, P_{o,t}, O_t, Y^{f}_{o,t}, Y^{f}_{M,t}, A_{o,t}, A_{M,t}, A_{nT,t}\}^{\infty}_{t=0}$of the shocks and the following market clearing conditions $b_t=b_{t-1}=0$, $b^{f}_{t}=\widetilde{b}^{f}_{t}$ and:

$$Y_{o,t} = Y^{d}_{o,t} + Y^{ex}_{o,t}, \tag{3.62}$$

$$Y^{d}_{o,t} = Y^{M}_{o,t} + Y^{nT}_{o,t}, \tag{3.63}$$

$$Y_{M,t} = Y^{d}_{M,t} + Y^{ex}_{M,t}. \tag{3.64}$$

According to McCallum and Nelson (1999) and Gertler, Gilchrist and Natalucci (2003), we assume that the foreign demand for the oil and the manufacturing goods, $Y^{ex}_{o,t}$, and $Y^{ex}_{T,t}$, are given by :

$$Y^{ex}_{o,t} = \nu_o \left(\frac{e_t P_{o,t}}{P^{f}_{t}}\right)^{-\omega_o} Y^{f}_{o,t} \quad \text{and} \quad Y^{ex}_{M,t} = \nu_M \left(\frac{e_t P_{M,t}}{P^{f}_{t}}\right)^{-\omega_M} Y^{f}_{M,t}$$

where ν_o and ν_M are parameters determining the fraction of domestic tradable goods exports in foreign spending. The economy is small, so domestic exports form an insignificant fraction of foreign expenditures and have a negligible weight in the foreign price index. $Y^{f}_{o,t}$ and $Y^{f}_{M,t}$ are the foreign output and ω_o and ω_M, denote the elasticity of demand for domestic tradable goods by foreigners. we assume that the foreign production of oil and tradable goods are exogenous and evolve according AR(1) processes.

The aggregate GDP is defined as:

$$Y_t = p_{M,t}Y^{va}_{M,t} + p_{nT,t}Y^{va}_{nT,t} + s_t p_{o,t}Y_{o,t}, \tag{3.65}$$

where $Y^{va}_{M,t}$, and $Y^{va}_{nT,t}$ are the value-added output in manufacturing and non-tradable sectors respectively. These variables are constructed by subtracting oil input as follow[5]:

$$Y^{va}_{M,t} = Y_{M,t} - s_t p_{o,t}\frac{Y^{M}_{o,t}}{p_{M,t}}, \tag{3.66}$$

$$Y^{va}_{nT,t} = Y_{nT,t} - s_t p_{o,t}\frac{Y^{nT}_{o,t}}{p_{nT,t}}. \tag{3.67}$$

Combining the households' budget constraint, the single period profit functions of manufactured and non-tradable goods producing firms and foreign good importers and the first order conditions of the three sectors and applying the market clearing conditions yields the following current account equation:

$$\frac{b^f_t}{R^f_t \kappa_t} = \frac{b^f_{t-1}}{\pi^f_t} + p_{o,t}Y^{ex}_{o,t} + \frac{p_{M,t}}{s_t}Y^{ex}_{M,t} - Y_{I,t}, \tag{3.68}$$

3.1.9 Exogenous processes

Our oil exporting economy is affected by twelve structural shock processes, including a taste shock, a labor supply shock, an oil price shock, an oil resource shock, foreign interest rate and the world inflation rate shocks, three technological shocks and a monetary policy shock.

Apart from the monetary policy shock, which is a zero-mean iid shock with a standard deviation, the rest of structural shocks follows an AR(1) process given by:

$$\log(F_t) = (1-\rho_F)\log(F) + \rho_F \log(F_{t-1}) + \varepsilon_{F,t}, \tag{3.69}$$

where F is the steady state value of F_t , ρ_F is the autocorrelation coefficients, and $\varepsilon_{F,t}$ is uncorrelated and normally distributed innovations with zero mean and standard deviation σ_F.

[5]Our model suppose that tradable and non-tradable firms use refined oil as material inputs in their productions which is defined as gross output. Thus, value added output in each sector can be constructed by substracting commodity inputs.

and $F=\left\{\eta_t, \varsigma_t, R_t^f, \pi_t^f, P_{o,t}, O_t, A_{o,t}, A_{T,t}, A_{nT,t}, Y_{o,t}^f, Y_{M,t}^f\right\}$.

3.2 Bayesian estimation

The model is estimated by using the Bayesian method as in Sungbae and Schorfheide (2007), Fernández-Villaverde (2010) and Del Negro and Schorfheide (2008).

There are 54 parameters to be estimated gathered in $\Theta=\{\eta,\ \varsigma,\ \varpi,\ \psi_o,\ \psi_M,\ \psi_{nT},\ \varphi_o,\ \varphi_M,\ \varphi_{nT},\ \alpha_o,\ \beta_o,\ \theta_o,\ \alpha_M,\ \beta_M,\ \theta_M,\ \phi_M,\ \alpha_{nT},\ \beta_{nT},\ \theta_{nT},\ \alpha_{ho},\ \alpha_{hM},\ \alpha_{hnT},\ \phi_{nT},\ \phi_I,\ \chi_I,\ \chi_{nT},\ \chi_M,\ \mu_\pi,\ \mu_e,\ \mu_y,\ \rho_r,\ \rho_{r^f},\ \rho_{p_o},\ \rho_o,\ \rho_{y_{of}},\ \rho_{y_{Mf}},\ \rho_{\pi^f},\ \rho_{a_o},\ \rho_{a_M},\ \rho_{a_{nT}},\ \rho_\eta,\ \rho_\varsigma,\ \sigma_r,\ \sigma_{r^f},\ \sigma_{p_o},\ \sigma_o,\ \sigma_{y_{of}},\ \sigma_{y_{Mf}},\ \sigma_{\pi^f},\ \sigma_{a_o},\ \sigma_{a_M},\ \sigma_{a_{nT}},\ \sigma_\eta,\ \sigma_\varsigma\}$. The rest of the parameters are calibrated, as commonly done in the DSGE literature. This procedure helps to cope with the problem of identification from which DSGE models commonly suffer, arising from the fact that the data used in the estimation may contain little information about some parameters.

3.2.1 Calibration

We calibrate some parameters which cannot be estimated. These parameter values are taken as fixed from the start of calculation. As in Almeida (2009), the parameters we chose to calibrate pertain mostly to three aspects: (i) those crucial to determine the steady-state; (ii) those for which we have reliable estimations from other sources; and (iii) those whose values are crucial to replicate the main steady-state key ratios of an oil exporting economy. The calibration matches some features of oil exporting countries[6]. Table 3.2 reports the calibration values.

The subjective discount factor, β, is set at $0,99$. Since, in the steady state, $\beta = 1/(1-r)$, this implies an annual real interest rate of 4%. The parameter, γ, is set at 2, as in Bouakez et al (2008) and Dib (2008), implying an elasticity of intertemporal substitution of consumption of 0.5. Following Devereux *et al.* (2006), the inverse of the

[6] We use all studies which could reflect features of oil exporting economies like Algeria, Canada and Mexico.

elasticity of the intertemporal substitution of labor, σ, is set at 1. The depreciation rate of capital is fixed at 0.025. This value is common to the three sectors.

Table 3.2: Calibration of structural parameters.

Description	Parameters	Values
Structural Parameters		
Subject discount factor	β	0.99
The inverse of the elasticity of intertemporal substitution of consumption	γ	2
The inverse of the Frish wage elasticity of labour supply	σ	1
Parameter measuring the risk premium	ϕ	0.0015
The depreciation rate of capital	δ	0.025
Lump-sum tax parameter	ϖ	0.2
Price elasticity of demand for imported and non-oil goods	τ	0.8
Share of import invoiced in the US dollar	μ	0.3
Oil price rule parameter	υ	0.3
Labor elasticity of substitution in the oil sector	α_{ho}	0.31
Labor elasticity of substitution in the non-oil sector	α_{hno}	0.69
Steady state values		
Gross steady-state domestic inflation rate	π	1.0085
Gross steady-state foreign inflation rate	π^f	1.0070
Steady state domestic interest rate	R	1.0185
Steady state foreign interest rate	R^f	1.0158

As in Dib (2008), we set the parameters that represent the degree of monopoly power in the intermediate good market, θ, and the labor market, ϑ, equal to 6 and 8 respectively. The steady state price and wage markup are equal to 20% and 14% respectively. The price elasticity of demand for imported, domestic tradable and non-tradable goods, τ, is set at $0,8$ as in Dib (2003, 2008). The labor elasticity of substitution in the three sectors namely, oil, non-tradable and manufacturing sectors are assigned values to match the shares of hours worked in the three sectors (oil, manufacturing and non-tradable sectors) of Algerian economy, so that, $\alpha_{h_o}, \alpha_{h_M}$ and $\alpha_{h_{nT}}$ are equal to 0.32, 0.13 and 0.55 respectively[7].

Since we have two samples of oil exporting countries, we choose two values of the fraction of domestic oil exports in foreign spending. The first value, $\nu^1_{o,t}$, is set equal to

[7]These values are chosen by using ONS (national office of statistics) data. These values are approximatively the same in our sample of oil exporting economies.

0.6 for the first sample which gather oil dependant countries. The second value, $\nu^2_{o,t}$, equal to 0.4 is assigned to the second sample. To match the ratio manufactured goods to GDP observed in the data of our sample, we set the parameter, ν_M, equal to 0.3. The risk premium parameter, ϕ, is set equal to 0.0115. This value is chosen to match the average ratio of foreign debt to GDP of our sample of oil exporting economies.

3.2.2 Data

To estimate our model, we use ten series of quarterly data collected from ECLAC (The Economic Commission for Latin America), WTO (World Trade Organization), OECD (Organization for Economic Cooperation and Development) and IMF (International Monetary Fund). Our series are: GDP, households consumption, investment (Gross Fixed Capital Formation), oil production, inflation rate, nominal exchange rate against the dollar, domestic interest rate (discount rate), international oil price, oil exports, and imports from 1980 to 2010. These series are chosen for sixteen oil exporting and emerging countries (Algeria, Argentina, Ecuador, Egypt, Gabon, Indonesia, Kuwait, Iran, Libya, Malaysia, Mexico, Nigeria, Oman, Qatar, Russian Federation, Saudi Arabia, United Arab Emirates and Venezuela). The choice of these countries was based essentially on their degree of oil dependent. As shown by Table 3.1, we divided our sample of countries into two subsamples: High oil dependent and Low oil dependent countries. All the data has been detrended by the Hodrick-Prescott filter and centred around their means.

3.2.3 Priors

To reflect our beliefs about structural parameters, we specify prior distributions for the entire vector Θ. We choose priors based on evidence from previous studies for oil exporting economies (like Medina and Soto (2005), Dib (2008), Romero (2008)), but for those for which we had no references we used common sense while trying to construct the least restrictive priors possible. These priors are summarized in Tables 3.3 and 3.4.

We assume Beta distribution for those parameters that must lie in the [0 1] interval. This applies to the persistence parameters of the exogenous stochastic processes which

Table 3.3: Prior distribution of the estimated parameters.

				Priors	
Coefficient	Description	Domain	Density	Mean	Std.
ϖ	Habit form parameter	[0 1]	Beta	0.5	0.25
ψ_o	Cap-adjust-oil	$\mathbb{R}$	Normal	5	2.00
ψ_M	Cap-adjust-manuf	$\mathbb{R}$	Normal	5	2.00
ψ_{nT}	Cap-adjust-non-trad	$\mathbb{R}$	Normal	5	2.00
α_o	Share of capital-oil	[0 1]	Beta	0.35	0.05
β_o	Share of labor-oil	[0 1]	Beta	0.14	0.05
θ_o	Share of oil-resource	[0 1]	Beta	0.51	0.05
α_M	Share of cap-manufac	[0 1]	Beta	0.41	0.05
β_M	Share of lab-manufac	[0 1]	Beta	0.27	0.05
θ_M	Share of oil-manufac	[0 1]	Beta	0.32	0.05
α_{nT}	Share of cap-non-trad	[0 1]	Beta	0.26	0.05
β_{nT}	Share of lab-non-trad	[0 1]	Beta	0.47	0.05
θ_{nT}	Share of oil-non-trad	[0 1]	Beta	0.27	0.05
ϕ_M	Calvo-price-manuf	[0 1]	Beta	0.67	0.05
ϕ_{nT}	Calvo-price-non-trad	[0 1]	Beta	0.67	0.05
ϕ_I	Calvo-price-import	[0 1]	Beta	0.67	0.05
χ_I	Share of imports	[0 1]	Beta	0.55	0.10
χ_{nT}	Share of non-trad	[0 1]	Beta	0.3	0.10
χ_M	Share of manufact	[0 1]	Beta	0.15	0.10
φ_o	Calvo-wage-oil	[0 1]	Beta	0.67	0.05
φ_M	Calvo-wage-manuf	[0 1]	Beta	0.67	0.05
φ_{nT}	Calvo-wage-non-trad	[0 1]	Beta	0.67	0.05

are assumed to follow a beta distribution with a mean of 0.6 and a standard deviation of 0.2. The Beta distribution is also assigned to the parameters of price and wage stickiness with a mean of 0.67 that corresponds to changing price and wage every 3 quarters on average. We set the shares of capital, α_o, labor, β_o, and oil resources, θ_o, in the production of oil to 0.35, 0.14 and 0.51 respectively. We also set to 0.41 (0.26), 0.27 (0.47) and 0.32 (0.27) the share of capital, α_M (α_{nT}), labor, β_M (β_{nT}), and a fraction of oil output, θ_M (θ_{nT}) ,in the production of non-oil goods. The standard deviations of these parameters are assumed to follow Beta distribution and a standard error of 0.05. As in Medina and Soto (2005) and Ben Aissa and Rebei (2010), we fix the mean of the habit formation parameter equal to 0.5. Its standard deviation is set at 0.25. The

Table 3.4: Prior distribution of the estimated parameters (continued).

				Priors	
Coefficient	Description	Domain	Density	Mean	Std.
μ_{π}	Inflation pol-rule	$\mathbb{R}$	Normal	0.50	0.30
μ_{e}	Exch-rate pol-rule	$\mathbb{R}$	Normal	0.50	0.30
μ_{y}	Output-pol-rule	$\mathbb{R}$	Normal	0.30	0.30
ρ_{r}	Interest rate coef	[0 1]	Beta	0.65	0.20
ρ_{rf}	AR inter-interest rate	[0 1]	Beta	0.65	0.20
ρ_{p_o}	AR oil-price	[0 1]	Beta	0.65	0.20
ρ_{o}	AR oil-resource	[0 1]	Beta	0.65	0.20
$\rho_{y_{of}}$	AR foreign oil-prod	[0 1]	Beta	0.65	0.20
$\rho_{y_{Mf}}$	AR foreign manuf-prod	[0 1]	Beta	0.65	0.20
$\rho_{\pi f}$	AR world inflation	[0 1]	Beta	0.65	0.20
ρ_{a_o}	AR tech-shock oil-sect	[0 1]	Beta	0.65	0.20
ρ_{a_M}	AR tech-shock manuf-sect	[0 1]	Beta	0.65	0.20
$\rho_{a_{nT}}$	AR tech-shock non-trad-sect	[0 1]	Beta	0.65	0.20
ρ_{η}	AR tast shock	[0 1]	Beta	0.65	0.20
ρ_{ς}	AR labor-supply shock	[0 1]	Beta	0.65	0.20
σ_{rf}	s.d inter-interest rate	$\mathbb{R}^+$	InvGamma	0.5	inf
$\sigma_{y_{of}}$	s.d oil produc	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{p_o}	s.d oil price	$\mathbb{R}^+$	InvGamma	0.5	inf
$\sigma_{y_{Mf}}$	s.d manufact produc	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{r}	s.d interest rate	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{o}	s.d oil resource	$\mathbb{R}^+$	InvGamma	0.5	inf
$\sigma_{\pi f}$	s.d world inflation	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{a_o}	s.d tech-shock oil-sect	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{a_M}	s.d tech-shock manuf-sect	$\mathbb{R}^+$	InvGamma	0.5	inf
$\sigma_{a_{nT}}$	s.d tech-shock non-trad-sect	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{η}	s.d tast shock	$\mathbb{R}^+$	InvGamma	0.5	inf
σ_{ς}	s.d labor-supply shock	$\mathbb{R}^+$	InvGamma	0.5	inf

fraction of imported goods in the final good, χ_I, is set to 0.55. Since in the most oil exporting economies the share of import and non-tradable goods in the production of the final goods is higher than the tradable goods, we set χ_{nT} and χ_M equal to 0.3 and 0.15 respectively.

We also assume Gamma and inverted Gamma distributions for the parameters that must be positive. This is the case of the standard errors of various innovations which are assumed to follow the inverse Gamma distribution, with a mean of 0.5 and a standard error of 2. The remaining parameters have a normal distribution. Thus, we use a normal distribution for the capital adjustment costs in each sector with a mean of 5 and a standard deviation of 2. The prior of the parameter, ψ_j, reflect the extent to which changes in capital stocks are delayed. Also, as in Rabanal and Rubio-Ramirez (2005) and Medina and Soto (2005) we do not impose non-negativity restrictions on the policy rule coefficients. Thus, we assume a normal distribution for all monetary policy coefficients with a mean of 0.50 for inflation, exchange rate and 0.30 output coefficients respectively. A standard deviation of 0.3 is assigned to these parameters. Finally, for the interest rate smoothing coefficient, ρ_R, we assume a beta distribution with mean 0.75 and a standard deviation of 0.2.

3.3 Estimations results

We analyze our estimations results in three steps. First, in order to see to what extent our baseline model is relevant, we consider the posterior means. In this first step, both high oil and low oil dependent countries are studied. Steps two and three are dedicated to economies suffering from the Dutch disease effect in the aftermath of positive oil price shock. In this perspective, step two analyzes the impulse response functions of several domestic macroeconomic variables to the oil shock. Finally, step 3 introduces alternative monetary policy rules to estimate to what extent exchange rate and / or inflation targeting rules perform better than the monetary strategy of the baseline model to prevent the Dutch disease.

3.3.1 Posterior distributions

Tables 3.5-3.8 report the Bayesian estimation results of the structural parameters of the baseline model.

The degree of habit formation in consumption (ϖ) is consistently higher in high oil dependent countries (Table 3.5) relative to low oil dependent economies (Table 3.7). Indeed, in the first group, the posterior means range from (0.57) in Nigeria to (0.89) for Oman while these lower-higher values in the second group are Argentina (0.16) and Russia (0.77). The higher degree of habit formation in consumption means that changes in the level of consumption lead to high welfare costs. Our results suggest that such welfare costs are especially high in low diversified economies (high oil dependent). Capital-adjustment costs (ψ) refer to the ability for an economy to change its capital stock from period to period. In oil sector, Tables 3.5 and 3.7 show that these costs are higher than prior means (5.0) in the major part of our studied countries. On average, there are no significant difference between our two groups of countries. The absence of a clear relationship between the capital-adjustment costs and the degree of oil dependence is confirmed inside each group. This parameter does not seem to depend from the weight of oil exports in total exports. For instance, for high oil dependent countries, the capital-adjustment cost is below the prior for Venezuela (3.63) and higher for Oman (8.34). Capital-adjustment costs are significantly higher in both manufacturing and non-tradable sectors in high oil dependent countries relative to low oil dependent ones. In the first group, Table 3.5 shows that posterior means are higher than the priors. Overall, the estimates of the capital-adjustment costs suggest that high oil dependent economies may meet more difficulties to respond to oil price shocks.

The shares of capital (α), labor (β), and oil resources (θ) in the different production sectors (oil, manufacturing, and non-tradable) estimated by posterior means are in line with our priors. This result suggests that our baseline model is relevant to analyze both high and low oil dependent countries.

In the two subsamples, posterior means suggest a higher prices rigidity (ϕ) in the non-tradable sector relative to the manufacturing and import ones. In the two latter sectors, posterior means are consistently below the priors. On average, the estimated Calvo probabilities of not resetting optimally prices are (0.72) and (0.69) in the non-tradable

Table 3.5: Estimation results of the high oil dependant countries.

	Libya	Algeria	Gabon	Nigeria	Oman	Saudi.A	Kuwait	Venezuela
ϖ	0.7533 [0.658 0.852]	0.5855 [0.466 0.714]	0.6314 [0.575 0.676]	0.5688 [0.158 0.976]	0.8949 [0.826 0.976]	0.8834 [0.778 0.999]	0.7846 [0.533 0.980]	0.6570 [0.391 0.946]
ψ_o	8.1028 [6.624 9.435]	8.7740 [6.220 11.177]	6.0440 [5.407 6.696]	7.1801 [4.820 9.550]	8.3405 [7.821 8.819]	7.9833 [6.802 9.154]	3.5331 [1.137 4.524]	3.6309 [1.885 5.488]
ψ_M	7.5628 [6.893 8.210]	8.2434 [6.136 10.293]	0.1962 [0.128 0.262]	0.2540 [0.095 0.407]	2.3133 [1.628 3.223]	9.0913 [7.880 10.480]	5.0308 [3.865 5.839]	6.0647 [4.285 7.927]
ψ_{nT}	4.1993 [3.589 4.727]	6.0035 [3.591 8.018]	5.6324 [5.282 6.030]	5.6586 [3.630 7.796]	10.4908 [9.766 11.331]	4.5019 [3.035 6.073]	3.6353 [2.490 4.367]	2.4032 [1.317 3.354]
α_o	0.3383 [0.292 0.372]	0.1934 [0.160 0.229]	0.3614 [0.346 0.376]	0.3200 [0.259 0.383]	0.3401 [0.315 0.366]	0.2618 [0.233 0.288]	0.3833 [0.304 0.444]	0.3743 [0.300 0.451]
β_o	0.0381 [0.014 0.059]	0.0744 [0.058 0.090]	0.0245 [0.018 0.030]	0.0835 [0.058 0.106]	0.0341 [0.015 0.054]	0.0273 [0.011 0.042]	0.0405 [0.022 0.057]	0.0731 [0.039 0.108]
θ_o	0.4578 [0.430 0.482]	0.4940 [0.425 0.564]	0.5101 [0.505 0.515]	0.4560 [0.379 0.523]	0.5802 [0.563 0.595]	0.4496 [0.413 0.479]	0.5568 [0.539 0.580]	0.4797 [0.412 0.549]
α_M	0.4128 [0.384 0.444]	0.3581 [0.285 0.432]	0.3499 [0.328 0.368]	0.4512 [0.363 0.536]	0.3880 [0.348 0.426]	0.3836 [0.331 0.456]	0.3745 [0.348 0.397]	0.4174 [0.374 0.464]
β_M	0.2518 [0.212 0.297]	0.4206 [0.361 0.488]	0.2968 [0.280 0.313]	0.2960 [0.212 0.361]	0.5030 [0.480 0.524]	0.2245 [0.185 0.257]	0.4483 [0.414 0.489]	0.3156 [0.254 0.366]
θ_M	0.3667 [0.334 0.408]	0.5092 [0.456 0.567]	0.3587 [0.354 0.366]	0.3364 [0.268 0.405]	0.5178 [0.501 0.533]	0.4006 [0.378 0.421]	0.5573 [0.523 0.586]	0.3078 [0.276 0.337]
α_{nT}	0.3620 [0.347 0.382]	0.3140 [0.275 0.352]	0.3154 [0.311 0.319]	0.3273 [0.292 0.364]	0.3573 [0.323 0.398]	0.2846 [0.259 0.307]	0.3971 [0.330 0.455]	0.3176 [0.281 0.362]
β_{nT}	0.4353 [0.421 0.449]	0.5214 [0.480 0.560]	0.4868 [0.480 0.493]	0.4586 [0.419 0.495]	0.4072 [0.365 0.441]	0.4932 [0.465 0.523]	0.3777 [0.316 0.439]	0.4273 [0.382 0.473]
θ_{nT}	0.0869 [0.081 0.092]	0.0856 [0.075 0.096]	0.1577 [0.153 0.162]	0.1307 [0.111 0.151]	0.0863 [0.080 0.092]	0.0925 [0.086 0.099]	0.0927 [0.078 0.107]	0.1282 [0.109 0.144]
ϕ_M	0.7547 [0.687 0.813]	0.6346 [0.555 0.708]	0.5495 [0.529 0.574]	0.5792 [0.539 0.623]	0.5981 [0.577 0.623]	0.6482 [0.618 0.673]	0.6139 [0.559 0.665]	0.3601 [0.336 0.383]
ϕ_{nT}	0.6969 [0.669 0.720]	0.6967 [0.633 0.771]	0.7108 [0.698 0.722]	0.6785 [0.602 0.746]	0.7146 [0.689 0.742]	0.8373 [0.811 0.861]	0.7155 [0.687 0.753]	0.6852 [0.619 0.744]
ϕ_I	0.6320 [0.603 0.662]	0.6517 [0.591 0.715]	0.5223 [0.514 0.530]	0.5639 [0.481 0.658]	0.7055 [0.684 0.724]	0.5762 [0.508 0.643]	0.6671 [0.643 0.692]	0.5058 [0.456 0.550]
χ_I	0.2407 [0.216 0.266]	0.0491 [0.047 0.051]	0.1558 [0.143 0.172]	0.1957 [0.131 0.261]	0.4409 [0.390 0.492]	0.2768 [0.208 0.333]	0.2642 [0.184 0.332]	0.1854 [0.150 0.218]
χ_M	0.2585 [0.212 0.315]	0.1476 [0.004 0.275]	0.1180 [0.107 0.131]	0.1042 [0.012 0.192]	0.1059 [0.010 0.188]	0.2411 [0.159 0.346]	0.1736 [0.103 0.256]	0.1220 [0.033 0.206]
χ_{nT}	0.1740 [0.134 0.219]	0.3594 [0.282 0.436]	0.4912 [0.461 0.518]	0.2183 [0.145 0.286]	0.5126 [0.461 0.555]	0.2946 [0.246 0.346]	0.3865 [0.315 0.437]	0.1567 [0.108 0.205]
φ_o	0.6692 [0.594 0.741]	0.6372 [0.568 0.705]	0.6706 [0.665 0.676]	0.7127 [0.648 0.783]	0.5645 [0.546 0.584]	0.6522 [0.592 0.715]	0.6700 [0.635 0.700]	0.6857 [0.629 0.732]
φ_M	0.7284 [0.706 0.750]	0.6808 [0.603 0.747]	0.6258 [0.615 0.635]	0.6929 [0.637 0.742]	0.7260 [0.705 0.744]	0.6981 [0.642 0.755]	0.6560 [0.576 0.736]	0.6914 [0.614 0.778]
φ_{nT}	0.8781 [0.859 0.897]	0.7811 [0.738 0.824]	0.5700 [0.562 0.575]	0.6816 [0.636 0.740]	0.8346 [0.816 0.850]	0.8219 [0.798 0.847]	0.7423 [0.712 0.776]	0.7569 [0.727 0.785]
μ_π	0.3159 [−0.025 0.645]	0.3233 [0.189 0.453]	−0.0370 [−0.084 0.010]	0.3637 [0.123 0.599]	0.9341 [0.756 1.076]	0.8779 [0.594 1.171]	0.2227 [0.086 0.346]	1.0755 [0.805 1.337]
μ_e	0.1180 [0.021 0.191]	1.1419 [1.004 1.358]	0.0013 [0.003 0.002]	0.7111 [0.373 1.099]	2.3305 [2.259 2.408]	1.6351 [1.346 1.881]	1.8625 [1.672 2.045]	2.3373 [2.240 2.408]
μ_y	−0.0358 [−0.067 0.004]	0.038 [−0.012 0.094]	−0.066 [−0.011 −0.020]	−0.0034 [−0.025 0.019]	0.0079 [0.000 0.016]	0.0033 [−0.007 0.015]	−0.0022 [−0.009 0.004]	−0.0459 [−0.092 0.001]

sectors for high and low oil dependent countries respectively. These probabilities are $(0.59) - (0.58)$ in the manufacturing sector and $(0.60) - (0.61)$ in the import sector. In other words, prices are adjusted every (2.4) and (2.6) quarters in the latter sectors while the adjustment take place every (3.6) (high oil dependent) and (3.2) (low oil dependent) quarters in the former. These parameters do not show significant differences in the two groups of countries.

As for prices, in high and low oil dependent economies, wages stickiness (φ) is higher in the non-tradable sector relative to oil and manufacturing ones. Considering for instance the high oil dependent sample (Table 3.5), on average, we see that wages are adjusted every (2.9) quarters in the oil sector and every (3.2) quarters in the manufacturing sector while the adjustment occurs every (4.2) quarters in the non-tradable sector. The share of imports in the final good (χ_I) tends to be lower in low oil dependent that in high oil dependent countries. In the two samples, the posterior means are below the priors, except for Argentina and United Arab Emirates. On average, in both high oil and low dependent economies, the share of manufacturing (χ_M) and non-tradable goods (χ_{NT}) are close to the prior means.

The lower part of tables 3.5 and 3.7 exhibits the monetary policy coefficients. In both high oil and low oil dependent countries, the posterior means on output target (μ_y) suggest that our studied countries do not consider output in the conduct of their monetary policy. Indeed, we see that for all countries posterior means are dramatically below the priors. To the opposite, the weights of the exchange rate (μ_e) estimated by the posterior means are consistently higher than those given by the prior means. This finding is broadly consistent with the evolution of exchange rate regimes in the studied countries. More precisely, *de facto* classification suggests that many countries in our two samples have chosen rigid exchange rate arrangements over the major part of the studied period. The inflation coefficients (μ_π) given by the posteriors are higher the priors in Oman (0.93), Saudi Arabia (0.88), and Venezuela (1.07) in the high oil dependent group. For the low oil dependent economies, Table 3.7 shows that only UAE (1.06) and Egypt (1.37) have posteriors higher than prior means.

Overall, our results suggest that in the two samples, exchange rate matters significantly in the conduct of the monetary policy. Inflation seems to be a secondary target for

Table 3.6: Estimation results of the high oil dependant countries (continued).

	Algeria	Libya	Gabon	Nigeria	Oman	Saudi.A	Kuwait	Venezuela
ρ_r	0.7852	0.1279	0.8454	0.5961	0.0550	0.2802	0.1290	0.0388
	[0.731 0.831]	[0.028 0.127]	[0.815 0.881]	[0.465 0.737]	[0.015 0.094]	[0.147 0.409]	[0.036 0.201]	[0.006 0.069]
ρ_{rf}	0.9567	0.7333	0.7952	0.7662	0.7413	0.7474	0.8416	0.5370
	[0.922 0.995]	[0.643 0.830]	[0.755 0.829]	[0.529 0.975]	[0.681 0.799]	[0.642 0.841]	[0.772 0.892]	[0.459 0.619]
ρ_{p_o}	0.5490	0.7052	0.5777	0.5335	0.5284	0.7569	0.4503	0.8560
	[0.445 0.661]	[0.637 0.751]	[0.560 0.598]	[0.410 0.665]	[0.464 0.592]	[0.710 0.799]	[0.385 0.512]	[0.803 0.906]
ρ_o	0.6796	0.4845	0.9368	0.5593	0.6379	0.7319	0.7560	0.8331
	[0.338 0.906]	[0.409 0.583]	[0.893 0.967]	[0.433 0.700]	[0.568 0.723]	[0.636 0.852]	[0.612 0.948]	[0.678 0.987]
$\rho_{y_{of}}$	0.3723	0.4145	0.9568	0.5725	0.4480	0.4810	0.5421	0.3821
	[0.253 0.501]	[0.319 0.501]	[0.949 0.964]	[0.383 0.742]	[0.325 0.564]	[0.403 0.557]	[0.471 0.650]	[0.256 0.505]
$\rho_{y_{Mf}}$	0.8261	0.7274	0.9977	0.8772	0.8560	0.8583	0.9444	0.8988
	[0.748 0.905]	[0.673 0.775]	[0.995 0.999]	[0.789 0.977]	[0.783 0.915]	[0.813 0.907]	[0.903 0.989]	[0.837 0.961]
$\rho_{\pi f}$	0.8456	0.6004	0.7994	0.7427	0.9899	0.7850	0.9114	0.7623
	[0.736 0.957]	[0.546 0.652]	[0.779 0.824]	[0.693 0.792]	[0.983 0.997]	[0.732 0.831]	[0.879 0.949]	[0.709 0.804]
ρ_{a_o}	0.6222	0.7564	0.6409	0.6463	0.7074	0.7468	0.8645	0.5896
	[0.259 0.904]	[0.609 0.900]	[0.603 0.687]	[0.396 0.888]	[0.649 0.767]	[0.646 0.846]	[0.790 0.930]	[0.325 0.851]
ρ_{a_M}	0.5758	0.5127	0.4027	0.6314	0.7543	0.3870	0.7909	0.4242
	[0.315 0.823]	[0.318 0.718]	[0.374 0.435]	[0.343 0.967]	[0.683 0.818]	[0.252 0.575]	[0.639 0.921]	[0.136 0.672]
$\rho_{a_{nT}}$	0.9639	0.7631	0.8957	0.6783	0.8944	0.8793	0.9381	0.7936
	[0.941 0.988]	[0.689 0.846]	[0.843 0.948]	[0.404 0.941]	[0.792 0.995]	[0.782 0.980]	[0.825 1.000]	[0.614 0.986]
ρ_η	0.7847	0.1781	0.7154	0.6815	0.5189	0.5625	0.6786	0.8130
	[0.744 0.822]	[0.100 0.238]	[0.698 0.728]	[0.452 0.914]	[0.424 0.620]	[0.480 0.656]	[0.506 0.889]	[0.675 0.941]
ρ_ς	0.5892	0.8555	0.7614	0.6854	0.8008	0.8659	0.8620	0.7344
	[0.300 0.882]	[0.767 0.944]	[0.721 0.787]	[0.484 0.913]	[0.683 0.905]	[0.747 0.986]	[0.746 0.963]	[0.545 0.958]
σ_{rf}	0.9227	0.1180	0.3251	2.7148	0.6796	0.1455	0.4224	5.9328
	[0.643 1.217]	[0.088 0.146]	[0.127 0.483]	[1.640 3.755]	[0.597 0.766]	[0.097 0.187]	[0.315 0.525]	[5.237 6.656]
$\sigma_{y_{of}}$	8.1616	8.4479	2.4298	9.7520	9.3771	16.8475	8.5713	8.3352
	[7.355 8.949]	[7.435 9.414]	[2.136 2.684]	[8.682 10.888]	[8.205 10.408]	[15.688 17.966]	[7.942 9.324]	[7.546 9.135]
$\sigma_{y_{Mf}}$	5.3860	1.9653	1.7661	4.8418	0.4739	12.3557	0.3964	0.9879
	[4.800 5.952]	[1.795 2.178]	[1.148 1.900]	[4.271 5.349]	[0.425 0.523]	[11.041 13.634]	[0.357 0.446]	[0.882 1.109]
σ_{p_o}	12.2449	12.0238	2.7852	1.6465	11.7221	1.9378	12.0662	12.1548
	[10.998 13.452]	[11.151 12.809]	[2.016 2.979]	[0.368 2.814]	[10.639 12.788]	[1.734 2.147]	[10.962 13.394]	[11.087 13.262]
σ_r	2.0881	0.1083	0.4869	4.8418	0.5167	0.1389	0.2056	4.6267
	[1.688 2.474]	[0.082 0.134]	[0.438 0.535]	[4.271 5.349]	[0.434 0.605]	[0.095 0.179]	[0.154 0.258]	[3.947 5.348]
σ_o	1.6106	5.4303	0.2251	1.7263	0.8361	0.5722	0.4040	0.3782
	[0.143 2.782]	[4.351 6.564]	[0.124 0.320]	[1.476 1.973]	[0.143 1.417]	[0.112 1.151]	[0.138 0.703]	[0.121 0.667]
$\sigma_{\pi f}$	0.6881	1.1205	2.0377	5.5883	0.1025	1.4278	0.8457	10.0467
	[0.262 1.142]	[0.983 1.311]	[1.680 2.338]	[4.044 7.290]	[0.082 0.121]	[1.204 1.658]	[0.750 0.957]	[8.872 11.097]
σ_{a_o}	0.6449	0.4161	1.3733	10.1655	0.6392	2.1710	2.6382	0.4780
	[0.144 1.182]	[0.127 0.690]	[1.193 1.509]	[8.604 11.647]	[0.226 0.960]	[1.869 2.439]	[2.184 3.177]	[0.117 1.009]
σ_{a_M}	0.5771	0.4180	0.3617	0.4852	0.2489	0.4101	2.6217	0.4798
	[0.118 1.303]	[0.131 0.779]	[0.143 0.647]	[0.121 0.978]	[0.117 0.373]	[0.119 0.734]	[0.442 5.199]	[0.122 0.944]
$\sigma_{a_{nT}}$	1.6445	0.1022	0.2907	0.5776	0.0735	0.1128	0.1863	0.2738
	[1.319 1.997]	[0.078 0.124]	[0.149 0.412]	[0.104 1.379]	[0.060 0.085]	[0.085 0.141]	[0.100 0.285]	[0.127 0.419]
σ_η	1.5805	0.3767	1.3000	0.3388	0.7946	0.5169	0.4645	0.5354
	[0.893 2.205]	[0.283 0.459]	[1.022 1.586]	[0.126 0.571]	[0.464 1.157]	[0.242 0.770]	[0.111 0.781]	[0.126 1.046]
σ_ς	0.4911	0.4896	1.9912	1.7662	0.4103	0.4026	0.4281	0.3661
	[0.116 1.009]	[0.127 1.007]	[1.290 2.703]	[0.111 4.668]	[0.117 0.773]	[0.119 0.759]	[0.116 0.764]	[0.121 0.629]

monetary authorities. To the opposite, countries disregard output target. Oil exporting countries may favor the stability of the exports receipts in dollar relative to domestic targets.

The middle part of Tables 3.6 and 3.8 displays the persistence of shocks affecting the macroeconomic variables considered in our model. In our two groups of countries, the persistence of the domestic interest rate shocks (ρ_r) given by the posteriors is lower than the priors. This finding is consistent with the role played by the exchange rate in the conduct of the monetary policy. More precisely, domestic authorities use the interest rate to manage their exchange rates, preventing a smoothing adjustment of this variable. Except for Venezuela (high oil dependent) and United Arab Emirates (low oil dependent), the persistence of the foreign interest rate shock (ρ_{rf}) estimated by the posteriors is higher than the priors. In addition, on average, the persistence is larger in high oil dependent countries. On average, the persistence of oil price shock (ρ_{po}) is close to the prior means. Among the high oil dependent economies, Kuwait exhibits the lowest persistence (0.45) while the shock has a sizeable persistence for Venezuela (0.85). In the other group, the lowest persistence is observed for Mexico (0.53) and the highest in Egypt (0.89). In the two samples, posterior means exhibit a stronger persistence of world inflation shock ($\rho_{\pi f}$) relative to priors. On average, world inflation shock tend to be more persistent in high oil dependent countries. As expected in RBC models, technological shocks (ρ_a) in oil, manufacturing and non-tradable sectors are persistent. Tables 3.6 and 3.8 show that this persistence is larger in high oil dependent countries, especially in oil and non-tradable sectors.

Overall, posterior means suggest that shocks persistence tend to be larger in high oil dependent economies. As a result, we expect more difficulties in the group of countries to face to macroeconomic shocks, and, more particularly, to oil shocks.

The lower part of tables 3.6 and 3.8 display to what extent the monetary policy in our studied countries must face to a volatile environment. The tables show that the volatility directly associated to oil is especially high in the two samples. On average, the volatility of oil price shock (σ_{po}) is significantly higher in high oil dependent countries relative to low oil dependent ones. In these two groups of countries, posteriors means are dramatically higher than priors. Countries such as Algeria, Ecuador, Egypt, Indonesia,

Table 3.7: Estimation results of the low oil dependant countries.

	Mexico	Argentina	Malaysia	Ecuador	Egypt	UAE	Indonesia	Russia
ϖ	0.5125	0.1611	0.2973	0.5387	0.4993	0.4074	0.7245	0.7686
	[0.033 0.919]	[0.045 0.288]	[0.142 0.466]	[0.345 0.716]	[0.336 0.620]	[0.239 0.631]	[0.625 0.827]	[0.627 0.935]
ψ_o	9.7215	8.6483	10.2419	4.5036	6.2511	4.6287	7.4428	1.9366
	[5.980 12.373]	[7.319 9.805]	[8.508 11.506]	[3.347 5.582]	[4.982 7.499]	[2.782 5.818]	[6.530 8.373]	[0.152 3.347]
ψ_M	0.2387	2.4348	9.0910	4.9060	0.3551	3.9994	6.7479	4.7793
	[0.095 0.395]	[1.838 3.021]	[7.513 10.562]	[3.679 6.600]	[0.245 0.476]	[2.508 5.386]	[4.716 8.746]	[1.326 8.367]
ψ_{nT}	2.4277	9.9594	1.4786	1.1040	5.5228	4.9074	0.4915	6.1441
	[1.068 4.331]	[9.300 10.670]	[0.868 2.097]	[0.671 1.607]	[4.523 6.647]	[3.235 6.923]	[0.215 0.770]	[4.143 8.433]
α_o	0.1979	0.1328	0.3246	0.3218	0.3226	0.3069	0.3050	0.3469
	[0.156 0.244]	[0.110 0.152]	[0.283 0.357]	[0.246 0.398]	[0.287 0.361]	[0.281 0.331]	[0.266 0.343]	[0.293 0.408]
β_o	0.0564	0.1801	0.0430	0.0833	0.0736	0.0266	0.1636	0.0599
	[0.042 0.072]	[0.136 0.216]	[0.025 0.067]	[0.064 0.107]	[0.051 0.094]	[0.014 0.039]	[0.153 0.176]	[0.033 0.089]
θ_o	0.5131	0.4406	0.5020	0.4883	0.4691	0.4596	0.4372	0.5136
	[0.465 0.561]	[0.366 0.522]	[0.438 0.546]	[0.447 0.523]	[0.441 0.494]	[0.437 0.483]	[0.409 0.466]	[0.444 0.565]
α_M	0.4596	0.4326	0.4040	0.3201	0.4196	0.3682	0.3532	0.4167
	[0.386 0.531]	[0.397 0.467]	[0.366 0.446]	[0.261 0.368]	[0.366 0.469]	[0.343 0.390]	[0.302 0.389]	[0.346 0.492]
β_M	0.4089	0.3229	0.2738	0.1611	0.2987	0.2957	0.2909	0.3377
	[0.358 0.460]	[0.293 0.354]	[0.242 0.304]	[0.136 0.187]	[0.271 0.326]	[0.266 0.334]	[0.258 0.331]	[0.300 0.376]
θ_M	0.4155	0.3830	0.4013	0.3193	0.4027	0.3427	0.3600	0.2890
	[0.358 0.468]	[0.328 0.447]	[0.346 0.459]	[0.275 0.349]	[0.337 0.458]	[0.318 0.373]	[0.323 0.397]	[0.244 0.328]
α_{nT}	0.3295	0.3690	0.3587	0.2509	0.3084	0.3342	0.3169	0.2854
	[0.271 0.395]	[0.341 0.398]	[0.302 0.440]	[0.220 0.282]	[0.288 0.324]	[0.310 0.355]	[0.286 0.349]	[0.245 0.330]
β_{nT}	0.4282	0.4210	0.3455	0.5349	0.4538	0.4786	0.3856	0.4906
	[0.341 0.500]	[0.403 0.441]	[0.275 0.392]	[0.497 0.565]	[0.434 0.479]	[0.456 0.492]	[0.357 0.419]	[0.441 0.535]
θ_{nT}	0.1213	0.0747	0.1351	0.1561	0.0938	0.2786	0.1558	0.1411
	[0.099 0.143]	[0.051 0.091]	[0.120 0.152]	[0.133 0.180]	[0.088 0.099]	[0.262 0.298]	[0.139 0.170]	[0.102 0.173]
ϕ_M	0.6039	0.5898	0.6656	0.4442	0.5188	0.6839	0.6715	0.4492
	[0.531 0.674]	[0.568 0.612]	[0.627 0.705]	[0.413 0.471]	[0.497 0.547]	[0.655 0.711]	[0.619 0.704]	[0.388 0.508]
ϕ_{nT}	0.6724	0.6719	0.6616	0.8238	0.6330	0.6808	0.6708	0.7284
	[0.613 0.743]	[0.628 0.713]	[0.616 0.733]	[0.779 0.850]	[0.594 0.666]	[0.658 0.711]	[0.620 0.699]	[0.674 0.778]
ϕ_I	0.5814	0.4674	0.7424	0.6691	0.5476	0.7421	0.5834	0.5296
	[0.509 0.654]	[0.449 0.486]	[0.688 0.809]	[0.634 0.699]	[0.523 0.570]	[0.681 0.808]	[0.543 0.641]	[0.474 0.585]
χ_I	0.0754	0.5971	0.2244	0.0526	0.0788	0.7231	0.5321	0.5489
	[0.047 0.096]	[0.532 0.634]	[0.165 0.282]	[0.047 0.060]	[0.064 0.097]	[0.645 0.810]	[0.497 0.559]	[0.453 0.646]
χ_M	0.1338	0.0574	0.2244	0.1534	0.1553	0.0921	0.2242	0.3638
	[0.008 0.257]	[0.004 0.100]	[0.165 0.282]	[0.078 0.211]	[0.079 0.235]	[0.026 0.144]	[0.091 0.358]	[0.115 0.530]
χ_{nT}	0.2268	0.4087	0.1715	0.6006	0.2175	0.4756	0.2371	0.5366
	[0.162 0.296]	[0.352 0.464]	[0.088 0.260]	[0.519 0.662]	[0.136 0.312]	[0.398 0.554]	[0.178 0.294]	[0.420 0.652]
φ_o	0.6894	0.6507	0.7357	0.6957	0.6099	0.6877	0.6481	0.6632
	[0.639 0.749]	[0.605 0.697]	[0.683 0.780]	[0.662 0.731]	[0.555 0.664]	[0.652 0.726]	[0.615 0.684]	[0.576 0.760]
φ_M	0.6566	0.6598	0.6622	0.5732	0.6031	0.6367	0.6020	0.6543
	[0.612 0.701]	[0.624 0.697]	[0.613 0.701]	[0.493 0.625]	[0.575 0.638]	[0.603 0.672]	[0.563 0.646]	[0.607 0.699]
φ_{nT}	0.7055	0.8930	0.7714	0.7331	0.8949	0.7393	0.7998	0.6433
	[0.665 0.750]	[0.880 0.905]	[0.742 0.807]	[0.701 0.757]	[0.862 0.913]	[0.718 0.761]	[0.772 0.831]	[0.591 0.695]
μ_π	0.3035	0.2891	0.2225	0.4589	1.3658	1.0607	−0.2864	0.4007
	[0.073 0.522]	[0.130 0.444]	[0.038 0.376]	[0.269 0.608]	[1.182 1.548]	[0.844 1.294]	[−0.364 −0.213]	[0.206 0.587]
μ_e	1.3183	2.3051	1.5025	1.1423	1.6896	1.0973	0.8725	0.5835
	[1.068 1.564]	[2.169 2.408]	[1.279 1.695]	[0.968 1.335]	[1.475 1.863]	[1.007 1.196]	[0.784 0.988]	[0.405 0.777]
μ_y	−0.1743	0.0115	0.1695	0.0090	0.0034	−0.0097	0.0060	−0.0773
	[−0.224 −0.126]	[−0.003 0.025]	[0.095 0.231]	[−0.004 0.025]	[−0.004 0.011]	[−0.038 0.016]	[−0.005 0.017]	[−0.137 −0.041]

Table 3.8: Estimation results of the low oil dependant countries (continued).

	Mexico	Malaysia	Argentina	Ecuador	Egypt	Indonesia	UAE	Russia
ρ_r	0.1902	0.0497	0.7632	0.2952	0.0744	0.3367	0.6831	0.5018
	[0.093 0.291]	[0.009 0.088]	[0.722 0.802]	[0.151 0.444]	[0.008 0.132]	[0.189 0.507]	[0.651 0.716]	[0.364 0.660]
ρ_{rf}	0.6650	0.6411	0.7770	0.8910	0.7538	0.9546	0.3375	0.7802
	[0.592 0.741]	[0.574 0.712]	[0.524 0.996]	[0.839 0.918]	[0.707 0.802]	[0.933 0.978]	[0.213 0.437]	[0.632 0.936]
ρ_{p_o}	0.5297	0.7256	0.8584	0.5570	0.5554	0.5668	0.6516	0.5756
	[0.431 0.628]	[0.624 0.818]	[0.781 0.938]	[0.459 0.654]	[0.450 0.656]	[0.503 0.631]	[0.583 0.713]	[0.469 0.688]
ρ_o	0.5595	0.6313	0.5103	0.5766	0.8977	0.5755	0.7371	0.8292
	[0.406 0.706]	[0.463 0.822]	[0.346 0.651]	[0.300 0.816]	[0.812 0.995]	[0.385 0.773]	[0.548 0.927]	[0.716 0.950]
$\rho_{y_o f}$	0.4329	0.8168	0.8129	0.7097	0.8663	0.4104	0.4001	0.6917
	[0.301 0.566]	[0.695 0.946]	[0.570 0.988]	[0.550 0.850]	[0.807 0.907]	[0.246 0.581]	[0.277 0.547]	[0.570 0.822]
$\rho_{y_M f}$	0.8372	0.6891	0.8121	0.5084	0.8855	0.7645	0.4645	0.8050
	[0.785 0.890]	[0.620 0.748]	[0.736 0.886]	[0.350 0.606]	[0.840 0.927]	[0.554 0.948]	[0.363 0.575]	[0.710 0.899]
$\rho_{\pi f}$	0.7652	0.8193	0.5088	0.7037	0.7425	0.8223	0.6948	0.9390
	[0.728 0.802]	[0.773 0.876]	[0.392 0.624]	[0.643 0.774]	[0.711 0.770]	[0.767 0.874]	[0.537 0.869]	[0.909 0.968]
ρ_{a_o}	0.5750	0.8471	0.8143	0.7174	0.8329	0.0985	0.5010	0.8307
	[0.369 0.762]	[0.806 0.893]	[0.728 0.894]	[0.639 0.782]	[0.779 0.891]	[0.025 0.165]	[0.392 0.615]	[0.690 0.983]
ρ_{a_M}	0.7182	0.6834	0.5765	0.2629	0.3900	0.4775	0.3290	0.7697
	[0.482 0.991]	[0.391 0.968]	[0.367 0.749]	[0.117 0.414]	[0.236 0.526]	[0.367 0.584]	[0.139 0.522]	[0.576 0.993]
$\rho_{a_{nT}}$	0.6217	0.8655	0.7153	0.9219	0.7331	0.8964	0.9379	0.5009
	[0.395 0.884]	[0.786 0.960]	[0.496 0.917]	[0.898 0.938]	[0.600 0.893]	[0.825 0.984]	[0.894 0.983]	[0.184 0.827]
ρ_η	0.4936	0.9811	0.7785	0.4891	0.9413	0.5648	0.4612	0.8878
	[0.119 0.830]	[0.956 0.999]	[0.679 0.891]	[0.310 0.663]	[0.901 0.980]	[0.457 0.702]	[0.388 0.535]	[0.807 0.968]
ρ_ς	0.7045	0.3397	0.5142	0.6929	0.9050	0.3828	0.7993	0.6478
	[0.448 0.950]	[0.115 0.540]	[0.387 0.655]	[0.431 0.961]	[0.834 0.979]	[0.116 0.591]	[0.610 0.995]	[0.423 0.901]
σ_{rf}	5.8890	1.2454	0.3950	5.3395	0.9600	9.6439	0.7993	0.4256
	[4.904 6.814]	[1.080 1.432]	[0.108 0.777]	[4.161 6.316]	[0.826 1.080]	[8.642 10.680]	[0.610 0.995]	[0.115 0.821]
$\sigma_{y_o f}$	8.6707	9.4071	0.7290	9.2425	10.3466	0.3509	0.0938	1.3197
	[7.776 9.559]	[8.309 10.460]	[0.131 1.296]	[8.337 10.104]	[9.269 11.416]	[0.127 0.611]	[0.073 0.114]	[1.084 1.503]
$\sigma_{y_M f}$	1.4067	11.8206	4.3753	0.4425	1.2107	0.4060	17.1384	4.9351
	[1.097 1.768]	[10.695 13.033]	[3.958 4.804]	[0.124 0.793]	[1.060 1.356]	[0.116 0.795]	[15.491 18.503]	[4.591 7.920]
σ_{p_o}	1.3530	12.9848	1.0320	11.4586	12.5252	11.9653	1.7602	1.4102
	[1.224 1.675]	[11.660 14.308]	[0.141 1.845]	[10.530 12.484]	[11.414 13.746]	[10.803 13.118]	[1.241 1.914]	[1.137 1.616]
σ_r	0.6088	0.3113	0.1805	8.5882	0.2125	4.7856	1.7926	3.7102
	[0.118 0.950]	[0.167 0.451]	[0.103 0.252]	[7.464 9.459]	[0.132 0.294]	[3.973 5.562]	[1.546 2.006]	[0.957 6.339]
σ_o	1.2923	0.4741	0.3577	0.5855	0.5493	0.4412	0.0849	0.6533
	[0.124 2.445]	[0.115 0.886]	[0.135 0.578]	[0.120 1.290]	[0.108 1.268]	[0.118 0.882]	[0.067 0.100]	[0.116 1.549]
$\sigma_{\pi f}$	11.8121	1.0897	9.2394	9.3806	6.4872	11.3810	0.3413	3.3903
	[9.907 13.824]	[0.950 1.216]	[7.915 10.391]	[7.766 10.792]	[5.806 7.129]	[10.182 12.468]	[0.116 0.602]	[3.002 4.143]
σ_{a_o}	0.7250	3.8869	2.9866	5.5227	4.6737	15.8658	0.1146	0.5263
	[0.149 1.232]	[3.394 4.387]	[2.531 3.506]	[4.328 6.603]	[4.028 5.296]	[14.442 17.564]	[0.085 0.143]	[0.131 1.003]
σ_{a_M}	0.4081	0.3790	0.3532	0.3709	0.6285	0.5337	1.8057	0.4130
	[0.119 0.721]	[0.124 0.651]	[0.140 0.621]	[0.128 0.678]	[0.105 1.615]	[0.117 1.061]	[1.595 2.003]	[0.111 0.760]
$\sigma_{a_{nT}}$	0.2909	0.2368	0.2534	9.6606	0.1538	0.3386	0.3119	0.4490
	[0.127 0.452]	[0.132 0.340]	[0.128 0.371]	[7.761 11.314]	[0.103 0.201]	[0.117 0.591]	[0.115 0.522]	[0.106 0.911]
σ_η	0.4456	0.2323	0.2104	0.4370	0.2939	0.4558	0.1070	1.2791
	[0.119 0.855]	[0.128 0.344]	[0.124 0.302]	[0.121 0.866]	[0.151 0.430]	[0.236 0.648]	[0.080 0.132]	[0.187 2.622]
σ_ς	0.4768	0.3926	0.4433	0.4119	0.4279	0.4561	0.1814	0.4633
	[0.117 0.863]	[0.115 0.703]	[0.122 0.904]	[0.104 0.745]	[0.115 0.885]	[0.113 0.897]	[0.100 0.260]	[0.118 0.936]

Kuwait, Libya, Malaysia, Oman, and Venezuela display oil prices volatility. Similarly, the volatility of technological shock in the oil sector (σ_{a_o}) is high in the two subsamples.

Foreign interest shocks (σ_{r^f}) exhibit higher volatility in low oil dependent countries. In addition, Table 3.8 shows that the dispersion between low oil dependent economies is significantly higher than in high oil dependent countries. If, on average, the volatility of the domestic interest rate (σ_r) is higher in low oil dependent countries, the two groups of economies exhibit a similar pattern. More precisely, Tables 3.6 and 3.8 show that Islamic countries (where the interest rates are highly regulated) and economies with more rigid exchange rate arrangements have the lowest domestic interest rate volatility. Overall, both high and low oil dependent countries are characterized by a volatile environment. Interestingly, on average, we can note that in these two groups of countries oil prices, foreign inflation, and technological shock in the oil sector exhibit the highest volatilities.

3.3.2 Impulses response functions

We consider the responses of sectorial composition of production (Figures 3.2-3.5), hours worked (Figure 3.6), wages (Figure 3.7), inflation rate and exchange rates (nominal and real) (Figures 3.8-3.10) to a positive oil price shock. The purpose of this analysis is to identify oil producing countries in which a positive oil price shock leads to a Dutch disease effect. Then, for this group of countries, we study the respective impact of the resource movement effect and the spending effect.

Recall that, an increase in oil price and its subsequent surge in resource exports cause an appreciation of the real exchange rate (through the appreciation of the nominal exchange rate and/or a rise in the domestic price level) which decreases the competitiveness of the country's other, non-resource manufactured goods. This manufacturing goods sector experiences a decrease in production insofar as their higher relative prices lead to competitiveness losses. In addition, since the windfall involves the domestic price level to increase, producers of manufactured goods faces higher production costs, which causes them to reduce their output. Consequently, the manufacturing goods sector contracts, and de-industrialization sets in Rudd (1996).

The impulse response functions in the different sectors after a positive oil price shock exhibit a Dutch disease effect in high oil dependent countries. Indeed, the production in the manufacturing sector decreases after the shock in Algeria, Kuwait, Oman, Saudi Arabia, and Venezuela. As expected with the Dutch disease effect, Figures (3.2-3.3) exhibit strong positive responses of the non-tradable and in Gabon, Libya, Nigeria, Saudi Arabia, and Venezuela. The increase in this sector is observed with a lag in Algeria, Kuwait, and Oman. Results concerning low oil dependent countries (Figures 3.4-3.5) suggest that, except Mexico to a certain extent, a positive oil price shock does not induce a Dutch disease effect.

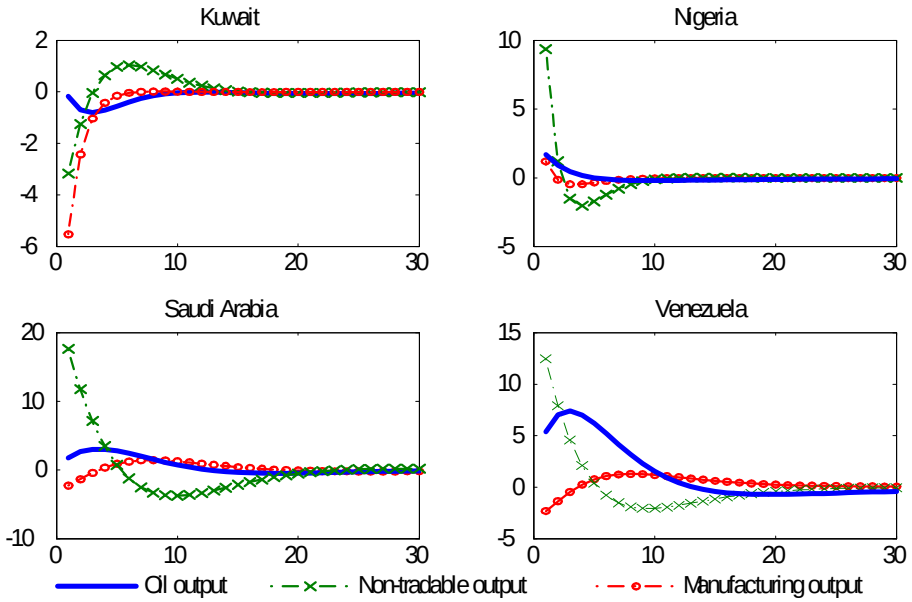


Figure 3.2: The effect of 1% positive oil price shock on sectoral output in high oil dependent countries.

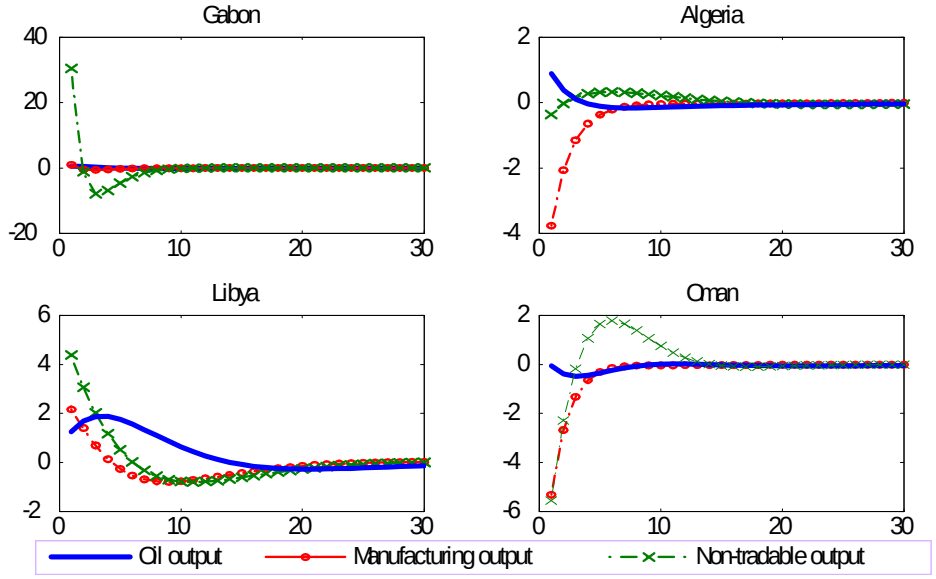


Figure 3.3: The effect of 1% positive oil price shock on sectoral output in high oil dependent countries (continue).

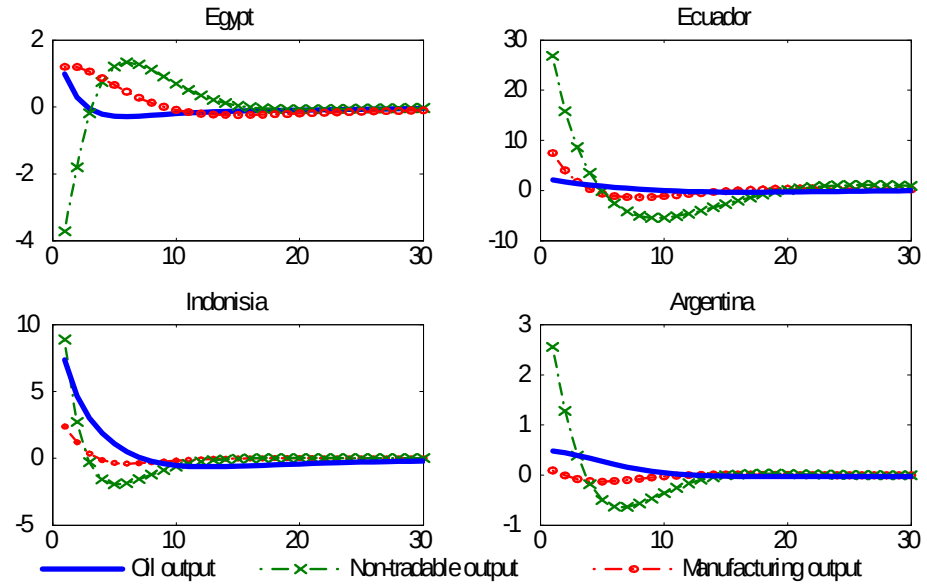


Figure 3.4: The effect of 1% positive oil price shock on sectoral output in low oil dependent countries.

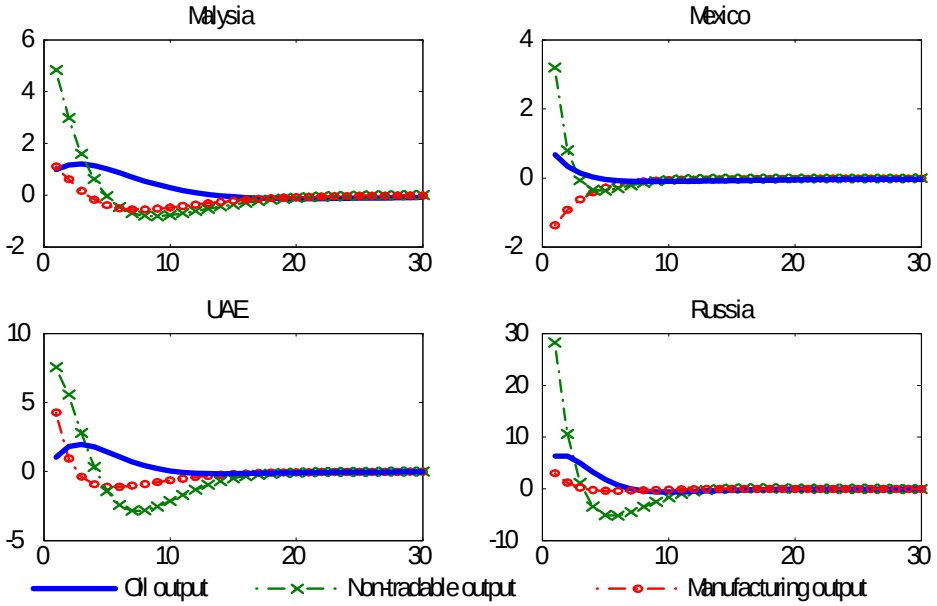


Figure 3.5: The effect of 1% positive oil price shock on sectoral output in low oil dependent countries (continue).

Figures 3.6 and 3.7 allow us to see to what extent the Dutch disease effect is explained by the resource movement effect and the spending effect respectively. The resource movement effect is based on the perfect capital and labor mobility between the production sectors. According to this effect, in the aftermath of a positive oil price shock, capital and labor move from the manufacturing sector to the oil and non-tradable sectors. As a result, if the resource movement effect is present, we expect a decrease (an increase) in the hours worked in the manufacturing sector (in the oil and non-tradable sectors). We must also observe a decrease (an increase) in the wages of the manufacturing sector (oil and non-tradable sectors).

Figure 3.6 displays the responses of hours worked to a positive oil price shock in countries suffering from a Dutch disease effect. The main result is a weak response in manufacturing sector suggesting that the resource movement effect is not very important. This finding is confirmed by the responses of wages to the oil price shock. In countries where wages in the manufacturing sector decrease -that is Algeria, Kuwait, Oman, and Saudi Arabia- the responses are weak and short-lived.

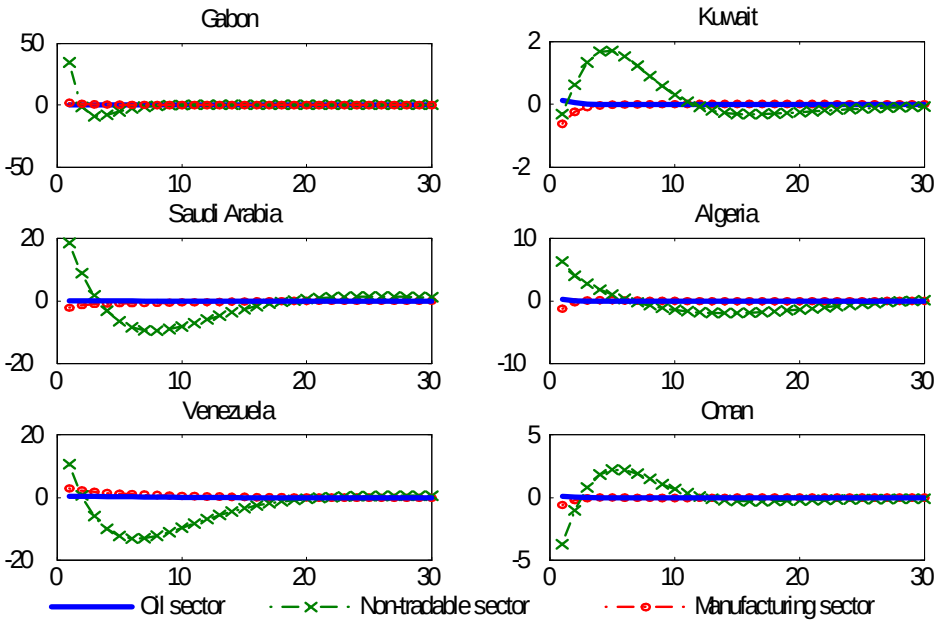


Figure 3.6: Responses of hours worked to oil price shock (Baseline model)

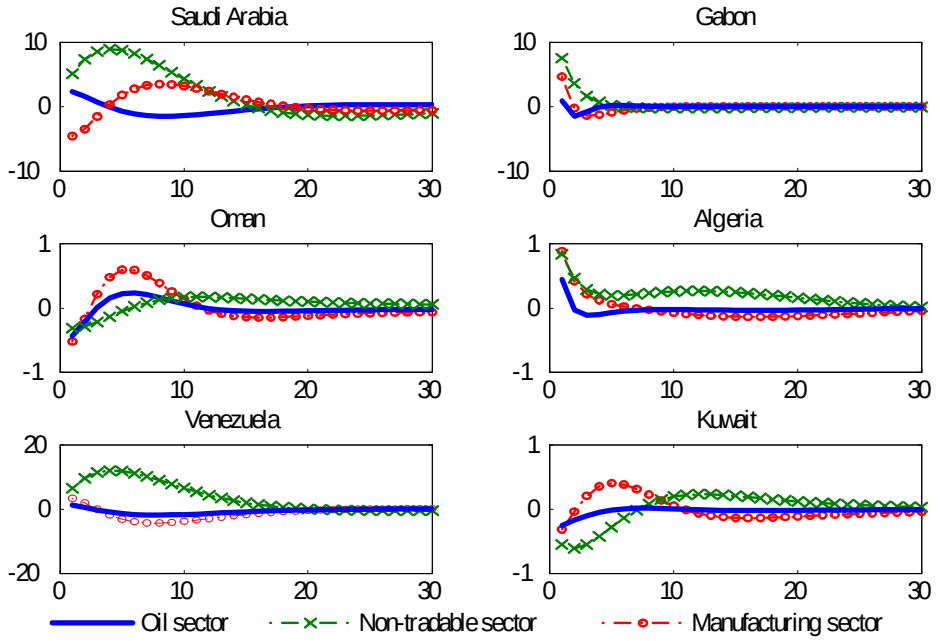


Figure 3.7: Response of wages to an oil price shock (Baseline model)

The spending effect refers to the negative consequence of the real exchange rate appreciation on the manufacturing production. Such appreciation rests on higher domestic incomes due to the increased revenues coming from an increase in oil price and/or the resource discovery. Figures (3.8-3.10) exhibit the responses of the real exchange rates to a positive oil price shock. In all countries, the oil shock is followed by a real appreciation of the domestic currency. The appreciation is persistent in all countries suffering from the Dutch disease. As shown by figures 3.9 and 3.10, this appreciation is explained by an appreciation of the nominal exchange rate in all countries (except Saudi Arabia and Venezuela) and an increase in domestic price level in all countries. These results are in line with the theoretical literature.

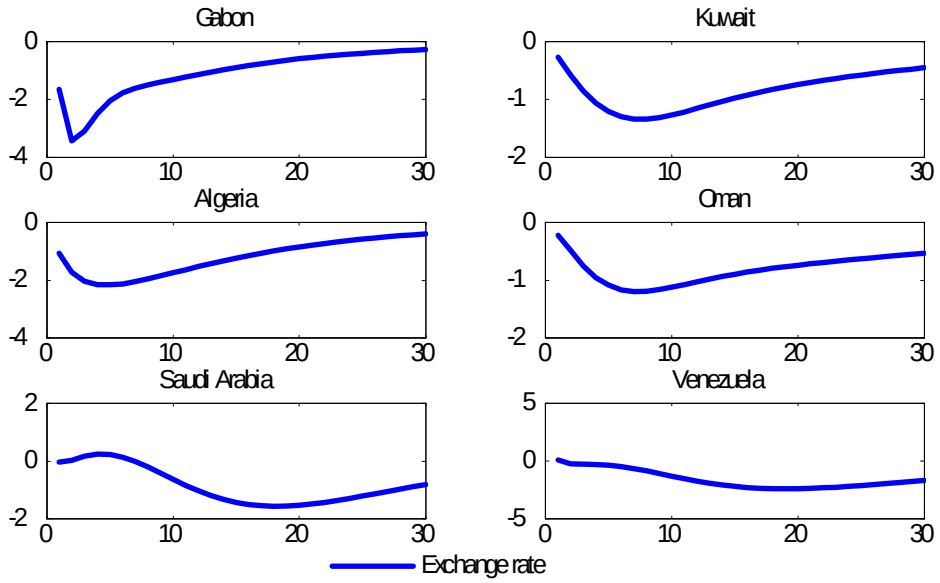


Figure 3.8: Responses of real exchange rate to an oil price shock (Baseline model)

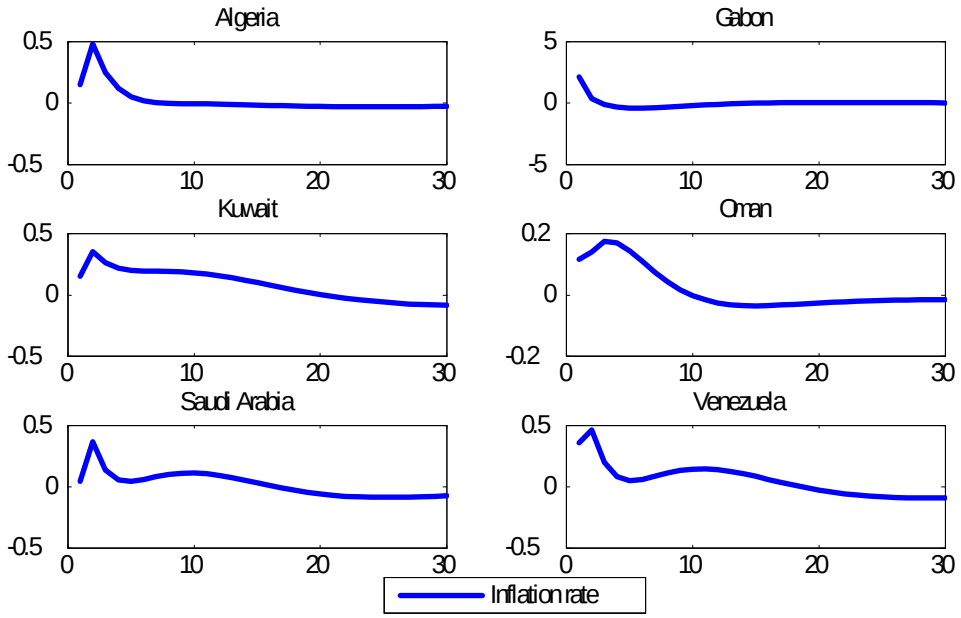


Figure 3.9: Response of inflation rate to an oil price shock (baseline model).

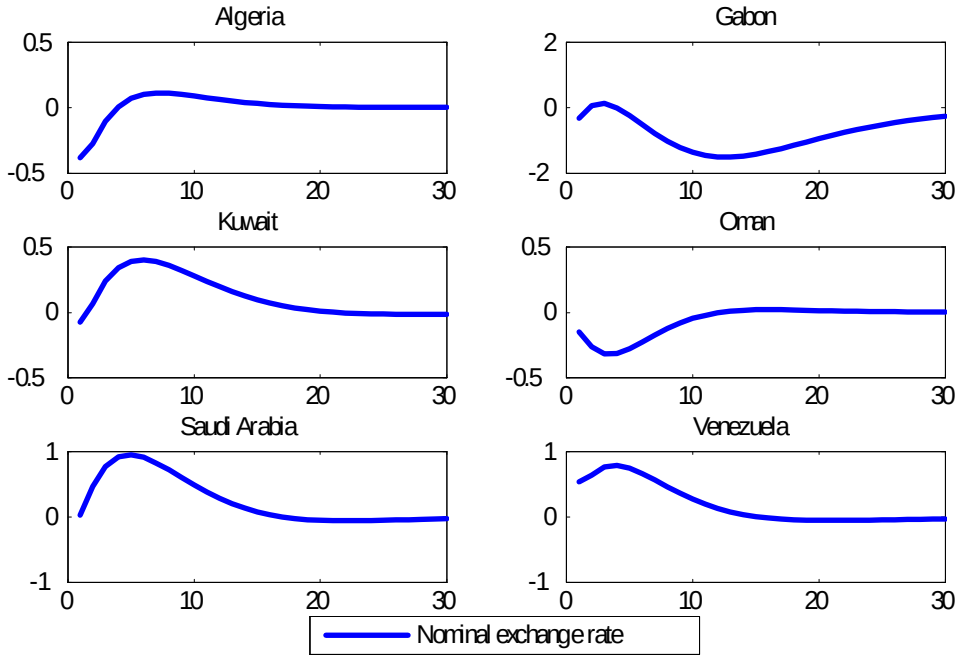


Figure 3.10: Response of nominal exchange rate to an oil price shock (baseline model)

Overall, the previous findings show that the main channel explaining the Dutch disease rests on the spending effect. The smaller importance of the resource movement effect may be due to the size of wages stickiness in the manufacturing sector.

3.4 The role of monetary policy

To evaluate the role of two monetary policy rules, exchange rate (ER) and inflation targeting (IT) rules, we proceed in two steps: i) we assess the responses of key variables (manufacturing output) under each rule only for countries that have suffered a Dutch Disease; ii) then, we compare the welfare implications of alternative monetary policy reaction function in the context of oil price shock.

3.4.1 Fixed exchange rate vs inflation targeting

In this step, we analyze the role of the monetary policy to limit the occurrence of the Dutch disease. More precisely, we compare the responses of selected macroeconomic variables which matter to understand the resource movement and the spending effects under the monetary policy defined in the baseline model and under two alternative monetary policy rules, the exchange rate rule and the inflation targeting rule.

Figures 3.11, 3.14, 3.17, 3.20, 3.23 and 3.26 display the responses of the production in the oil, manufacturing and non-tradable sectors according to our alternative monetary policy rules. If we focus on the manufacturing production, our main finding is that both the exchange rate and the inflation targeting rules exhibit mixed results relative to the baseline model. Except Gabon for the exchange rate rule, no monetary rules prevent a negative response to a positive oil price shock. However, inflation targeting rule allows weaker negative reaction in Kuwait, Saudi Arabia, and Venezuela. We get a similar conclusion for the responses of the non-tradable production in the aftermath of a positive oil price shock. Overall, monetary policy, whatever the monetary rule adopted by the authorities, seems to have only a weak influence on the production changes in the different economic sectors.

Figures 3.12, 3.15, 3.21, 3.24 and 3.27 exhibit the changes in hours worked after a positive oil price shock. Our main finding is the following: the two monetary policy

rules get better performances than the baseline model to decrease the negative impact of the positive oil price shock on hours worked in the manufacturing sector. There are only two exceptions: Gabon and Oman. This two countries -with Saudi Arabia- share a similar characteristic: over the major part of the period, they have adopted the most rigid exchange rate regimes. More precisely, in Algeria, Kuwait, Saudi Arabia, and Venezuela, the contemporaneous response of the hours worked in the manufacturing sector is positive while the response expected by the Dutch disease effect is negative (as in the baseline model). In other words, the inflation targeting rule has a stabilizing influence. Exchange rate rule offers a similar stabilizing impact in Saudi Arabia and Venezuela. The analysis of the responses of the wages in the manufacturing sector (Figures 3.13, 3.16, 3.19, 3.22, 3.25 and 3.28) show more mixed results. In Kuwait and Saudi Arabia the response of wages in the manufacturing sector on the impact of a positive oil price shock is positive under the inflation targeting rule while the response is negative in the baseline model. Inflation targeting rule allows smaller fluctuations in Gabon and Oman.

Overall, even if the monetary policy does not exert a strong influence on the resource movement effect in countries suffering from a Dutch disease effect, our results show that the inflation targeting rule is more efficient to contain the occurrence of the resource movement effect.

The figure 30 displays the responses of the real exchange rates according the alternative monetary policy rules. The exchange rate rule produces the best performances in all countries (only at long-horizon) exept in Oman.

3.4.2 Welfare analysis

To conduct this analysis, we solve the model to a second order approximation around its deterministic steady state[8]. The main goal is to compare the welfare implications of alternative optimized monetary policy reaction function. Following these studies, we compute the welfare using the unconditional expectation of the utility function. Form-

[8] In the deterministic steady state, all shocks are set to zero and there is no uncertainty. This method allows us to compare welfare implications of alternative monetary policy because the deterministic steady-state is invariant across all policy regimes considered.

ally, the welfare criterion is derived from the following single period utility function:

$$u(.) = \frac{1}{1-\gamma}\eta_t \left(\frac{c_t}{{c_{t-1}}^{\varpi}} \right)^{1-\gamma} - \varsigma_t \frac{{h_t}^{1+\sigma}}{1+\sigma}, \tag{3.70}$$

The welfare cost is measured by using the compensating variation. This method allows us to measure the percentage changes in consumption in the deterministic steady state.

We calculate the welfare implications for each country that suffered a Dutch Disease after an oil price shock. We use in each case two monetary policy rules: ER rule and IT rule. For this purpose, we follow the typical way to examine the welfare implications of monetary policy rules which consist to estimating the baseline model with a given monetary policy, then varying parameters in the monetary policy rule, while keeping all other parameters the same as in the baseline model. An advantage of this procedure is that policy parameters are the only factors that create differences in the welfare measure.

Table 3.9: Welfare results (in percentage of the steady state of consumption).

	Oil price shock	
	IT rule	ER rule
Algeria	0.00136	0.00335
Gabon	0.0033	0.00210
Kuwait	0.001204	0.000624
Oman	0.00166	0.00085
Saudi Arabia	0.0056	0.0105
Venezuela	0.0134	0.0121

Table 3.9 reports that after an oil price shock, the inflation targeting rule yields the lowest welfare cost in Algeria, and Saudi Arabia. In other words, inflation targeting lowers, in these countries, the welfare cost which is at around 0.00136%, and 0.0056% of consumption in the deterministic steady state respectively in Algeria and Saudi Arabia. However, in the other economies, the exchange rate rule seems to be the best way to avoid the negative effects of an oil price shock. Indeed, the implied welfare cost of an oil price shock, in the case of four high dependent countries (Gabon, Kuwait, Oman and Venezuela), is higher in the model under ER rule. For example, after an oil price shock, using ER rule, the implied welfare is about 0.0121% in Venezuela

and 0.0021% in Gabon. These values jump to 0.0033% and 0.0134% in Gabon and Venezuela respectively under an IT rule. These results are in line with our estimation results. Indeed, recall that our estimations suggest that in the high oil dependent countries, exchange rate matters significantly in the conduct of the monetary policy. Inflation seems to be a secondary target for monetary authorities.

3.5 Conclusion

In this chapter, we built a multisector DSGE model for a sample of countries that depend on oil exports (high and low oil dependent). The aim of this study is to investigate if the Dutch disease effect occurs in both high and low oil dependent countries, or only in one of them. To do so, the model takes into account three production sectors, namely, oil, manufacturing and non-tradable sectors. The oil producer operates under perfect competition and the other two sectors under monopolistic competition. We have, thus, attempted to compare the response of selected variables to an oil price shock in each subsample and then how monetary policy should be conducted to insulate the economy from the impact of this shock.

Our results show that high oil dependent countries are most likely vulnerable to oil price shock than low oil dependent ones. Regarding the appropriate monetary policy rule, we find that both inflation targeting and exchange rate rules may be effective to contain the size of the Dutch disease effect. Our results suggest that in Algeria and Saudi Arabia, inflation targeting offers better performances. We observe the opposite in Gabon, Kuwait, Oman, and Venezuela. Such results are consistent with economic theory. Indeed, we see that in more open economies and smaller countries (in terms of economic size), the exchange rate rule is preferable to inflation rule. Venezuela seems an exception. Such country does not fulfill the traditional criteria favoring the choice of the exchange rule. In fact, this exception is only apparent. First, if we consider the volatility (see Table 3.6), we see that Venezuela is among the most volatile economy. Second, Venezuela suffers from a fiscal dominance effect: both inflation rate and fiscal deficit are the highest relative to other studied countries.

Thesis conclusion

In this thesis we have analyzed the consequences of oil shocks' effects on oil exporting economies and the role of monetary policy in this context. Using DSGE models, an extensive literature is referred to aiming to understand business cycle fluctuations in many developed and developing economies. However, in terms of constructing oil exporting economic models and confronting them with the data, the research agenda is in an early stage of development, at least compared with studies trying to explain these same phenomena in more developed economies like in U.S and Euro area. These essays, then, attempted to conceptualize an oil exporting economy to characterize the impacts of exogenous shocks, especially the oil shocks, on the economic activity of these countries.

Main results and policy implications

The first chapter develops a multisector DSGE model in order to replicate the Dutch disease phenomenon. The discussion focused on analyzing the monetary policy responses to oil shocks, namely the windfall (oil price shock) and the boom (oil resource shock). Three main results emerge from the analysis. First, our impulse functions show that the Dutch disease, under both spending and resource movement effects, seems to appear in the case of flexible wages and sticky prices only under a fixed exchange rate. Second, the windfall leads to a strong effect of Dutch disease in terms of de-industrialization compared to a boom. Third, the choice of a flexible exchange rate regime helps to improve welfare compared to fixed exchange rate.

The second chapter estimates a DSGE model for an oil exporting economy based on features of the Algerian economy. The aim is to analyze the economic consequences of four external shocks and to evaluate three alternative monetary policy rules. The parameter estimates reveal that core inflation target is the best monetary rule to stabilize both output and inflation. These results are two main policy implications. First, they suggest that Algeria should modify its monetary policy in order to adopt a core inflation targeting framework. This implies fulfilling some preconditions such as central bank independence. Second, Algerian authorities must strengthen the influence of interest rate as a transmission channel of monetary policy. To this end, they must promote banking lending to the private sector and the development of the capital market. On

these two points, Algeria lags relative to other upper middle income countries, especially in MENA region, preventing the use of the interest rate as the main instrument of the monetary policy.

The third chapter estimates a multisector DSGE model for a sample of oil exporting economies. The aim of this study is twofold: i) we investigate if the Dutch disease effect occurs in both high and low oil dependent countries, or only in one of them; ii) and evaluate the response of monetary authorities to the oil price shock only in the economies affected by the Dutch disease. Our results show that high oil dependent countries are most likely vulnerable to oil price shock than low oil dependent ones. Regarding the appropriate monetary policy rule, we find that both inflation targeting and exchange rate rules may be effective to contain the size of the Dutch disease effect. Our results suggest that in Algeria and Saudi Arabia, inflation targeting offers better performances. We observe the opposite in Gabon, Kuwait, Oman, and Venezuela. Such results are consistent with economic theory. Indeed, we see that in more open economies and smaller countries (in terms of economic size), the exchange rate rule is preferable to inflation rule. Venezuela seems an exception. Such country does not fulfill the traditional criteria favoring the choice of the exchange rule. In fact, this exception is only apparent. First, if we consider the volatility (see Table 4b), we see that Venezuela is among the most volatile economy. Second, Venezuela suffers from a fiscal dominance effect: both inflation rate and fiscal deficit are the highest relative to other studied countries.

The conclusions drawn from the three chapters carry important implications for a small open oil exporting economy central bank's stabilization policy. The inflation targeting rule seems to be the best way for the central bank to avoid the economic consequences of international shocks.

Future research directions

The above findings and conclusions rest on quite a few important modeling assumptions.

In the first chapter we have adopted some assumptions which can be considered as unrealistic. First, following Corden and Neary (1982) we assumed that the economy produces two goods (manufacturing and oil goods) which are traded at exogenously

given world prices, and a third non-tradable good whose prices are fixed domestically. Regarding the tradable goods sector, the perfect competition assumption is limited for the reason that in emerging oil exporting countries the price of manufacturing production is mostly determined domestically. This is due to the fact that the tradable sector is not sufficiently competitive and its exports are very low or even nonexistent. In other words, the price of manufacturing goods moves to equalize domestic supply and demand. Second, even though the wage rigidity is considered to limit the labor mobility across sectors, the labor market frictions are absent. Indeed, it would more realistic to assume imperfections in the labor market given that its structural characteristic in the most oil exporting economies where the unemployment rate is very high. Thus, it would be necessary for future research to shed more light on these contentious assumptions. More precisely, we expect to explore the existence of a new transmission channel of the Dutch disease effect by introducing a labor market model with matching frictions into the baseline model.

In the second chapter, the main drawback of the study is the absence of fiscal policy in the model. Indeed, as in some primary commodity countries, such as Chile, Algeria has established in 2000 an hydrocarbon stabilization fund (Fonds de régulation des recettes). One of the targets of this fund is to reduce the sensitivity of the fiscal policy to hydrocarbon revenues fluctuations. Indeed, public spending tends to go hand in hand with oil receipts, generating an unstable fiscal policy stance. The integration of fiscal policy, and its interaction with monetary policy, in our model is the main avenue for future research. This is also a new research direction for the last chapter.

Another potential area of research is to address the problem related to the estimation method of our models. More precisely, we expect to use a new methodology that consists to estimate non-linear DSGE model by using Particle Filter.[9] Indeed, as reported

[9] The implementation of Bayesian estimation is more complicated by using non-linear model solution techniques. This difficulty is due to the fact that it is computationally more demanding to obtain the non-linear solution. The most common approach in the literature on estimated DSGE models is to use second order perturbation methods. A comparison of solution methods for DSGE models can be found in Aruoba, Fernandez-Villaverde and Ramirez (2004). Also, the likelihood function becomes more difficult to evaluate because both the state transition equation and the measurement equation of the state-space model are non-linear. Instead of Kalman filter, some authors propose a new filter named Particle Filter. Fernandez-Villaverde, and Ramirez (2007) and Fernandez-Villaverde, and Ramirez (2008) show how a this filter can be used to evaluate the likelihood function associated

by (the Oxford Handbook of Bayesian Econometric by Gewek J, Koop G and Van Dijk H [2011]). DSGE models are inherently nonlinear, as can be seen from the equilibrium conditions. Nonetheless, given the magnitude of the business cycle fluctuations of a country like the United States or the European Union, many researchers take the stand that the equilibrium dynamics are well approximated by a linear state space system. However, this linear approximation becomes unreliable if economies are hit by large shocks , as is often the case for emerging markets economies, or if the goal of the analysis is to study asset pricing implications or consumer welfare.

with a non-linear DSGE model. A detailed description of the particle filter is provided in Pitt, Silva, Giordani, and Kohn (2011).

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Appendix A

Appendix-Chapter 1

A.1 Household's first order conditions

Given initial value, the household chooses $\{c_t,\ k_{o,t+1},\ k_{T,t+1},\ k_{nT,t+1},\ B_t^d$ and $B_t^f\}$ to maximize its expected utility function subject to capital accumulation equation, the budget constraint and the no-Ponzi game restriction. This latter take the following form :

$$\lim_{T\to\infty}\left(\prod_{t=0}^{T}\frac{1}{\kappa_t R_t^f}\right)B_T^f = 0 \tag{A.1}$$

Equation $(A.1)$ implies that households are unable to finance consumption indefinitely by borrowing, i.e, by having negative financial asset.
The function value, V_t, of the household ι is:

$$V_t = \max_{c_t\ ,k_{j,t+1}\ ,B_t^d\ ,B_t^f} \left\{ \begin{array}{c} \frac{1}{1-\gamma}{c_t}^{1-\gamma} - \frac{{h_t}^{1+\sigma}}{1+\sigma} + \beta E_t V_{t+1} - \lambda_t \\ \{P_t c_t + \sum_{j=o,T,nT} P_{j,t}(k_{j,t+1} - \\ (1-\sigma)k_{j,t} + \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right)^2 k_{j,t}\} \\ + \frac{B_t^d}{R_t} + \frac{e_t B_t^f}{R_t^f k_t}) - B_{t-1}^d - e_t B_{t-1}^f - \sum_{j=o,T,nT} Q_{j,t}k_{j,t} - \\ \sum_{j=o,T,nT} W_{j,t}h_{j,t} - D_t + \Gamma_t \end{array} \right\}$$

The solution gives the following first order conditions:

$$\frac{\partial V_t}{\partial c_t} = 0 \rightarrow c_t^{-\gamma} - \lambda_t = 0,$$

$$\frac{\partial V_t}{\partial c_t} = 0 \rightarrow c_t^{-\gamma} = \lambda_t, \tag{A.2}$$

The equation $(A.2)$ is the marginal utility of household's consumption.

$$\frac{\partial V_t}{\partial k_{j,t+1}} = 0 \rightarrow \beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)\left(-\frac{k_{j,t+2}}{k_{j,t+1}^2}\right)k_{j,t+1} + \frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)^2 - (1-\delta)) - q_{j,t+1}\right)\right] - \lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right) + 1\right] = 0,$$

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow -\beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)\left(\frac{k_{j,t+2}}{k_{j,t+1}}\right) - \frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)^2 + 1 - \delta + q_{j,t+1}\right)\right] - \lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right) + 1\right] = 0,$$

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow \beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)\left(\frac{k_{j,t+2}}{k_{j,t+1}}\right) - \frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)^2 + 1 - \delta + q_{j,t+1}\right)\right] = \lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right) + 1\right],$$

we get:

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1} \left(\psi_j \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1 \right) \frac{k_{j,t+2}}{k_{j,t+1}} - \frac{\psi_j}{2} \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1 \right)^2 + q_{j,t+1} + 1 - \delta \right) \right]}{\psi_j \left(\frac{k_{j,t+1}}{k_{j,t}} - 1 \right) + 1}, \tag{A.3}$$

for $j = o, T, nT$

Equation $(A.3)$ corresponds to the optimal distribution of capital between the three production sectors, namely oil, tradable good and non-tradable good sectors.

$$\frac{\partial V_t}{\partial b_t^d} = 0 \rightarrow \lambda_t \left(-\frac{1}{R_t} \right) + \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) = 0,$$

with $b_t^d = \frac{B_t^d}{P_t}$,

$$\frac{\partial V_t}{\partial b_t^d} = 0 \rightarrow \frac{\lambda_t}{R_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right), \tag{A.4}$$

and for $b_t^f = \frac{B_t^d}{P_t}$,

$$\frac{\partial V_t}{\partial b_t^f} = 0 \rightarrow \lambda_t \left(-\frac{s_t}{R_t^f k_t} \right) + \beta E_t \left(\lambda_{t+1} \frac{s_{t+1}}{\pi_{t+1}^f} \right) = 0,$$

$$\frac{\partial V_t}{\partial b_t^f} = 0 \rightarrow \frac{\lambda_t s_t}{R_t^f k_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1}}{\pi_{t+1}^f} \right), \tag{A.5}$$

A.2 Wage setting

In each production sector, the demand for the household's labor is given by the following maximization problem:

$$\max_{h_{j,t}} W_{j,t} h_{j,t} - \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota = 0, \tag{A.6}$$

$$s.t : h_{j,t} = \left(\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \tag{A.7}$$

with $j = [o, nT, T]$.

Note that $h_{o,t}, h_{T,t}$ and $h_{nT,t}$ that follow the standard Dixit-Stiglitz form represent the aggregate labor supplies to oil, tradable and non-tradable sectors respectively, and θ denotes the constant elasticity of substitution between different labor services. Note also that $W_{j,t}(\iota)$ is the wage rate set by the household ι and $W_{o,t}, W_{T,t}$ and $W_{nT,t}$ are the aggregate wage index, or the unit cost of sales the units of the labor index to the oil, manufacturing and non-tradable sectors, respectively.

The first order condition gives:

$$W_{j,t}\left(\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}} - \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota = 0,$$

$$\frac{\theta}{\theta-1} W_{j,t}\left(\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}-1} \frac{\theta-1}{\theta}\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}-1} - W_{j,t}(\iota) = 0,$$

$$h_{j,t}^{\frac{1}{\theta}} h_{j,t}(\iota)^{\frac{-1}{\theta}} = \frac{W_{j,t}(\iota)}{W_{j,t}},$$

we get finally:

$$h_{j,t}(\iota) = \left(\frac{W_{j,t}(\iota)}{W_{j,t}}\right)^{-\theta} h_{j,t} \tag{A.8}$$

where $W_{j,t}(\iota)$ is the nominal wage of houshold ι in each sector j.

Using the zero profit condition, $W_{j,t}h_{j,t} = \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota$, and solving, we obtain the aggregate wage index $W_{j,t}$ as follows:

$$W_{j,t}h_{j,t}-\int_0^1 W_{j,t}\left(\iota\right)h_{j,t}\left(\iota\right)d\iota=0$$

$$W_{j,t}h_{j,t}-\int_0^1 W_{j,t}\left(\iota\right)\left(\frac{W_{j,t}\left(\iota\right)}{W_{j,t}}\right)^{-\theta}h_{j,t}d\iota=0$$

$$W_{j,t}=\int_0^1 W_{j,t}\left(\iota\right)W_{j,t}\left(\iota\right)^{-\theta}W_{j,t}^{\theta}d,$$

we obtain:

$$W_{j,t}=\left(\int_0^1 W_{j,t}\left(\iota\right)^{1-\theta}d\iota\right)^{\frac{1}{1-\theta}} \tag{A.9}$$

where $W_{j,t}$ and $h_{j,t}$ are considered as given.
For the production sectors $i=o,T,nT$, the household ι chooses $\widetilde{W}_{j,t}\left(\iota\right)$ to maximize:

$$\max_{\widetilde{W}_{j,t}(\iota)}E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{U\left(c_{t+s}\left(\iota\right),h_{t+s}\left(\iota\right)\right)+\lambda_{t+s}\pi^s\widetilde{W}_{j,t+s}\left(\iota\right)h_{j,t+s}\left(\iota\right)/P_{t+s}\right\}\right] \tag{A.10}$$

subject to:

$$h_{j,t+s}\left(\iota\right)=\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s} \tag{A.11}$$

Replacing $(A.11)$ in $(A.10)$ we obtain:

$$\max_{\widetilde{W}_{j,t}(\iota)}E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{U\left(c_{t+s}\left(\iota\right),h_{t+s}\left(\iota\right)\right)+\lambda_{t+s}\pi^s\frac{\widetilde{W}_{j,t+s}\left(\iota\right)}{P_{t+s}}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s}\right\}\right],$$

The first order condition is:

$$E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{\frac{\partial U_{t+s}}{\partial h_{j,t+s}\left(\iota\right)}\frac{\partial h_{j,t+s}\left(\iota\right)}{\widetilde{W}_{j,t}\left(\iota\right)}+(1-\theta)\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{\pi^s h_{j,t+s}}{P_{t+s}}\right\}\right]=0,$$

where $\frac{\partial h_{j,t+s}(\iota)}{\partial\widetilde{W}_{j,t}(\iota)}=-\theta\left(\frac{\pi^s\widetilde{W}_{j,t}(\iota)}{W_{j,t+s}}\right)^{-\theta-1}\frac{\pi^s h_{j,t+s}}{W_{j,t+s}}$,

Let $\Lambda_{j,t+s}=-\frac{\partial U_{t+s}}{\partial h_{j,t+s}}/\frac{\partial U_{t+s}}{\partial c_{t+s}(\iota)}$ represents the marginal rate of substitution between $c_{t+s}\left(\iota\right)$ and $h_{t+s}\left(\iota\right)$ and $\frac{\partial U_{t+s}}{\partial c_{t+s}(\iota)}=\lambda_{t+s}$ denotes the marginal utility of consumption.
Thus we obtain,

$$E_t[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\{-\frac{\partial U_{t+s}}{\partial h_{j,t+s}\left(\iota\right)}\theta\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{h_{j,t+s}}{W_{j,t+s}}+(1-\theta)\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{\pi^s h_{j,t+s}}{P_{t+s}}\}]=0,$$

$$E_t[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\{\theta\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s}\,\Lambda_{j,t+s}\lambda_{t+s}+(1-\theta)\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{\pi^s h_{j,t+s}}{P_{t+s}}\widetilde{W}_{j,t}\left(\iota\right)\}]=0,$$

$$E_t[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\{\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s}\left(\Lambda_{j,t+s}+\frac{\theta-1}{\theta}\frac{\widetilde{W}_{j,t}\left(\iota\right)\pi^s}{P_{t+s}}\right)\}]=0,$$

$$\Rightarrow\quad E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{\lambda_{t+s}w_{j,t+s}^{\theta}h_{j,t+s}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}\left(\Lambda_{j,t+s}+\frac{\theta-1}{\theta}\widetilde{w}_{j,t}\left(\iota\right)\prod_{k=1}^{s}\pi^s\pi_{t+k}^{-1}\right)\right\}\right]=0,$$

where $\widetilde{w}_{j,t}\left(\iota\right)=\frac{\widetilde{W}_{j,t}(\iota)}{P_t}$ and $w_{j,t+s}=\frac{W_{j,t+s}}{P_{t+s}}$ denote the real optimized wage and the real wage index in the sector j respectively.
Rearranging the last equation yields:

$$\widetilde{w}_{j,t}\left(\iota\right)=\frac{\theta}{\theta-1}\frac{E_t\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\lambda_{t+s}h_{j,t+s}\Lambda_{j,t+s}w_{j,t+s}^{\theta}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}}{E_t\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\lambda_{t+s}h_{j,t+s}w_{j,t+s}^{\theta}\prod_{k=1}^{s}\pi^{s(1-\theta)}\pi_{t+k}^{\theta-1}},\tag{A.12}$$

Note that for each sector j, $\Lambda_{j,t} = \alpha_{j,t}\frac{h_t^{1+\sigma}}{h_{j,t}\lambda_t}$.

A.3 Non-linear recursive procedure:

Following approach developed by Schmitt-Grohé and Uribe (2007), we rewrite equation $(A.13)$ in a recursive fashion that does away with the use of infinite sums. To do so, the real optimized wage, $\widetilde{w}_{j,t}$, in the sector j, can be written as:

$$\widetilde{w}_{j,t} = \frac{\theta}{\theta - 1}\frac{x_{j,t}^1}{x_{j,t}^2},$$

where $x_{j,t}^1$ and $x_{j,t}^2$ are two auxiliary variables. Let

$$x_{j,t}^1 = E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} \Lambda_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{-\theta s} \pi_{t+k}^{\theta},$$

$$x_{j,t}^1 = \lambda_t h_{j,t} \Lambda_{j,t} w_{j,t}^{\theta} + E_t \left(\beta\varphi_j\right)^s (\pi^{-\theta}\pi_{t+1}^{\theta}) E_t \sum_{s=1}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} \Lambda_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=2}^{s} \pi^{-\theta s} \pi_{t+k}^{\theta},$$

$$x_{j,t}^1 = \lambda_t h_{j,t} \Lambda_{j,t} w_{j,t}^{\theta} + E_t \left(\beta\varphi_j\right)^s (\pi^{-\theta}\pi_{t+1}^{\theta}) x_{j,t+1}^1,$$

$$x_{j,t}^1 = \lambda_t h_{j,t} \Lambda_{j,t} w_{j,t}^{\theta} + \beta\varphi_j E_t \left[\left(\frac{\pi_{t+1}}{\pi}\right)^{\theta} x_{j,t+1}^1\right], \tag{A.13}$$

Similarly, let

$$x_{j,t}^2 = E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{s(1-\theta)} \pi_{t+k}^{\theta-1},$$

$$x_{j,t}^2 = \lambda_t h_{j,t} w_{j,t}^{\theta} + \beta\varphi_j E_t \left[\left(\frac{\pi_{t+1}}{\pi}\right)^{\theta-1} x_{j,t+1}^2\right] \tag{A.14}$$

The same procedure is used in the case of price setting.

A.4 Intermediate good producers' FOC:

A.4.1 Oil and Tradable goods producers

The maximization problem of the oil and tradable goods producers can be written as follow:

$$\begin{array}{cc} \max\limits_{k_{o,t},h_{o,t},O_t} \left[e_{l,t}P_{o,t}Y_{o,t}-Q_{o,t}k_{o,t}-W_{o,t}h_{o,t}-P_{O,t}O_t\right]/P_t \\ s.t \qquad\qquad Y_{o,t} \preceq k_{o,t}^{\alpha_o}h_{o,t}^{\beta_o}O_t^{\theta_o} \end{array}$$

The first order conditions are:

$$\begin{aligned}
\frac{\partial \Delta_t}{\partial k_{o,t}} &= 0 \rightarrow \left[e_t P_{o,t}^f \alpha_o k_{o,t}^{\alpha_o - 1} h_{o,t}^{\beta_o} O_t^{\theta_o} - Q_{o,t}\right]/P_t = 0 \\
\frac{\partial \Delta_t}{\partial k_{o,t}} &= 0 \rightarrow s_{o,t} p_{o,t}^f \alpha_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta o}}{k_{o,t}} - q_{o,t} = 0, \\
\frac{\partial \Delta_t}{\partial k_{o,t}} &= 0 \rightarrow q_{o,t} = s_{o,t} p_{o,t}^f \alpha_o \frac{Y_{o,t}}{k_{o,t}}, \\
\frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow \left[e_t P_{o,t}^f \beta_o k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o - 1} O_t^{\theta_o} - W_{o,t}\right]/P_t = 0 \\
\frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow s_t p_{o,t}^f \beta_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}}{h_{o,t}} - w_{o,t} = 0 \\
\frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow w_{o,t} = s_t p_{o,t}^f \beta_o \frac{Y_{o,t}}{h_{o,t}}, \\
\frac{\partial \Delta_t}{\partial O_{o,t}} &= 0 \rightarrow \left[e_t P_{o,t}^f \theta_o k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o - 1} - P_{O,t}\right]/P_t = 0 \\
\frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow s_t p_{o,t}^f \theta_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}}{O_t} - p_{O,t} = 0 \\
\frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow p_{o,t} = s_t p_{o,t}^f \theta_o \frac{Y_{o,t}}{O_t}.
\end{aligned}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p_{o,t}^f = \frac{P_{o,t}^f}{P_t^f}$, $p_{O,t} = \frac{P_{O,t}}{P_t}$ and $s_t = e_t \frac{P_t^f}{P_t}$ denote respectively the real capital return, the real wage and the real oil price, oil price resource and real exchange rate.

The same method is used for the tradable good producer's problem.

A.4.2 Non-tradable good producer

The following is the lagrangian associated:

$$\begin{aligned}\Lambda &= \pi^s \widetilde{P}_{nT,t}(i) Y_{nT,t+s}(i) - Q_{nT,t+s} k_{nT,t+s}(i) - W_{nT,t+s} h_{nT,t+s}(i) - P_{o,t} Y_{o,t}^{I_{nT}}(i) \\ &\quad + \lambda_t \left(Y_{nT,t}(i) - A_{nT,t} k_{nT,t}^{\alpha_{nT}}(i) h_{nT,t}^{\beta_{nT}}(i) Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i) \right)\end{aligned}$$

where λ_t denotes the lagrangian multiplier which can be defined as the marginal cost, $MC_{nT,t}$, of the non-tradable firm.

$$\begin{aligned}\frac{\partial \Lambda_t}{\partial k_{nT,t}(i)} &= 0 \rightarrow -Q_{nT,t} - MC_{nT,t}\alpha_{nT}\left(A_{nT,t} k_{nT,t}^{\alpha_{nT}-1}(i) h_{nT,t}^{\beta_{nT}}(i) Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i) \right) = 0 \\ \frac{\partial \Lambda_t}{\partial k_{nT,t}(i)} &= 0 \rightarrow -Q_{nT,t} - MC_{nT,t}\alpha_{nT}\frac{Y_{nT,t}(i)}{k_{nT,t}(i)} = 0\end{aligned}$$

$$q_{nT,t} = \alpha_{nT}\frac{Y_{nT,t}(i)}{k_{nT,t}(i)} mc_{nT,t}. \tag{A.15}$$

$$\begin{aligned}\frac{\partial \Lambda_t}{\partial h_{nT,t}(i)} &= 0 \rightarrow -W_{nT,t} - MC_{nT,t}\beta_{nT}\left(A_{nT,t} k_{nT,t}^{\alpha_{nT}}(i) h_{nT,t}^{\beta_{nT}-1}(i) Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i) \right) = 0, \\ \frac{\partial \Lambda_t}{\partial h_{nT,t}(i)} &= 0 \rightarrow -W_{nT,t} - MC_{nT,t}\beta_{nT}\frac{Y_{nT,t}(i)}{h_{nT,t}(i)} = 0,\end{aligned}$$

$$w_{nT,t} = \beta_{nT}\frac{Y_{nT,t}(i)}{h_{nT,t}(i)} mc_{nT,t}. \tag{A.16}$$

$$\begin{aligned}
\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I_{nT}}(i)} &= 0 \rightarrow -P_{o,t} - MC_{nT,t}\theta_{nT}\left(A_{nT,t}k_{nT,t}^{\alpha_{nT}}(i)\, h_{nT,t}^{\beta_{nT}}(i)\, {Y_{o,t}^{I_{nT}}}^{\theta_{nT}-1}(i)\right) = 0, \\
\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I_{nT}}(i)} &= 0 \rightarrow -P_{o,t} - MC_{nT,t}\theta_{nT}\frac{Y_{nT,t}(i)}{Y_{o,t}^{I_{nT}}(i)} = 0,
\end{aligned}$$

$$p_{o,t} = \theta_{nT}\frac{Y_{nT,t}(i)}{Y_{o,t}^{nT}(i)}mc_{nT,t}. \tag{A.17}$$

where $q_{nT,t} = \frac{Q_{nT,t}}{P_t}, w_{nT,t} = \frac{W_{nT,t}}{P_t}, mc_{nT,t} = \frac{MC_{nT,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real domestic oil price.

A.5 Final good producer

The maximization problem of the final good producer is given by:

$$\max_{Y_{I,t},Y_{T,t}^d,Y_{nT,t}} P_t z_t - P_{I,t}Y_{I,t} - P_{T,t}Y_{T,t}^d - P_{nT,t}Y_{nT,t},$$

$$s.t: \qquad \left[\chi_T^{\frac{1}{\tau}}{Y_T^d}^{\frac{\tau-1}{\tau}} + \chi_{nT}^{\frac{1}{\tau}}Y_{nT}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}}Y_I^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}} = 1$$

we get:

$$\begin{aligned}
P_{I,t} - \lambda_{1,t}\chi_I^{\frac{1}{\tau}}Y_{I,t}^{-\frac{1}{\tau}}z_t^{\frac{1}{\tau}} &= 0, \\
P_{T,t} - \lambda_{1,t}\chi_T^{\frac{1}{\tau}}Y_{T,t}^{d(-\frac{1}{\tau})}z_t^{\frac{1}{\tau}} &= 0, \\
P_{nT,t} - \lambda_{1,t}\chi_{nT}^{\frac{1}{\tau}}Y_{nT,t}^{-\frac{1}{\tau}}z_t^{\frac{1}{\tau}} &= 0,
\end{aligned}$$

Combining the three expressions, we obtain:

$$
\begin{aligned}
P_{I,t} + P_{T,t} + P_{nT,t} - \lambda_{1,t}\left[\chi_I^{\frac{1}{\tau}} Y_{I,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}} + \chi_T^{\frac{1}{\tau}} Y_{T,t}^{d(-\frac{1}{\tau})} z_t^{\frac{1}{\tau}} + \chi_{nT}^{\frac{1}{\tau}} Y_{nT,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}}\right] &= 0, \\
P_{I,t}^{1-\tau} + P_{T,t}^{1-\tau} + P_{nT,t}^{1-\tau} - \lambda_{1,t}^{1-\tau}\left[\chi_I^{\frac{1-\tau}{\tau}} Y_{I,t}^{\frac{\tau-1}{\tau}} + \chi_T^{\frac{1-\tau}{\tau}} Y_{T,t}^{d(\frac{\tau-1}{\tau})} + \chi_{nT}^{\frac{1-\tau}{\tau}} Y_{nT,t}^{\frac{\tau-1}{\tau}}\right] &= 0, \\
\chi_I P_{I,t}^{1-\tau} + \chi_M P_{T,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau} - \lambda_{1,t}^{1-\tau}\left[\chi_I^{\frac{1}{\tau}} Y_{I,t}^{\frac{\tau-1}{\tau}} + \chi_T^{\frac{1}{\tau}} Y_{T,t}^{d(\frac{\tau-1}{\tau})} + \chi_{nT}^{\frac{1}{\tau}} Y_{nT,t}^{\frac{\tau-1}{\tau}}\right] &= 0,
\end{aligned}
$$

we find:

$$
\lambda_{1,t} = \left[\chi_I P_{I,t}^{1-\tau} + \chi_T P_{T,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau}\right]^{\frac{1}{1-\tau}} = P_t
$$

this equation implies that $P_t = \lambda_{1,t}$. Thus, replacing $\lambda_{1,t}$ by P_t we get:

$$
\begin{aligned}
P_{I,t} - P_t\left(\frac{z_t}{Y_{I,t}}\right)^{\frac{1}{\tau}} \chi_I^{\frac{1}{\tau}} &= 0, \\
P_{T,t} - P_t\left(\frac{z_t}{Y_{T,t}^d}\right)^{\frac{1}{\tau}} \chi_T^{\frac{1}{\tau}} &= 0, \\
P_{nT,t} - P_t\left(\frac{z_t}{Y_{nT,t}}\right)^{\frac{1}{\tau}} \chi_{nT}^{\frac{1}{\tau}} &= 0,
\end{aligned}
$$

we find finally, the following demand function:

$$
Y_{I,t} = \chi_I\left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t, \quad Y_{T,t} = \chi_T\left(\frac{P_{T,t}}{P_t}\right)^{-\tau} z_t, \quad Y_{nT,t} = \chi_{nT}\left(\frac{P_{nT,t}}{P_t}\right)^{-\tau} z_t \tag{A.18}
$$

The zero-profit condition implies that:

$$P_t z_t - P_{I,t} Y_{I,t} - P_{T,t} Y_{T,t}^d - P_{nT,t} Y_{nT,t} = 0,$$

$$P_t z_t = P_{I,t} \chi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\tau} z_t + P_{T,t} \chi_T \left(\frac{P_{T,t}}{P_t} \right)^{-\tau} z_t + P_{nT,t} \chi_{nT} \left(\frac{P_{nT,t}}{P_t} \right)^{-\tau} z_t,$$

$$P_t = P_{I,t} \chi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\tau} + P_{M,t} \chi_T \left(\frac{P_{T,t}}{P_t} \right)^{-\tau} + P_{nT,t} \chi_{nT} \left(\frac{P_{nT,t}}{P_t} \right)^{-\tau},$$

we obtain finally the following price index:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_T P_{T,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau} \right]^{\frac{1}{1-\tau}} \tag{A.19}$$

A.6 Price setting

The non-tradable firms' maximization problem can be written as follow:

$$\max_{k_{nT,t}(i), h_{nT,t}(i), P_{nT,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta \phi_{nT})^s \lambda_{t+s} D_{nT,t+s}(i) / P_{t+s}], \tag{A.20}$$

subject to the production function $(A.22)$ and the demand function $(A.23)$:

$$Y_{nT,t}(i) \preceq A_{nT,t} k_{nT,t}^{\alpha_{nT}}(i) \, h_{nT,t}^{\beta_{nT}}(i) \, Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i) \tag{A.21}$$

$$Y_{nT,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}} \right)^{-\vartheta} Y_{nT,t+s}, \tag{A.22}$$

where $D_{nT,t+s}(i)$ is the profit function:

$$D_{nT,t+s}(i) = \pi^s \widetilde{P}_{nT,t}(i) \, Y_{nT,t+s}(i) - Q_{nT,t+s} k_{nT,t+s}(i) - W_{nT,t+s} h_{nT,t+s}(i) - P_{o,t} Y_{o,t}^{I_T}(i),$$

where $\beta^s \lambda_{t+s}$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$.
The optimal pricing condition is given by the maximization of $(A.22)$:

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} = 0 \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s}[\pi^s \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta} Y_{nT,t+s} - \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta-1}$$
$$\frac{\pi^s Y_{nT,t+s}}{P_{nT,t+s}} \pi^s \widetilde{P}_{nT,t}(i) + \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta-1} \frac{\pi^s Y_{nT,t+s}}{P_{nT,t+s}} MC_{nT,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta} Y_{nT,t+s}[\pi^s - \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-1}$$
$$\frac{\pi^s}{P_{nT,t+s}} \pi^s \widetilde{P}_{nT,t}(i) + \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-1} \frac{\pi^s}{P_{nT,t+s}} MC_{nT,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta} [(1-\vartheta)\pi^s + \vartheta \frac{mc_{nT,t+s}}{\widetilde{p}_{nT,t}(i)} \pi_{t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}$$
$$[(1-\vartheta)\widetilde{p}_{nT,t}(i) \prod_{k=1}^{s} \pi^s \pi_{t+s}^{-1} + \vartheta mc_{nT,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta} [(1-\vartheta)\widetilde{p}_{nT,t}(i)$$
$$\prod_{k=1}^{s} \pi^s \pi_{t+s}^{-1} + \vartheta mc_{nT,t+s}] = 0,$$

we get finally:

$$\widetilde{p}_{nT,t}(i) = \left(\frac{\vartheta}{\vartheta-1}\right) \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} mc_{nT,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}} \tag{A.23}$$

where $p_{nT,t+s} = \frac{P_{nT,t+s}}{P_{t+s}}, mc_{nT,t+s} = \frac{MC_{nT,t+s}}{P_{t+s}}, \widetilde{p}_{nT,t}(i) = \frac{\widetilde{P}_{nT,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$denote respectively the relative price of non-tradable goods, the real marginal cost in non-tradable sector, the real optimized price for non-tradable goods and the CPI inflation rate.

The same procedure is used in the imports sector.

A.7 Current account

Combining the households' budget constraint, the single period profit functions of non-tradable good producing firms and foreign good importers and the first order conditions of the three sectors and applying the market clearing conditions yields the following current account equation:

$$P_t(c_t + i_t) + \frac{B_t^d}{R_t} + \frac{e_t B_t^f}{R_t^f \kappa_t} \preceq B_{t-1}^d + e_t B_{t-1}^f + \sum_{j=o,T,nT} Q_{j,t} k_{j,t} + \sum_{j=o,T,nT} W_{j,t} h_{j,t} + \varpi P_{O,t} O_t + D_t - \Gamma_t,$$

In a symmetric equilibrium, $B_t^d = 0$. This implies that:

$$\frac{e_t B_t^f}{R_t^f \kappa_t} - e_t B_{t-1}^f = \sum_{j=o,T,nT} Q_{j,t} k_{j,t} + \sum_{j=o,T,nT} W_{j,t} h_{j,t} + P_{O,t} O_t + D_t - \Gamma_t - P_t(c_t + i_t),$$

In real term:

$$\frac{s_t b_t^f}{R_t^f \kappa_t} - s_t \frac{b_{t-1}^f}{\pi_t^f} = \sum_{j=o,T,nT} q_{j,t} k_{j,t} + \sum_{j=o,T,nT} w_{j,t} h_{j,t} + p_{O,t} O_t + D_{nT} + D_I - \Gamma_t - (c_t + i_t),$$

Replacing the first order conditions of the three sectors in the household' budget constraint, we get:

$$\begin{aligned}\frac{s_t b_t^f}{R_t^f \kappa_t} - s_t \frac{b_{t-1}^f}{\pi_t^f} &= (\alpha_o + \beta_o) s_t p_{o,t}^f Y_{o,t} + (\alpha_T + \beta_T) s_t p_T Y_{T,t} + (\alpha_{nT} + \beta_{nT}) Y_{nT,t} mc_{nT,t} + \\ &+ \theta_o s_t p_{o,t}^f Y_{o,t} + D_{nT} + D_I - \Gamma_t - (c_t + i_t),\end{aligned}$$

combining the single period profit functions, the government's budget constraint and the market clearing conditions:

$$\begin{aligned}\frac{s_t b_t^f}{R_t^f \kappa_t} - s_t \frac{b_{t-1}^f}{\pi_t^f} &= (\alpha_o + \beta_o) s_t p_{o,t}^f Y_{o,t} + (\alpha_T + \beta_T) s_t p_T Y_{T,t} + (\alpha_{nT} + \beta_{nT}) Y_{nT,t} mc_{nT,t} + \theta_o s_t p_{o,t}^f Y_{o,t} \\ &+ \widetilde{p}_{nT,t} Y_{nT,t} - q_{nT,t+s} k_{nT,t} - w_{nT,t+s} h_{nT,t} - p_{o,t} Y_{o,t}^{I_{nT}} + \widetilde{p}_{I,t} Y_{I,t} - s_t Y_{I,t} + p_{o,t} Y_{o,t}^I \\ &+ s_t p_{o,t}^f Y_{o,t} - s_t p_{o,t}^f Y_{o,t}^I - w_{o,t} h_{o,t} - q_{o,t} k_{o,t} - p_{O,t} O_t - p_{I,t} Y_{I,t} - p_{T,t} Y_{T,t}^d - p_{nT,t} Y_{nT,t},\end{aligned}$$

$$\begin{aligned}\frac{s_t b_t^f}{R_t^f \kappa_t} - s_t \frac{b_{t-1}^f}{\pi_t^f} &= s_t p_{o,t}^f Y_{o,t} + (\alpha_T + \beta_T) s_t p_T Y_{T,t} + (\alpha_{nT} + \beta_{nT}) Y_{nT,t} mc_{nT,t} - Y_{nT,t} mc_{nT,t} \\ &- s_t Y_{I,t} + p_{o,t} \left(Y_{o,t}^{I_T} + Y_{o,t}^{I_{nT}} \right) - s_t p_{o,t}^f Y_{o,t}^I - p_{T,t} Y_{T,t}^d,\end{aligned}$$

knowing that $\alpha_M + \beta_M + \theta_M = 1$ and $\alpha_{nT} + \beta_{nT} + \theta_{nT} = 1$, we find the following current account equation:

$$\frac{b_t^f}{R_t^f \kappa_t} = \frac{b_{t-1}^f}{\pi_t^f} + p_{o,t}^f Y_{o,t} + p_T Y_{T,t}^{ex} - Y_{I,t} - p_{o,t}^f Y_{o,t}^I, \tag{A.24}$$

A.8 Welfare measure

The welfare criterion is derived from the following single-period utility function:

$$u(.) = \frac{1}{1-\gamma} {c_t}^{1-\gamma} - \frac{{h_t}^{1+\sigma}}{1+\sigma}, \tag{A.25}$$

aa second order Taylor expansion of $u\left(.\right)$ yields:

$$\mu(.) \simeq \frac{1}{1-\gamma}\overline{c}^{1-\gamma} - \frac{\overline{h}^{1+\sigma}}{1+\sigma} + \overline{c}^{-\gamma}(c_t - \overline{c}) - \overline{h}^{\sigma}\left(h_t - \overline{h}\right) - \frac{\gamma}{2}\overline{c}^{-\gamma-1}\left(c_t - \overline{c}\right)^2 - \frac{\sigma}{2}\overline{h}^{\sigma-1}\left(h_t - \overline{h}\right)^2,$$

where bars denote steady-state values and hats represent percentage deviations from the steady-state.
Multiplying c and h components by $\frac{\overline{c}}{\overline{c}}$ and $\frac{\overline{h}}{\overline{h}}$ respectively and taking expectation, we get:

$$\mu(.) \simeq \frac{1}{1-\gamma}\overline{c}^{1-\gamma} - \frac{\overline{h}^{1+\sigma}}{1+\sigma} + \frac{\overline{c}}{\overline{c}}\overline{c}^{-\gamma}E(c_t - \overline{c}) - \overline{h}^{\sigma}\frac{\overline{h}}{\overline{h}}E\left(h_t - \overline{h}\right) - \frac{\gamma}{2}\frac{\overline{c}}{\overline{c}}\overline{c}^{-\gamma-1}E\left(c_t - \overline{c}\right)^2 - \frac{\sigma}{2}\frac{\overline{h}}{\overline{h}}\overline{h}^{\sigma-1}E\left(h_t - \overline{h}\right)^2,$$

the equation above becomes:

$$\mu(.) \simeq \frac{1}{1-\gamma}\overline{c}^{1-\gamma} - \frac{\overline{h}^{1+\sigma}}{1+\sigma} + \overline{c}^{1-\gamma}E(\frac{c_t - \overline{c}}{\overline{c}}) - \overline{h}^{1+\sigma}E\left(\frac{h_t - \overline{h}}{\overline{h}}\right) - \frac{\gamma}{2}\overline{c}^{1-\gamma}E\left[\left(\frac{c_t - \overline{c}}{\overline{c}}\right)^2\right] - \frac{\sigma}{2}\overline{h}^{1+\sigma}E\left[\left(\frac{h_t - \overline{h}}{\overline{h}}\right)^2\right],$$

Let $\widehat{x}_t = \frac{x_t - \overline{x}}{\overline{x}}$, the last equation becomes:

$$\mu(.) \simeq \overline{\mu} + \overline{c}^{1-\gamma} E(\widehat{c}_t) - \overline{h}^{1+\sigma} E\left(\widehat{h}_t\right) - \frac{\gamma}{2}\overline{c}^{1-\gamma} E\left[(\widehat{c}_t)^2\right] - \frac{\sigma}{2}\overline{h}^{1+\sigma} E\left[\left(\widehat{h}_t\right)^2\right]$$

Since $E\left(x^2\right) = var\left(x\right) + \left[E\left(x\right)^2\right]$, the welfare criterion can be rewrite as follow:

$$\begin{aligned} \mu(.) \quad \simeq \quad & \overline{\mu} + \overline{c}^{1-\gamma} E(\widehat{c}_t) - \overline{h}^{1+\sigma} E\left(\widehat{h}_t\right) - \\ & \frac{\gamma}{2}\overline{c}^{1-\gamma} E\left(var\left(\widehat{c}_t\right) + \left[E\left(\widehat{c}_t\right)^2\right]\right) - \frac{\sigma}{2}\overline{h}^{1+\sigma} E\left(var\left(\widehat{h}_t\right) + \left[E\left(\widehat{h}_t\right)^2\right]\right) \end{aligned} \tag{A.26}$$

A.9 The Non-Linear Equilibrium System

$$\lambda_t = c_t^{-\gamma},$$

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1} \left(\psi_o \left(\frac{k_{o,t+2}}{k_{o,t+1}\lambda_t} - 1 \right) \frac{k_{o,t+2}}{k_{o,t+1}} - \frac{\psi_o}{2} \left(\frac{k_{o,t+1}}{k_{o,t}} - 1 \right)^2 + q_{o,t+1} + 1 - \delta \right) \right]}{\psi_j \left(\frac{k_{o,t+1}}{k_{o,t}} - 1 \right) + 1},$$

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1} \left(\psi_T \left(\frac{k_{T,t+2}}{k_{T,t+1}\lambda_t} - 1 \right) \frac{k_{Tt+2}}{k_{T,t+1}} - \frac{\psi_T}{2} \left(\frac{k_{T,t+1}}{k_{T,t}} - 1 \right)^2 + q_{T,t+1} + 1 - \delta \right) \right]}{\psi_T \left(\frac{k_{T,t+1}}{k_{T,t}} - 1 \right) + 1},$$

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1} \left(\psi_{nT} \left(\frac{k_{nT,t+2}}{k_{nT,t+1}\lambda_t} - 1 \right) \frac{k_{nT,t+2}}{k_{nT,t+1}} - \frac{\psi_{nT}}{2} \left(\frac{k_{nT,t+1}}{k_{nT,t}} - 1 \right)^2 + q_{nT,t+1} + 1 - \delta \right) \right]}{\psi_{nT} \left(\frac{k_{nT,t+1}}{k_{nT,t}} - 1 \right) + 1},$$

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

$$\frac{\lambda_t s_t}{R_t^f \kappa_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1}}{\pi_{t+1}^f} \right),$$

$$h_t = {h_{o,t}}^{\alpha_{ho}} {h_{T,t}}^{\alpha_{hT}} {h_{nT,t}}^{\alpha_{hnT}},$$

$$\kappa_t = \exp\left(-\phi \frac{s_t \widetilde{b_t^f}}{Y_t} \right),$$

$$i_{o,t} = k_{o,t+1} - (1-\delta)k_{o,t} + \frac{\psi_o}{2} \left(\frac{k_{o,t+1}}{k_{o,t}} - 1 \right)^2 k_{o,t},$$

$$i_{T,t} = k_{T,t+1} - (1-\delta)k_{T,t} + \frac{\psi_T}{2} \left(\frac{k_{T,t+1}}{k_{T,t}} - 1 \right)^2 k_{T,t},$$

$$i_{nT,t} = k_{nT,t+1} - (1-\delta)k_{nT,t} + \frac{\psi_{nT}}{2}\left(\frac{k_{nT,t+1}}{k_{nT,t}} - 1\right)^2 k_{nT,t},$$

$$\widetilde{w}_{o,t} = \frac{\theta}{\theta-1}\frac{E_t\sum_{s=0}^{\infty}(\beta\varphi_o)^s\,\lambda_{t+s}h_{o,t+s}\Lambda_{o,t+s}w_{o,t+s}^{\theta}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}}{E_t\sum_{s=0}^{\infty}(\beta\varphi_o)^s\,\lambda_{t+s}h_{o,t+s}w_{o,t+s}^{\theta}\prod_{k=1}^{s}\pi^{s(1-\theta)}\pi_{t+k}^{\theta-1}},$$

$$(w_{o,t})^{1-\theta} = \varphi_o\left(\pi\frac{w_{o,t-1}}{\pi_t}\right)^{1-\theta} + (1-\varphi_o)\left(\widetilde{w}_{o,t}\right)^{1-\theta},$$

$$\widetilde{w}_{T,t} = \frac{\theta}{\theta-1}\frac{E_t\sum_{s=0}^{\infty}(\beta\varphi_T)^s\,\lambda_{t+s}h_{T,t+s}\Lambda_{T,t+s}w_{T,t+s}^{\theta}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}}{E_t\sum_{s=0}^{\infty}(\beta\varphi_T)^s\,\lambda_{t+s}h_{T,t+s}w_{T,t+s}^{\theta}\prod_{k=1}^{s}\pi^{s(1-\theta)}\pi_{t+k}^{\theta-1}},$$

$$(w_{T,t})^{1-\theta} = \varphi_T\left(\pi\frac{w_{T,t-1}}{\pi_t}\right)^{1-\theta} + (1-\varphi_T)\left(\widetilde{w}_{T,t}\right)^{1-\theta},$$

$$(p_{nT,t})^{1-\vartheta} = \phi_{nT}\left(\pi\frac{p_{nT,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_{nT})\left(\widetilde{p}_{nT,t}\right)^{1-\vartheta},$$

$$\widetilde{p}_{nT,t} = \left(\frac{\vartheta}{\vartheta-1}\right)\frac{E_0\sum_{s=0}^{\infty}(\beta\phi_{nT})^s\,\lambda_{t+s}Y_{nT,t+s}p_{nT,t+s}^{\vartheta}mc_{nT,t+s}\prod_{k=1}^{s}\pi^{-s\vartheta}\pi_{t+k}^{\vartheta}}{E_0\sum_{s=0}^{\infty}(\beta\phi_{nT})^s\,\lambda_{t+s}Y_{nT,t+s}p_{nT,t+s}^{\vartheta}\prod_{k=1}^{s}\pi^{s(1-\vartheta)}\pi_{t+k}^{\vartheta-1}}$$

$$\widetilde{w}_{nT,t} = \frac{\theta}{\theta-1}\frac{E_t\sum_{s=0}^{\infty}(\beta\varphi_{nT})^s\,\lambda_{t+s}h_{nT,t+s}\Lambda_{nT,t+s}w_{nT,t+s}^{\theta}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}}{E_t\sum_{s=0}^{\infty}(\beta\varphi_{nT})^s\,\lambda_{t+s}h_{nT,t+s}w_{nT,t+s}^{\theta}\prod_{k=1}^{s}\pi^{s(1-\theta)}\pi_{t+k}^{\theta-1}},$$

$$(w_{nT,t})^{1-\theta} = \varphi_{nT}\left(\pi\frac{w_{nT,t-1}}{\pi_t}\right)^{1-\theta} + (1-\varphi_{nT})\left(\widetilde{w}_{nT,t}\right)^{1-\theta},$$

$$Y_{o,t} = k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o},$$

$$q_{o,t} = \alpha_o s_t p_{o,t}^f \frac{Y_{o,t}}{k_{o,t}},$$

$$w_{o,t} = \beta_o s_t p_{o,t}^f \frac{Y_{o,t}}{h_{o,t}},$$

$$p_{O,t} = \theta_o s_t p_{o,t}^f \frac{Y_{o,t}}{O_t},$$

$$Y_{T,t} = k_{T,t}^{\alpha_T} h_{T,t}^{\beta_T} Y_{o,t}^{I_T^{\theta_T}},$$

$$q_{T,t} = \alpha_T s_t p_{T,t} \frac{Y_{T,t}}{k_{T,t}},$$

$$w_{T,t} = \beta_T s_t p_{T,t} \frac{Y_{T,t}}{h_{T,t}},$$

$$p_{o,t} = \theta_T s_t p_{T,t} \frac{Y_{T,t}}{Y_{o,t}^{I_T}},$$

$$s_t p_{T,t} = \frac{q_{T,t}^{\alpha_T} w_{T,t}^{\beta_T} p_{o,t}^{\theta_T}}{\alpha_T^{\alpha_T} \beta_T^{\beta_T} \theta_T^{\theta_T}},$$

$$Y_{nT,t} = k_{nT,t}^{\alpha_{nT}} h_{nT,t}^{\beta_{nT}} Y_{o,t}^{I_{nT}{}^{\theta_{nT}}},$$

$$q_{nT,t} = \alpha_{nT} \frac{Y_{nT,t}}{k_{nT,t}} mc_{nT,t},$$

$$w_{nT,t} = \beta_{nT} \frac{Y_{nT,t}}{h_{nT,t}} mc_{nT,t},$$

$$p_{o,t} = \theta_{nT} \frac{Y_{nT,t}}{Y_{o,t}^{I_{nT}}} mc_{nT,t},$$

$$mc_{nT,t} = \frac{q_{nT,t}^{\alpha_{nT}} w_{nT,t}^{\beta_{nT}} p_{o,t}^{\theta_{nT}}}{\alpha_{nT}^{\alpha_{nT}} \beta_{nT}^{\beta_{nT}} \theta_{nT}^{\theta_{nT}}},$$

$$\widetilde{p}_{I,t} = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta \phi_I)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} mc_{I,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta \phi_I)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}},$$

$$(p_{I,t})^{1-\vartheta} = \phi_I \left(\pi \frac{p_{I,t-1}}{\pi_t} \right)^{1-\vartheta} + (1 - \phi_I) \left(\widetilde{p}_{I,t} \right)^{1-\vartheta},$$

$$Y_{I,t} = \chi_I \left(p_{I,t} \right)^{-\tau} z_t,$$

$$Y_{T,t}^d = \chi_T \left(p_{T,t} \right)^{-\tau} z_t,$$

$$Y_{nT,t} = \chi_{nT} \left(p_{nT,t} \right)^{-\tau} z_t,$$

$$\Lambda_{o,t} = \alpha_{ho} \left(\frac{h_t^{1+\sigma}}{h_{o,t} \lambda_t} \right),$$

$$\Lambda_{T,t} = \alpha_{hT} \left(\frac{h_t^{1+\sigma}}{h_{T,t} \lambda_t} \right),$$

$$\Lambda_{nT,t} = \alpha_{hnT} \left(\frac{h_t^{1+\sigma}}{h_{nT,t} \lambda_t} \right),$$

$$i_t = i_{o,t} + i_{T,t} + i_{nT,t},$$

$$p_{o,t} = (1 - \upsilon)(p_{o,t-1}/\pi_t) + \upsilon s_t p_{o,t}^f,$$

$$Y_{T,t}^{va} = Y_{T,t} - s_t p_{o,t}^f \frac{Y_{o,t}^{I_T}}{p_{T,t}},$$

$$Y_{nT,t}^{va} = Y_{nT,t} - s_t p_{o,t}^f \frac{Y_{o,t}^{I_{nT}}}{p_{nT,t}},$$

$$\pi_{nT,t} = \pi_t \frac{p_{nT,t}}{p_{nT,t-1}},$$

$$\pi_{I,t} = \pi_t \frac{p_{I,t}}{p_{I,t-1}},$$

$$\frac{e_t}{e_{t-1}} = \frac{s_t}{s_{t-1}} \frac{\pi_t}{\pi_t^f},$$

$$Y_{o,t}^I = Y_{o,t}^{I_T} + Y_{o,t}^{I_{nT}},$$

$$Y_{T,t}^{ex} = \nu_T \left(\frac{e_t P_{T,t}}{P_t^f} \right)^{-\omega_T} Y_{T,t}^f,$$

$$Y_t = p_{T,t} Y_{T,t}^{va} + p_{nT,t} Y_{nT,t}^{va} + s_t p_{o,t}^f Y_{o,t},$$

$$\frac{b_t^f}{\kappa_t R_t^f} = \frac{b_{t-1}^f}{\pi_t^f} + p_{T,t} Y_{T,t}^{ex} + p_{o,t}^f Y_{o,t} - p_{o,t}^f Y_{o,t}^I - Y_{I,t},$$

$$z_t = c_t + i_{o,t} + i_{T,t} + i_{nT,t},$$

$$mc_{I,t} = s_t,$$

$$\log\left(\frac{R_t}{R}\right) = \zeta_\pi \log\left(\frac{\pi_t}{\pi}\right) + \zeta_e \log\left(\frac{\Delta e_t}{\Delta e}\right),$$

$$\log(R_t^f) = (1 - \rho_{R^f}) \log(R^f) + \rho_{R^f} \log(R_{t-1}^f) + \varepsilon_{R^f,t},$$

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

$$\log(P^f_{o,t}) = (1-\rho_{P^f_o})\log(P^f_o) + \rho_{P^f_o}\log(P^f_{o,t-1}) + \varepsilon_{P^f_o,t},$$

$$\log(O_t) = (1-\rho_O)\log(O) + \rho_O\log(O_{t-1}) + \varepsilon_{O,t},$$

$$\log(Y^f_{T,t}) = (1-\rho_{Y^f_T})\log(Y^f_T) + \rho_{Y^f_T}\log(Y^f_{T,t-1}) + \varepsilon_{Y^f_T,t}.$$

A.10 The Log-Linear Equilibrium System

In this section, we log-linearize our real model around its steady state. The log-linearization has some advantages compared to linearization in level which can be summarize as follow: (i) the log-linearization is a better approximation than linearization when the models are approximately log-linear; (ii) interpretation of variables in log-linearized model is easy because they are relative deviation from steady state; (iii) parameters in the log-linearized model are easy to interpret because they are elasticity[1]. The principle of log-linearization is to use a Taylor approximation around the steady state to replace all equations by approximations, which are linear functions in the log-deviation of the variable. The log-linearized system can be written as follow:

$$X_t Y_t = XY e^{\widehat{x}_t + a\widehat{y}_t} \simeq XY\left(1 + \widehat{x}_t + a\widehat{y}_t\right)$$

$$x_t y_t \simeq 0,$$

$$E_t\left[a e^{x_{t+1}}\right] \simeq E_t\left[a\widehat{x}_{t+1}\right].$$

where X_t and Y_t are the vector of variables and X and Y are their steady state. The vectors of log-deviations, $\widehat{x}_t$ and $\widehat{y}_t$, are close to zero[2].
Following this method, our linear model is (64 non-linear equations):

$$\widehat{\lambda}_t = -\gamma\widehat{c}_t,$$

$$\widehat{i}_{o,t} = \frac{1}{\delta}\widehat{k}_{o,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{o,t},$$

$$\widehat{i}_{T,t} = \frac{1}{\delta}\widehat{k}_{T,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{T,t},$$

[1] See Thijs van Rens and Uhlig' notes for more details about log-linearization method.
[2] This is because: $X_t = e^{\log X_t} = e^{\log X} e^{\log X_t - \log X} = X e^{x_t}$

$$\widehat{i}_{nT,t} = \frac{1}{\delta}\widehat{k}_{nT,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{nT,t},$$

$$E_t\left(\beta\widehat{k}_{o,t+2} - \beta E_t\widehat{k}_{o,t+1} + \widehat{\lambda}_{t+1} + \overline{q}_o\widehat{q}_{o,t+1}\right) = \widehat{\lambda}_t + \psi_o\widehat{k}_{o,t+1} - \psi_o\widehat{k}_{o,t}$$

$$E_t\left(\beta\widehat{k}_{T,t+2} - \beta\widehat{k}_{T,t+1} + \widehat{\lambda}_{t+1} + \overline{q}_T\widehat{q}_{T,t+1}\right) = \widehat{\lambda}_t + \psi_T\widehat{k}_{T,t+1} - \psi_T\widehat{k}_{T,t}$$

$$E_t\left(\beta\widehat{k}_{nT,t+2} - \beta\widehat{k}_{nT,t+1} + \widehat{\lambda}_{t+1} + \overline{q}_{nT}\widehat{q}_{nT,t+1}\right) = \widehat{\lambda}_t + \psi_{nT}\widehat{k}_{nT,t+1} - \psi_{nT}\widehat{k}_{nT,t}$$

$$\widehat{\lambda}_t - \widehat{R}_t = E_t\widehat{\lambda}_{t+1} - E_t\widehat{\pi}_{t+1},$$

$$\widehat{\lambda}_t + \widehat{s}_t - \widehat{R}^f_t - \widehat{\kappa}_t = E_t\widehat{\lambda}_{t+1} + E_t\widehat{s}_{t+1} - E_t\widehat{\pi}^f_{t+1},$$

$$\widehat{\kappa}_t = \left(\phi\frac{s\widetilde{b^f}}{Y}\right)\left(\widehat{Y}_t - \widehat{s}_t - \widehat{b}^f_t\right),$$

$$\widehat{\pi}^{w_o}_t = \beta\pi^{w_o}_{t+1} + \frac{(1-\varphi_o)(1-\beta\varphi_o)}{\varphi_o}\left[\widehat{\Lambda}_{o,t} - \widehat{w}_{o,t}\right],$$

$$\widehat{\pi}^{w_T}_t = \beta\pi^{w_T}_{t+1} + \frac{(1-\varphi_T)(1-\beta\varphi_T)}{\varphi_T}\left[\widehat{\Lambda}_{T,t} - \widehat{w}_{T,t}\right],$$

$$\widehat{\pi}^{w_{nT}}_t = \beta\pi^{w_{nT}}_{t+1} + \frac{(1-\varphi_{nT})(1-\beta\varphi_{nT})}{\varphi_{nT}}\left[\widehat{\Lambda}_{nT,t} - \widehat{w}_{nT,t}\right],$$

$$\widehat{h}_t = \alpha_{h_o}\widehat{h}_{o,t} + \alpha_{hT}\widehat{h}_{T,t} + \alpha_{hnT}\widehat{h}_{nT,t},$$

$$\widehat{Y}_{o,t} = \alpha_o\widehat{k}_{o,t} + \beta_o\widehat{h}_{o,t} + \theta_o\widehat{O}_t,$$

$$\widehat{q}_{o,t} = \widehat{s}_t + \widehat{p}_{o,t} + \widehat{Y}_{o,t} - \widehat{k}_{o,t},$$

$$\widehat{w}_{o,t} = \widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{Y}_{o,t} - \widehat{h}_{o,t},$$

$$\widehat{p}_{O,t} = \widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{Y}_{o,t} - \widehat{O}_{o,t},$$

$$\widehat{Y}_{T,t} = \alpha_T \widehat{k}_{T,t} + \beta_T \widehat{h}_{T,t} + I_T^{\theta_T} \widehat{Y}_{o,t},$$

$$\widehat{q}_{T,t} = \widehat{s}_t + \widehat{p}_{T,t} + \widehat{Y}_{T,t} - \widehat{k}_{T,t},$$

$$\widehat{w}_{T,t} = \widehat{s}_t + \widehat{p}_{T,t} + \widehat{Y}_{T,t} - \widehat{h}_{T,t},$$

$$\widehat{p}_{o,t} = \widehat{s}_t + \widehat{p}_{T,t} + \widehat{Y}_{T,t} - \widehat{Y}^{I_T}_{o,t},$$

$$\widehat{s}_t + \widehat{p}_{T,t} = \alpha_T \widehat{q}_{T,t} + \beta_T \widehat{w}_{T,t} + \theta_T \widehat{p}_{o,t},$$

$$\widehat{Y}_{nT,t} = \alpha_{nT} \widehat{k}_{nT,t} + \beta_{nT} \widehat{h}_{nT,t} + \theta_{nT} \widehat{Y}^{I_{nT}}_{o,t},$$

$$\widehat{q}_{nT,t} = \widehat{Y}_{nT,t} - \widehat{k}_{M,t} + \widehat{mc}_{nT,t},$$

$$\widehat{w}_{nT,t} = \widehat{Y}_{nT,t} - \widehat{h}_{nT,t} + \widehat{mc}_{nT,t},$$

$$\widehat{p}_{o,t} = \widehat{Y}_{nT,t} - \widehat{Y}^{nT}_{o,t} + \widehat{mc}_{nT,t},$$

$$\widehat{mc}_{nT,t} = \alpha_{nT} \widehat{q}_{nT,t} + \beta_{nT} \widehat{w}_{nT,t} + \theta_{nT} \widehat{p}_{o,t},$$

$$\widehat{\pi}_{nT,t} = \beta E_t \pi_{nT,t+1} + \frac{(1-\phi_{nT})(1-\beta\phi_{nT})}{\phi_{nT}} \widehat{mc}_{nT,t},$$

$$\widehat{\pi}_{I,t} = \beta E_t \pi_{I,t+1} + \frac{(1-\phi_I)(1-\beta\phi_I)}{\phi_I}\widehat{mc}_{I,t},$$

$$\widehat{y}_{I,t} = -\tau \widehat{p}_{I,t} + \widehat{z}_t,$$

$$\widehat{Y}^d_{T,t} = -\tau \widehat{p}_{T,t} + \widehat{z}_t,$$

$$\widehat{Y}_{nT,t} = -\tau \widehat{p}_{nT,t} + \widehat{z}_t,$$

$$\widehat{\Lambda}_{o,t} = (1+\sigma)\widehat{h}_t - \widehat{h}_{o,t} - \widehat{\lambda}_t,$$

$$\widehat{\Lambda}_{T,t} = (1+\sigma)\widehat{h}_t - \widehat{h}_{T,t} - \widehat{\lambda}_t,$$

$$\widehat{\Lambda}_{nT,t} = (1+\sigma)\widehat{h}_t - \widehat{h}_{nT,t} - \widehat{\lambda}_t,$$

$$i_t = \frac{i_o}{\bar{i}}\widehat{i}_{o,t} + \frac{i_M}{\bar{i}}\widehat{i}_{M,t} + \frac{i_{nT}}{\bar{i}}\widehat{i}_{nT,t},$$

$$\overline{p}_o \widehat{p}_{o,t} = (1-\upsilon)(\widehat{p}_{o,t-1} - \widehat{\pi}_t) + \upsilon s \overline{p}_o \left(\widehat{s}_t + \widehat{p}^f_{o,t}\right), \tag{A.27}$$

$$\overline{Y}^{va}_T \widehat{Y}^{va}_{T,t} = \overline{Y}_T \widehat{Y}_{T,t} - \overline{sp}^f_o \frac{\overline{Y}^{I_T}_o}{\overline{p}_T}\left(\widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{Y}^{I_T}_{o,t} - \widehat{p}_{T,t}\right),$$

$$\overline{Y}^{va}_{nT} \widehat{Y}^{va}_{nT,t} = \overline{Y}_{nT} \widehat{Y}_{nT,t} - \overline{sp}^f_o \frac{\overline{Y}^{I_{nT}}_o}{\overline{p}_{nT}}\left(\widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{Y}^{I_{nT}}_{o,t} - \widehat{p}_{nT,t}\right),$$

$$\widehat{\pi}_{nT,t} = \widehat{\pi}_t + \widehat{p}_{nT,t} - \widehat{p}_{nT,t-1},$$

$$\widehat{\pi}_{I,t} = \widehat{\pi}_t + \widehat{p}_{I,t} - \widehat{p}_{I,t-1},$$

$$\widehat{e}_t - \widehat{e}_{t-1} = \widehat{s}_t - \widehat{s}_{t-1} + \widehat{\pi}_t - \widehat{\pi}_t^f,$$

$$\widehat{Y}_{o,t}^I = \frac{\overline{Y}_o^{I_T}}{\overline{Y}_o^I}\widehat{Y}_{o,t}^{I_T} + \frac{\overline{Y}_o^{I_T}}{\overline{Y}_o^I}\widehat{Y}_{o,t}^{I_{nT}},$$

$$\widehat{Y}_{T,t}^{ex} = -\omega_T\left(\widehat{s}_t + \widehat{p}_{T,t}\right) + \widehat{Y}_{T,t}^f,$$

$$\widehat{Y}_t = \frac{\overline{p}_T\overline{Y}_T^{va}}{\overline{Y}}\left(\widehat{p}_{T,t} + \widehat{Y}_{T,t}^{va}\right) + \frac{\overline{p}_{nT}\overline{Y}_{nT}^{va}}{\overline{Y}}\left(\widehat{p}_{nT,t} + \widehat{Y}_{nT,t}^{va}\right) + \frac{\overline{sp}_o^f\overline{Y}_o}{\overline{Y}}\left(\widehat{s}_t + \widehat{p}_{o,t}^f + \widehat{Y}_{o,t}\right),$$

$$\frac{b^f}{\kappa R^f}\left(\widehat{b}_t^f - \widehat{\kappa}_t - \widehat{R}_t^f\right) = b^f\left(\widehat{b}_{t-1}^f - \widehat{\pi}_t^f\right) + \overline{p}_T\overline{Y}_T^{ex}\left(\widehat{p}_{T,t} + \widehat{Y}_{T,t}^{ex}\right) + \overline{p}_o^f\overline{Y}_o\left(\widehat{p}_{o,t}^f + \widehat{Y}_{o,t}\right) - \overline{p}_o^f\overline{Y}_o^I\left(\widehat{p}_{o,t}^f + \widehat{Y}_{o,t}^I\right) - \overline{Y}$$

$$\widehat{z}_t = \frac{\overline{c}}{\overline{z}}\widehat{c}_t + \frac{\overline{i}_o}{\overline{z}}\widehat{i}_{o,t} + \frac{\overline{i}_T}{z}\widehat{i}_{T,t} + \frac{\overline{i}_{nT}}{z}\widehat{i}_{nT,t},$$

$$\widehat{mc}_{I,t} = \widehat{s}_t,$$

$$\widehat{R}_t = \zeta_\pi\widehat{\pi}_t + \zeta_e\Delta\widehat{e}_t$$

$$\widehat{R}_t^f = \rho_{R^f}\widehat{R}_{t-1}^f + \varepsilon_{R^f,t},$$

$$\widehat{\pi}_t^f = \rho_{\pi^f}\widehat{\pi}_{t-1}^f + \varepsilon_{\pi^f,t},$$

$$\widehat{P}_{o,t}^f = \rho_{P_o^f}\widehat{P}_{o,t-1}^f + \varepsilon_{P_o^f,t},$$

$$\widehat{O}_t = \rho_O\widehat{O}_{t-1} + \varepsilon_{O,t},$$

$$\widehat{Y}^f_{T,t} = \rho_{Y^f_T} \widehat{Y}^f_{T,t-1} + \varepsilon_{Y^f_T,t},$$

Table 1.4: Recent literature of the Dutch disease

	Sectors	Main assumptions	Main results
Sosunov and Zamulin (2007)	Non-tradable good sector	- Endogenous rate of time preference; -Sticky price of non-tradable goods; - Russian economy; - Increase in commodity prices.	- The use of international reserve management as a tool to stabilize the economy only if a true fiscal stabilization fund is not available; - the monetary authority should respond primarily to inflation and then to the real exchange rate.
Lartey (2008)	- Tradable sector; - Non-tradable sector.	- Incomplete Financial market; - Sticky price of non-tradable goods; - Alternative monetary policy rules; - Increase in capital inflow.	- Dutch disease effects when monetary authority target the nominal exchange rate; - Welfare result reveal that a generalized Taylor rule outperforms a fixed nominal exchange rate regime.
Batt et *al* (2008)	- Monetary union DSGE model; - Tradable sector; - Non-tradable sector.	- Complete financial market; - Three monetary Policy rules; - Negeria economy; - Increase in oïl price and non-oïl price (agricultural price). - Sticly price and wage.	- The economy is affected by a Dutch diseas following the shocks; - Flexible exchange rate regime with exogenous money supply allow to avoid the Dutch disease in the absence of a stabilization fund;
Acosta et *al* (2009)	- Tradable sector; - Non-tradable sector.	- El Salvador economy; - Bayesian estimation; - Rise of level of Remittances. - VAR analysis.	- Decline of labor supply; - Increase in consumption demand; - Higher non-tradable prices and appreciation of real exchange rate. - The same results with a VAR's impulse responses.
Lama and Medina (2010)	- Commodity sector	-Learning-by-doing externality in tradable sector; - nominal rigidities;	- Learning against an appreciated exchange rate can prevent an inefficient loss of tradable output but at the cost of generating a misallocation of resource in other sectors; - Welfare is a decreasing function of exchange rate intervention.

Appendix B

Appendix-Chapter 2

B.1 Figures and Tables

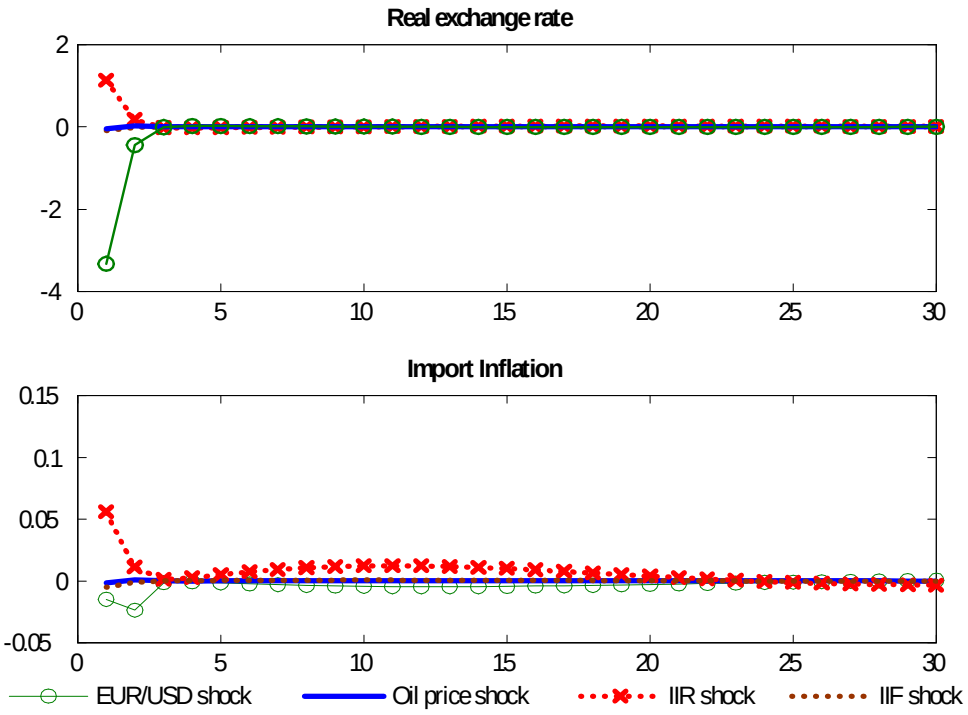


Figure 2.3: Responses to multiple shocks (baseline model)

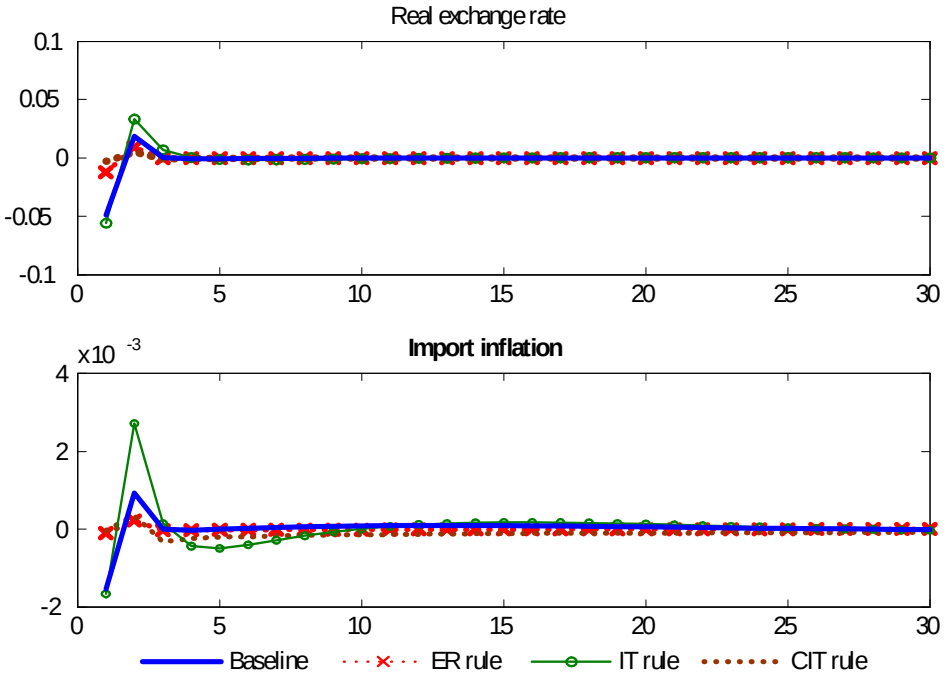


Figure 2.6: The effect of 1% positive oil price shock

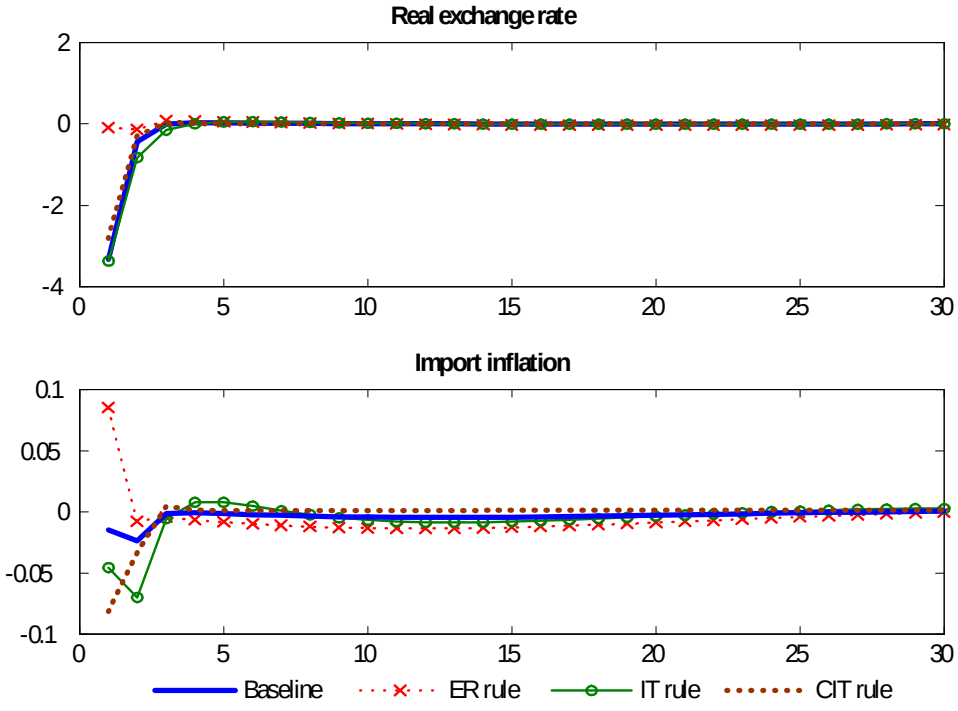


Figure 2.9: The effect of 1% positive EUR/USD shock

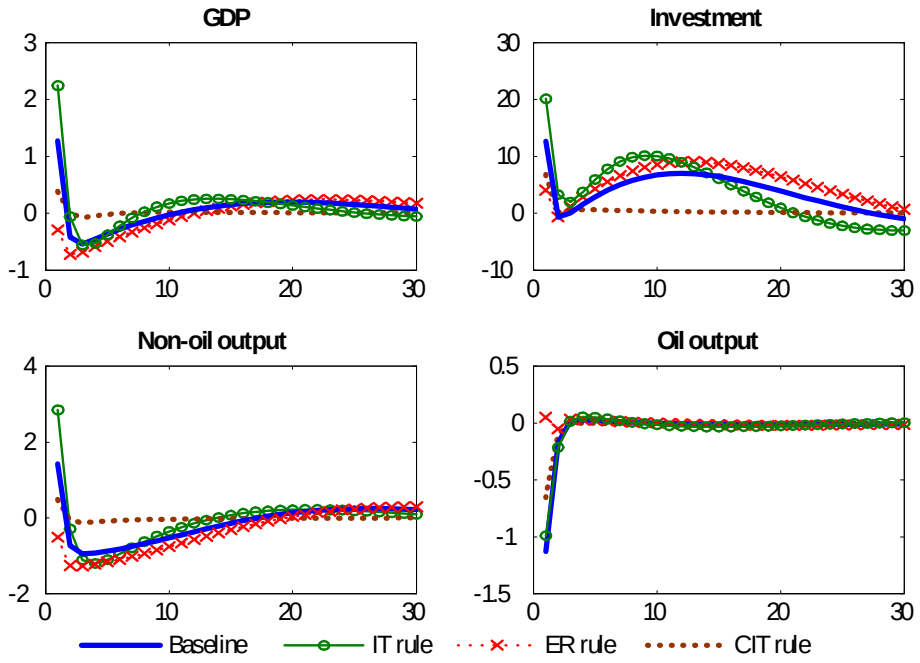


Figure 2.10: The effect of 1% positive international interest rate shock

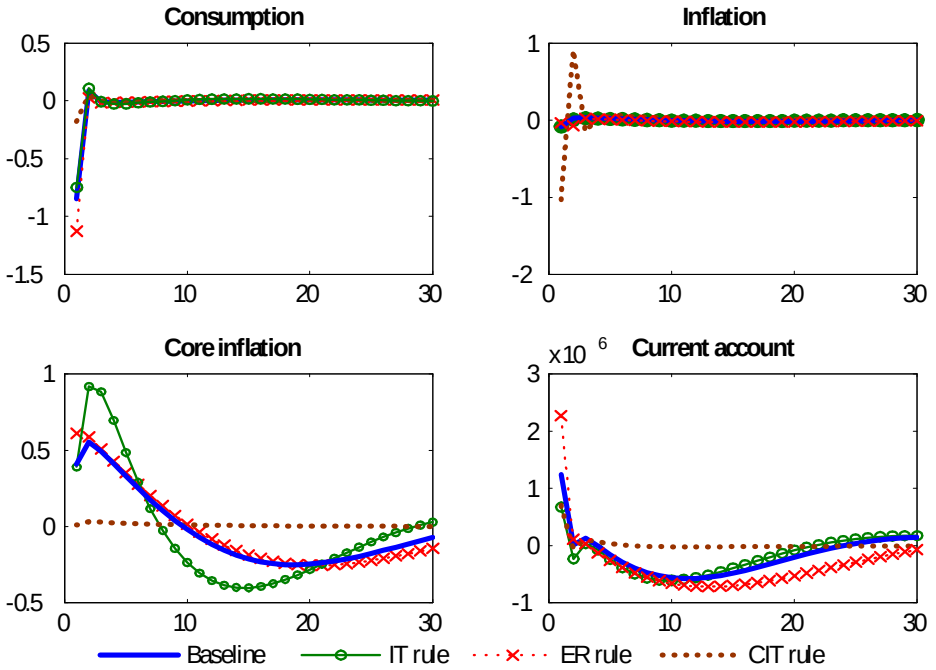


Figure 2.11: The effect of 1% positive international interest rate shock

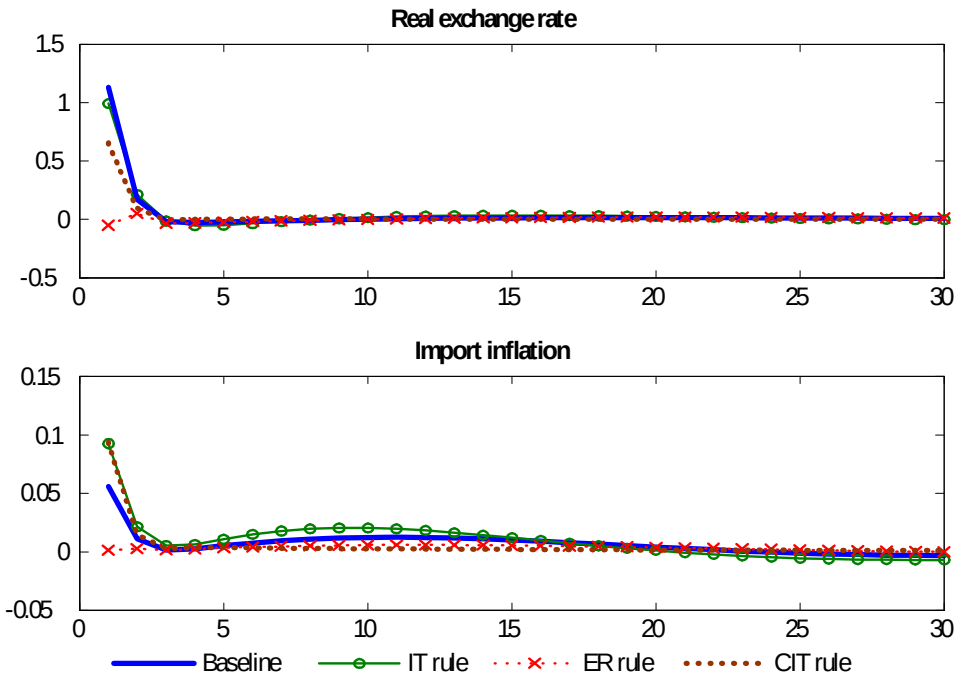


Figure 2.12: The effect of 1% positive international interest rate shock

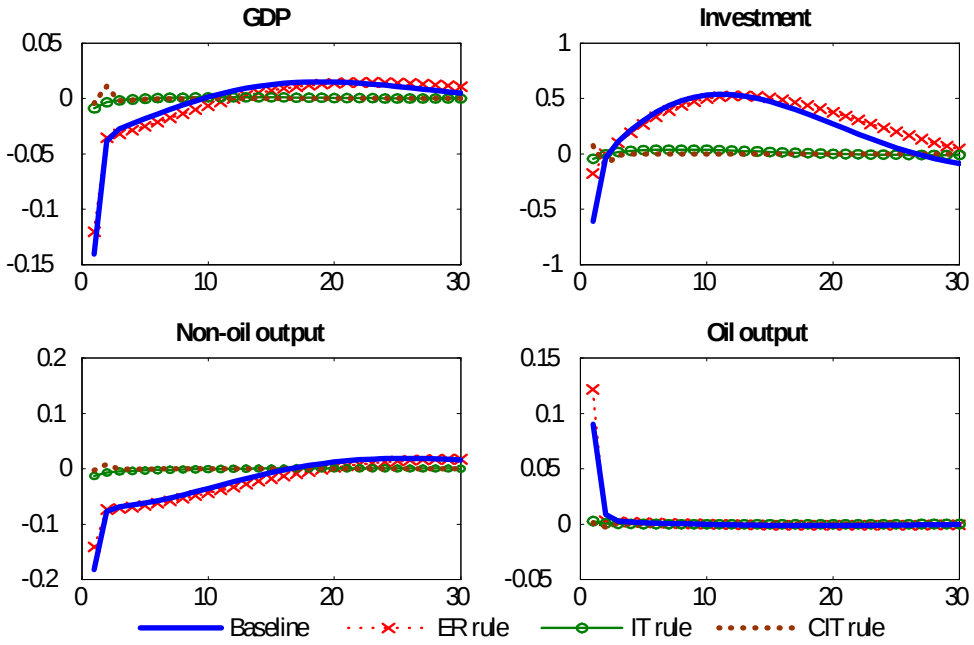


Figure 2.13: The effect of 1% positive foreign inflation shock

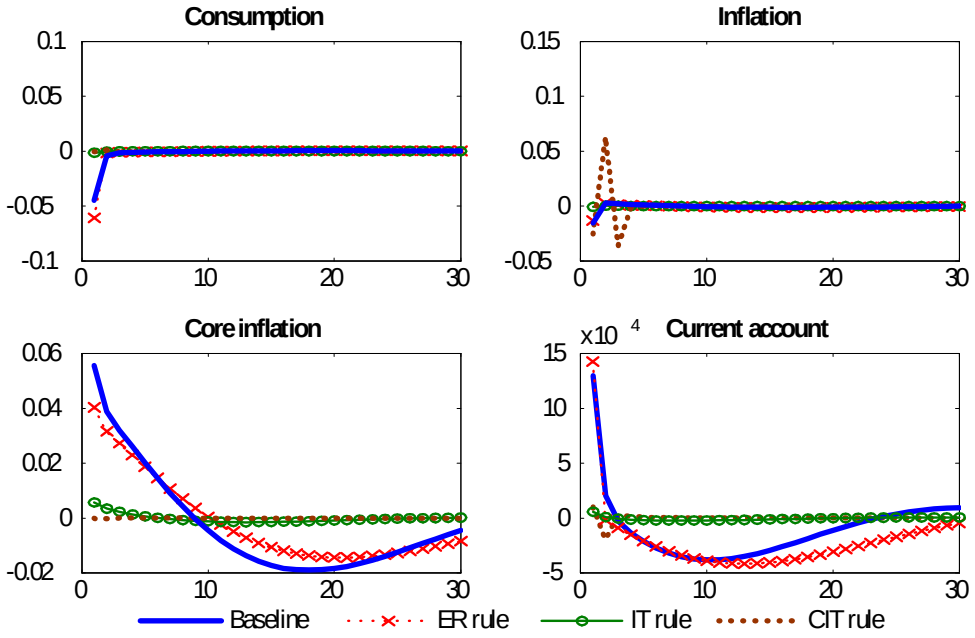


Figure 2.14: The effect of 1% positive foreign inflation shock

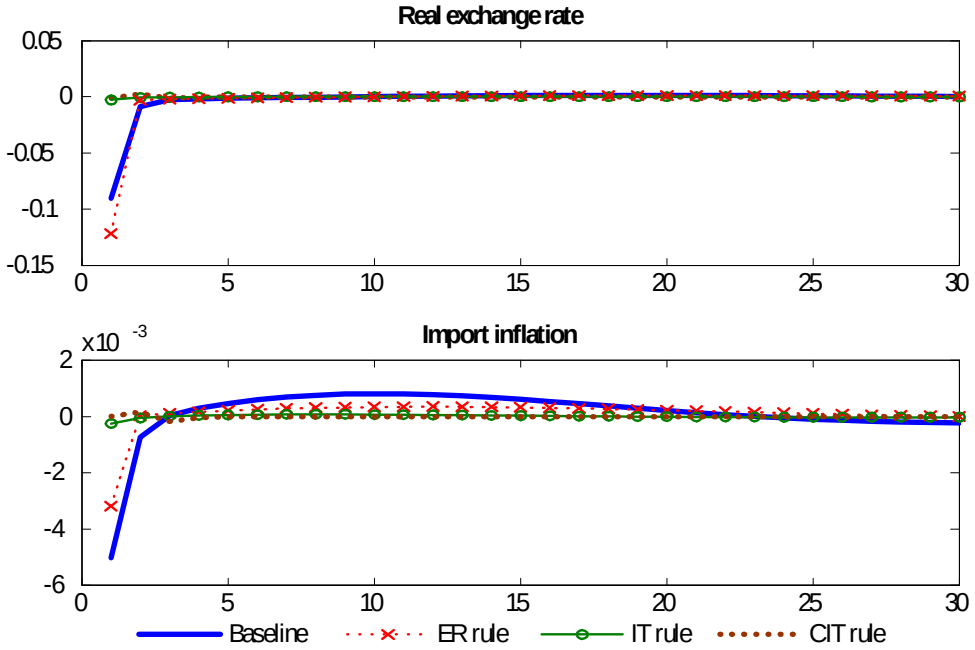


Figure 2.15: The effect of 1% positive foreign inflation shock

B.2 Household's first order conditions

Given initial value, the representative household chooses $\{c_t,\ k_{o,t+1},\ k_{no,t+1},\ \mathrm{h}_{o,t},\ \mathrm{h}_{no},\ B_t^d$ and $B_t^f\}$ to maximize its lifetime utility function subject to capital accumulation equation, the budget constraint and the no-Ponzi game restriction. This latter takes the following form:

$$\lim_{T\to\infty}\left(\prod_{t=0}^{T}\frac{1}{\kappa_t R_t^f}\right)B_T^f=0 \tag{B.1}$$

Equation $(B.1)$ implies that household is unable to finance consumption indefinitely by borrowing, *i.e.* by having negative financial asset.
The function value, V_t, of the representative household is:

$$V_t(\iota)=\max_{c_t\ ,\ h_{j,t},\ k_{j,t+1}\ ,B_t^d\ ,B_t^f}\left\{\begin{array}{c}\frac{1}{1-\gamma}{c_t}^{1-\gamma}-\frac{{h_t}^{1+\sigma}}{1+\sigma}+\beta E_t V_{t+1}-\lambda_t\{P_t c_t+\\ \sum_{j=o,no}P_{j,t}(k_{j,t+1}-(1-\sigma)k_{j,t}\\ +\frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)^2 k_{j,t})+\frac{B_t^d}{R_t}+\frac{e_t\xi_t B_t^f}{R_t^f k_t}\}\\ -B_{t-1}^d-e_t\xi_t B_{t-1}^f-\sum_{j=o,no}Q_{j,t}k_{j,t}-\\ (1-\varpi)\sum_{j=o,no}W_{j,t}h_{j,t}-D_t\end{array}\right\}$$

The solution gives the following first order conditions:

$$\frac{\partial V_t}{\partial c_t}=0\rightarrow c_t^{-\gamma}-\lambda_t=0,$$

$$\frac{\partial V_t}{\partial c_t}=0\rightarrow c_t^{-\gamma}=\lambda_t, \tag{B.2}$$

The equation $(B.2)$ is the marginal utility of household's consumption.

$$\frac{\partial V_t}{\partial k_{j,t}}=0\rightarrow\beta E_t[\lambda_{t+1}\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)\left(-\frac{k_{j,t+2}}{k_{j,t+1}^2}\right)k_{j,t+1}+\frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)^2-(1-\sigma))]$$
$$-q_{j,t+1}-\lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)+1\right]=0,$$

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow -\beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)\left(\frac{k_{j,t+2}}{k_{j,t+1}}\right)-\frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)^2+1-\sigma+q_{j,t+1}\right)\right] + \lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)+1\right]=0,$$

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow \beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)\left(\frac{k_{j,t+2}}{k_{j,t+1}}\right)-\frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)^2+1-\sigma+q_{j,t+1}\right)\right] = \lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)+1\right],$$

we get:

$$\lambda_t = \frac{\beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)\frac{k_{j,t+2}}{k_{j,t+1}}-\frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}}-1\right)^2+q_{j,t+1}+1-\delta\right)\right]}{\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}}-1\right)+1}, \tag{B.3}$$

Equation $(B.3)$ corresponds to the optimal distribution of capital between the three production sectors, namely oil, tradable good and non-tradable good sectors.

$$\begin{aligned}\frac{\partial V_t}{\partial h_{j,t}} &= 0 \rightarrow -(1+\sigma)\frac{{h_t}^{\sigma}}{1+\sigma}\alpha_{hj}\frac{h_t}{h_{j,t}}+\lambda_t(1-\varpi)w_{j,t}=0,\\ \frac{\partial V_t}{\partial h_{j,t}} &= 0 \rightarrow \lambda_t(1-\varpi)w_{j,t}=\alpha_{hj}\frac{{h_t}^{1+\sigma}}{h_{j,t}},\end{aligned}$$

$$\lambda_t = \alpha_{hj}\frac{h_t^{1+\sigma}}{h_{j,t}(1-\varpi)w_{j,t}}, \tag{B.4}$$

$$\frac{\partial V_t}{\partial b_t^d} = 0 \rightarrow \lambda_t\left(-\frac{1}{R_t}\right)+\beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right)=0,$$

with $b_t^d = \frac{B_t^d}{P_t}$,

$$\frac{\lambda_t}{R_t} = \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right), \tag{B.5}$$

and for $b_t^f = \frac{B_t^d}{P_t}$,

$$\frac{\partial V_t}{\partial b_t^f} = 0 \rightarrow \lambda_t \left(-\frac{s_t \Xi_t}{R_t^f k_t} \right) + \beta E_t \left(\lambda_{t+1} \frac{s_{t+1} \Xi_{t+1}}{\pi_{t+1}^f} \right) = 0,$$

$$\frac{\lambda_t s_t \Xi_t}{R_t^f k_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1} \Xi_{t+1}}{\pi_{t+1}^f} \right), \tag{B.6}$$

B.3 Intermediate good producers' FOC:

B.3.1 Oil good producer

The maximization problem of the oil good producer can be written as follow:

$$\begin{array}{cc} \max\limits_{k_{o,t}, h_{o,t}, O_t} \left[e_{l,t} P_{o,t} Y_{o,t} - Q_{o,t} k_{o,t} - W_{o,t} h_{o,t} - P_{O,t} O_t \right] / P_t \\ s.t \qquad\qquad Y_{o,t} \preceq k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o} \end{array}$$

The first order conditions are:

$$\begin{aligned} \frac{\partial \Delta_t}{\partial k_{o,t}} &= 0 \rightarrow \left[e_t P_{o,t}^f \alpha_o k_{o,t}^{\alpha_o - 1} h_{o,t}^{\beta_o} O_t^{\theta_o} - Q_{o,t} \right] / P_t = 0, \\ \frac{\partial \Delta_t}{\partial k_{o,t}} &= 0 \rightarrow s_{o,t} p_{o,t}^f \alpha_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta o}}{k_{o,t}} - q_{o,t} = 0, \end{aligned}$$

$$q_{o,t} = s_{o,t} p_{o,t}^f \alpha_o \frac{Y_{o,t}}{k_{o,t}}, \tag{B.7}$$

$$\begin{aligned} \frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow \left[e_t P_{o,t}^f \beta_o k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o - 1} O_t^{\theta_o} - W_{o,t} \right] / P_t = 0, \\ \frac{\partial \Delta_t}{\partial h_{o,t}} &= 0 \rightarrow s_t p_{o,t}^f \beta_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}}{h_{o,t}} - w_{o,t} = 0, \end{aligned}$$

$$w_{o,t} = s_t p^f_{o,t} \beta_o \frac{Y_{o,t}}{h_{o,t}}, \tag{B.8}$$

$$\begin{aligned}
\frac{\partial \Delta_t}{\partial O_{o,t}} &= 0 \rightarrow \left[e_t P^f_{o,t} \theta_o k^{\alpha_o}_{o,t} h^{\beta_o}_{o,t} O^{\theta_o - 1}_t - P_{O,t} \right] / P_t = 0, \\
\frac{\partial \Delta_t}{\partial Q_{o,t}} &= 0 \rightarrow s_t p^f_{o,t} \theta_o \frac{k^{\alpha_o}_{o,t} h^{\beta_o}_{o,t} O^{\theta_o}_t}{O_t} - p_{O,t} = 0,
\end{aligned}$$

$$p_{O,t} = s_t p^f_{o,t} \theta_o \frac{Y_{o,t}}{O_t}. \tag{B.9}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p^f_{o,t} = \frac{P^f_{o,t}}{P^f_t}$, $p_{O,t} = \frac{P_{O,t}}{P_t}$ and $s_t = e_t \frac{P^f_t}{P_t}$ denote respectively the real capital return, the real wage and the real oil price, oil price resource and real exchange rate.

B.3.2 Non-oil good producer

The following is the lagrangian associated:

$$\begin{aligned}
\Lambda &= \pi^s \widetilde{P}_{no,t}(i) Y_{no,t+s}(i) - Q_{no,t+s} k_{no,t+s}(i) - W_{no,t+s} h_{no,t+s}(i) - P_{o,t} Y^I_{o,t}(i) \\
&\quad + \lambda_t \left(Y_{no,t}(i) - A_{no,t} k^{\alpha_{no}}_{no,t}(i) h^{\beta_{no}}_{no,t}(i) Y^{I^{\theta_{no}}}_{o,t}(i) \right)
\end{aligned}$$

where λ_t denotes the lagrangian multiplier which can be defined as the marginal cost, $MC_{no,t}$, of the non-tradable firm.

$$\begin{aligned}
\frac{\partial \Lambda_t}{\partial k_{no,t}(i)} &= 0 \rightarrow -Q_{no,t} - MC_{no,t} \alpha_{no} \left(A_{no,t} k^{\alpha_{nT}-1}_{no,t}(i) h^{\beta_{no}}_{no,t}(i) Y^{I^{\theta_{no}}}_{o,t}(i) \right) = 0, \\
\frac{\partial \Lambda_t}{\partial k_{no,t}(i)} &= 0 \rightarrow -Q_{no,t} - MC_{no,t} \alpha_{no} \frac{Y_{no,t}(i)}{k_{no,t}(i)} = 0,
\end{aligned}$$

$$q_{no,t} = \alpha_{no} \frac{Y_{no,t}(i)}{k_{no,t}(i)} mc_{no,t}. \tag{B.10}$$

$$\begin{aligned}
\frac{\partial \Lambda_t}{\partial h_{no,t}(i)} &= 0 \rightarrow -W_{no,t} - MC_{no,t}\beta_{no}\left(A_{no,t}k_{no,t}^{\alpha_{no}}(i)\, h_{no,t}^{\beta_{no}-1}(i)\, Y_{o,t}^{I^{\theta_{no}}}(i)\right) = 0, \\
\frac{\partial \Lambda_t}{\partial h_{no,t}(i)} &= 0 \rightarrow -W_{no,t} - MC_{no,t}\beta_{no}\frac{Y_{no,t}(i)}{h_{no,t}(i)} = 0,
\end{aligned}$$

$$w_{no,t} = \beta_{no} \frac{Y_{no,t}(i)}{h_{no,t}(i)} mc_{no,t}. \tag{B.11}$$

$$\begin{aligned}
\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I}(i)} &= 0 \rightarrow -P_{o,t} - MC_{no,t}\theta_{no}\left(A_{no,t}k_{no,t}^{\alpha_{no}}(i)\, h_{no,t}^{\beta_{no}}(i)\, Y_{o,t}^{I^{\theta_{no}-1}}(i)\right) = 0, \\
\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I}(i)} &= 0 \rightarrow -P_{o,t} - MC_{no,t}\theta_{no}\frac{Y_{no,t}(i)}{Y_{o,t}^{I}(i)} = 0,
\end{aligned}$$

$$p_{o,t} = \theta_{no} \frac{Y_{no,t}(i)}{Y_{o,t}^{I}(i)} mc_{no,t}. \tag{B.12}$$

where $q_{no,t} = \frac{Q_{no,t}}{P_t}, w_{no,t} = \frac{W_{no,t}}{P_t}, mc_{no,t} = \frac{MC_{no,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real domestic oil price.

B.4 Final good producer

The maximization problem of the final good producer is given by:

$$\max_{Y_{I,t}, Y_{no,t}} P_t z_t - P_{I,t} Y_{I,t} - P_{no,t} Y_{no,t},$$

$$s.t: \qquad \left[\chi_{no}^{\frac{1}{\tau}} Y_{nT}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}} Y_I^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}} = 1$$

we get:

$$\begin{aligned} P_{I,t} - \lambda_{1,t}\chi_I^{\frac{1}{\tau}} Y_{I,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}} &= 0, \\ P_{no,t} - \lambda_{1,t}\chi_{no}^{\frac{1}{\tau}} Y_{no,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}} &= 0, \end{aligned}$$

Combining the three expressions, we obtain:

$$\begin{aligned} P_{I,t} + P_{no,t} - \lambda_{1,t}\left[\chi_I^{\frac{1}{\tau}} Y_{I,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}} + \chi_{no}^{\frac{1}{\tau}} Y_{no,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}}\right] &= 0, \\ P_{I,t}^{1-\tau} + P_{no,t}^{1-\tau} - \lambda_{1,t}^{1-\tau}\left[\chi_I^{\frac{1-\tau}{\tau}} Y_{I,t}^{\frac{\tau-1}{\tau}} + \chi_{no}^{\frac{1-\tau}{\tau}} Y_{no,t}^{\frac{\tau-1}{\tau}}\right] &= 0, \\ \chi_I P_{I,t}^{1-\tau} + \chi_{no} P_{no,t}^{1-\tau} - \lambda_{1,t}^{1-\tau}\left[\chi_I^{\frac{1}{\tau}} Y_{I,t}^{\frac{\tau-1}{\tau}} + \chi_{no}^{\frac{1}{\tau}} Y_{no,t}^{\frac{\tau-1}{\tau}}\right] &= 0, \end{aligned}$$

we find:

$$\lambda_{1,t} = \left[\chi_I P_{I,t}^{1-\tau} + \chi_{no} P_{no,t}^{1-\tau}\right]^{\frac{1}{1-\tau}} = P_t$$

this equation implies that $P_t = \lambda_{1,t}$. Thus, replacing $\lambda_{1,t}$ by P_t we get:

$$\begin{aligned} P_{I,t} - P_t\left(\frac{z_t}{Y_{I,t}}\right)^{\frac{1}{\tau}} \chi_I^{\frac{1}{\tau}} &= 0, \\ P_{no,t} - P_t\left(\frac{z_t}{Y_{no,t}}\right)^{\frac{1}{\tau}} \chi_{no}^{\frac{1}{\tau}} &= 0, \end{aligned}$$

we find finally, the following demand function:

$$Y_{I,t} = \chi_I \left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t, \quad Y_{no,t} = \chi_{no} \left(\frac{P_{no,t}}{P_t}\right)^{-\tau} z_t \tag{B.13}$$

The zero-profit condition implies that:

$$\begin{aligned} P_t z_t - P_{I,t} Y_{I,t} - P_{no,t} Y_{no,t} &= 0, \\ P_t z_t = P_{I,t} \chi_I \left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t + P_{no,t} \chi_{no} \left(\frac{P_{no,t}}{P_t}\right)^{-\tau} z_t, \\ P_t = P_{I,t} \chi_I \left(\frac{P_{I,t}}{P_t}\right)^{-\tau} + P_{no,t} \chi_{no} \left(\frac{P_{no,t}}{P_t}\right)^{-\tau}, \end{aligned}$$

we obtain finally the following price index:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_{no} P_{no,t}^{1-\tau}\right]^{\frac{1}{1-\tau}}, \tag{B.14}$$

B.5 Price setting

The non-tradable firms' maximization problem can be written as follow:

$$\max_{k_{no,t}(i), h_{no,t}(i), P_{no,t}(i)} E_0 \sum_{s=0}^{\infty} \left[(\beta \phi_{no})^s \lambda_{t+s} D_{no,t+s}(i)/P_{t+s}\right], \tag{B.15}$$

subject to the production function ($B.16$) and the demand function ($B.17$):

$$Y_{np,t}(i) = A_{no,t} k_{no,t}^{\alpha_{no}}(i) h_{no,t}^{\beta_{no}}(i) Y_{o,t}^{I^{\theta_{no}}}(i) \tag{B.16}$$

$$Y_{no,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}}\right)^{-\vartheta} Y_{no,t+s}, \tag{B.17}$$

where $D_{no,t+s}(i)$ is the profit function:

$$D_{no,t+s}(i) = \pi^s \widetilde{P}_{no,t}(i) Y_{no,t+s}(i) - Q_{no,t+s} k_{no,t+s}(i) - W_{no,t+s} h_{no,t+s}(i) - P_{o,t} Y^I_{o,t}(i),$$

where $\beta^s \lambda_{t+s}$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$.
The optimal pricing condition is given by the maximization of $(B.15)$:

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{no,t}(i)} = 0 \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} [\pi^s \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-\vartheta} Y_{no,t+s} - \vartheta \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-\vartheta-1}$$
$$\frac{\pi^s Y_{no,t+s}}{P_{no,t+s}} \pi^s \widetilde{P}_{no,t}(i) + \vartheta \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-\vartheta-1} \frac{\pi^s Y_{no,t+s}}{P_{no,t+s}} MC_{no,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{no,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-\vartheta} Y_{no,t+s} [\pi^s - \vartheta \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-1}$$
$$\frac{\pi^s}{P_{no,t+s}} \pi^s \widetilde{P}_{no,t}(i) + \vartheta \left(\frac{\pi^s \widetilde{P}_{no,t}(i)}{P_{no,t+s}} \right)^{-1} \frac{\pi^s}{P_{no,t+s}} MC_{no,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{no,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} Y_{no,t+s} p^{\vartheta}_{no,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi^{\vartheta}_{t+k} [(1-\vartheta)\pi^s + \vartheta \frac{mc_{no,t+s}}{\widetilde{p}_{no,t}(i)} \pi_{t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{no,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} Y_{no,t+s} p^{\vartheta}_{no,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi^{\vartheta}_{t+k}$$
$$[(1-\vartheta)\widetilde{p}_{no,t}(i) \prod_{k=1}^{s} \pi^s \pi^{-1}_{t+s} + \vartheta mc_{no,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{no,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta} [(1-\vartheta)\widetilde{p}_{no,t}(i) \prod_{k=1}^{s} \pi^s \pi_{t+s}^{-1} + \vartheta mc_{no,t+s}] = 0,$$

we get finally:

$$\widetilde{p}_{no,t}(i) = \left(\frac{\vartheta}{\vartheta-1}\right) \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} mc_{no,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}} \tag{B.18}$$

where $p_{no,t+s} = \frac{P_{no,t+s}}{P_{t+s}}, mc_{no,t+s} = \frac{MC_{no,t+s}}{P_{t+s}}, \widetilde{p}_{no,t}(i) = \frac{\widetilde{P}_{no,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$denote respectively the relative price of non-tradable goods, the real marginal cost in non-tradable sector, the real optimized price for non-tradable goods and the CPI inflation rate.

The same procedure is used in the imports sector.

B.6 Current account

Combining the households' budget constraint, the single period profit functions of non-oil good producing firms and foreign good importers and the first order conditions of the two sectors and applying the market clearing conditions yields the following current account equation:

$$P_t(c_t + i_t) + \frac{B_t^d}{R_t} + \frac{e_t \xi_t B_t^f}{R_t^f \kappa_t} \preceq B_{t-1}^d + e_t \xi_t B_{t-1}^f + \sum_{j=o,no} Q_{j,t} k_{j,t} + (1-\varpi) \sum_{j=o,no} W_{j,t} h_{j,t} + P_{O,t} O_t + D_t, \tag{B.19}$$

In a symmetric equilibrium, $B_t^d = 0$. This implies that:

$$\frac{e_t\xi_t B_t^f}{R_t^f\kappa_t} - e_t\xi_t B_{t-1}^f = \sum_{j=o,no} Q_{j,t}k_{j,t} + (1-\varpi)\sum_{j=o,no} W_{j,t}h_{j,t} + D_t + P_{O,t}O_t - P_t\left(c_t + i_t\right),$$

In real term:

$$\frac{s_t\Xi_t b_t^f}{R_t^f\kappa_t} - \frac{s_t\Xi_t b_{t-1}^f}{\widetilde{\pi}_t^f} = \sum_{j=o,no} q_{j,t}k_{j,t} + (1-\varpi)\sum_{j=o,no} w_{j,t}h_{j,t} + D_t + P_{O,t}O_t - c_t - i_t,$$

Replacing the first order conditions of the three sectors in the household' budget constraint, we get:

$$\begin{aligned}\frac{s_t\Xi_t b_t^f}{R_t^f\kappa_t} - \frac{s_t\Xi_t b_{t-1}^f}{\widetilde{\pi}_t^f} &= \left(\alpha_o + \beta_o\right)s_t p_{o,t}^f Y_{o,t} + \left(\alpha_{no} + \beta_{no}\right)Y_{no,t}mc_{no,t} \\ &\quad -\varpi\sum_{j=o,no} w_{j,t}h_{j,t} + p_{O,t}O_t + D_I + D_{no} - c_t - i_t,\end{aligned}$$

combining the single period profit functions, the government's budget constraint and the market clearing conditions:

$$\begin{aligned}\frac{s_t\Xi_t b_t^f}{R_t^f\kappa_t} - \frac{s_t\Xi_t b_{t-1}^f}{\widetilde{\pi}_t^f} &= \left(\alpha_o + \beta_o\right)s_t p_{o,t}^f Y_{o,t} + \left(\alpha_{no} + \beta_{no}\right)Y_{no,t}mc_{no,t} + s_t p_{o,t}^f\theta_o Y_{o,t} \\ &\quad + s_t p_{o,t}^f Y_{o,t} - \left(s_t p_{o,t}^f - p_{o,t}\right)Y_{o,t}^I - w_{o,t}h_{o,t} - q_{o,t}k_{o,t} - p_{O,t}O_t + \widetilde{p}_{I,t}Y_{I,t} \\ &\quad - s_t\left(\mu + (1-\mu)\Xi_t\right)Y_{I,t} + \widetilde{p}_{no,t}Y_{no,t} - q_{no,t+s}k_{no,t} - w_{no,t}h_{no,t} - p_{o,t}Y_{o,t}^I - p_{I,t}Y_{I,}\end{aligned}$$

$$\begin{aligned}\frac{s_t\Xi_t b_t^f}{R_t^f\kappa_t} - \frac{s_t\Xi_t b_{t-1}^f}{\widetilde{\pi}_t^f} &= \left(\alpha_o + \beta_o + \theta_o\right)s_t p_{o,t}^f Y_{o,t} + \left(\alpha_{no} + \beta_{no} + \theta_{no}\right)Y_{no,t}mc_{no,t} \\ &\quad + s_t p_{o,t}^f Y_{o,t} - s_t p_{o,t}^f Y_{o,t}^I - s_t p_{o,t}^f Y_{o,t} - s_t\left(\mu + (1-\mu)\Xi_t\right)Y_{I,t} - Y_{no,t}mc_{no,t},\end{aligned}$$

knowing that $\alpha_M + \beta_M + \theta_M = 1$ and $\alpha_{nT} + \beta_{nT} + \theta_{nT} = 1$, we find the following current account equation:

$$\frac{b_t^f}{\kappa_t R_t^f} = \frac{b_{t-1}^f}{\pi_t^f} + p_{o,t}^f Y_{o,t}/\Xi_t - p_{o,t}^f Y_{o,t}^I - (\mu + (1-\mu)\,\Xi_t)\, Y_{I,t}/\Xi_t. \tag{B.20}$$

B.7 Data descritpion

In this paper we used Algerian data obtained from IMF-IFS and ONS (National Office of Statistics). The common period covered by all series is 1990:Q1-2010:Q4.

Oil production: is measured by crude petroleum production, IMF-IFS database.

Domestic inflation: is measured by the percentage change in the consumer price index. The CPI is obtained from IMF-IFS database and ONS.

Domestic real interest rate: is the discount rate of the bank of Algeria, IMF-IFS source.

USD/DZD real exchange rate: is the real effective exchange rate, IMF-IFS database.

Domestic Output: is the Gross Domestic Product. In the IMF-IFS database, the GDP serie is published in annual frequency. We transformed it into quarterly frequency. The GDP is also seasonally adjusted by using X-11 procedure.

Real oil price: is the world oil price. It comes from IMF primary commodity prices database.

B.8 The Non-Linear Equilibrium System

$$h_t = h_{o,t}^{\alpha_{ho}} h_{no,t}^{\alpha_{hno}},$$

$$\kappa_t = \exp\left(-\phi \frac{s_t \Xi_t \widetilde{b_t^f}}{Y_t}\right),$$

$$i_{o,t} = k_{o,t+1} - (1-\delta)k_{o,t} + \frac{\psi_o}{2}\left(\frac{k_{o,t+1}}{k_{o,t}} - 1\right)^2 k_{o,t},$$

$$i_{no,t} = k_{no,t+1} - (1-\delta)k_{no,t} + \frac{\psi_{no}}{2}\left(\frac{k_{no,t+1}}{k_{no,t}} - 1\right)^2 k_{no,t},$$

$$\lambda_t = c_t^{-\gamma},$$

$$\lambda_t = \alpha_{ho} \frac{h_t^{1+\sigma}}{h_{o,t}\left(1-\varpi\right) w_{o,t}},$$

$$\lambda_t = \alpha_{hno} \frac{h_t^{1+\sigma}}{h_{no,t}\left(1-\varpi\right) w_{no,t}},$$

$$\lambda_t = \frac{\beta E_t\left[\lambda_{t+1}\left(\psi_o\left(\frac{k_{o,t+2}}{k_{o,t+1}} - 1\right)\frac{k_{o,t+2}}{k_{o,t+1}} - \frac{\psi_o}{2}\left(\frac{k_{o,t+1}}{k_{o,t}} - 1\right)^2 + q_{o,t+1} + 1 - \delta\right)\right]}{\psi_o\left(\frac{k_{o,t+1}}{k_{o,t}} - 1\right) + 1},$$

$$\lambda_t = \frac{\beta E_t\left[\lambda_{t+1}\left(\psi_{no}\left(\frac{k_{no,t+2}}{k_{no,t+1}} - 1\right)\frac{k_{no,t+2}}{k_{no,t+1}} - \frac{\psi_{no}}{2}\left(\frac{k_{no,t+1}}{k_{no,t}} - 1\right)^2 + q_{no,t+1} + 1 - \delta\right)\right]}{\psi_{no}\left(\frac{k_{no,t+1}}{k_{no,t}} - 1\right) + 1},$$

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

$$\frac{\lambda_t s_t \Xi_t}{R_t^f \kappa_t} = \beta E_t\left(\frac{\lambda_{t+1} s_{t+1} \Xi_{t+1}}{\pi_{t+1}^f}\right),$$

$$Y_{o,t} = k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o},$$

$$q_{o,t} = \alpha_o s_t p_{o,t}^f \frac{Y_{o,t}}{k_{o,t}},$$

$$w_{o,t} = \beta_o s_t p_{o,t}^f \frac{Y_{o,t}}{h_{o,t}},$$

$$p_{O,t} = \theta_o s_t p_{o,t}^f \frac{Y_{o,t}}{O_t},$$

$$Y_{no,t} = k_{no,t}^{\alpha_{no}} h_{no,t}^{\beta_{no}} Y_{o,t}^{I^{\theta_{no}}},$$

$$q_{no,t} = \alpha_{no} \frac{Y_{no,t}}{k_{no,t}} mc_{no,t},$$

$$w_{no,t} = \beta_{no} \frac{Y_{no,t}}{h_{no,t}} mc_{no,t},$$

$$p_{o,t} = \theta_{no} \frac{Y_{no,t}}{Y_{o,t}^I} mc_{no,t},$$

$$mc_{no,t} = \frac{q_{no,t}^{\alpha_{no}} w_{no,t}^{\beta_{no}} p_{o,t}^{\theta_{no}}}{\alpha_{no}^{\alpha_{no}} \beta_{no}^{\beta_{no}} \theta_{no}^{\theta_{no}}},$$

$$z_t = c_t + i_{o,t} + i_{no,t},$$

$$\widetilde{p}_{no,t} = \left(\frac{\vartheta}{\vartheta - 1}\right) \frac{E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} mc_{no,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta \phi_{no})^s \lambda_{t+s} Y_{no,t+s} p_{no,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}},$$

$$(p_{no,t})^{1-\vartheta} = \phi_{no} \left(\pi \frac{p_{no,t-1}}{\pi_t}\right)^{1-\vartheta} + (1 - \phi_{no}) (\widetilde{p}_{no,t})^{1-\vartheta},$$

$$\widetilde{p}_{I,t} = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} mc_{I,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_I)^s \lambda_{t+s} Y_{I,t+s} p_{I,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}},$$

$$(p_{I,t})^{1-\vartheta} = \phi_I \left(\pi \frac{p_{I,t-1}}{\pi_t} \right)^{1-\vartheta} + (1 - \phi_I) (\widetilde{p}_{I,t})^{1-\vartheta},$$

$$mc_{I,t} = s_t (\mu + (1 - \mu) \Xi_t),$$

$$Y_{no,t} = \chi_{no} (p_{no,t})^{-\tau} z_t,$$

$$Y_{I,t} = \chi_I (p_{I,t})^{-\tau} z_t,$$

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

$$p_{o,t} = (1 - \upsilon)(p_{o,t-1}/\pi_t) + \upsilon s_t \Xi_t p_{o,t}^f,$$

$$\frac{b_t^f}{\kappa_t R_t^f} = \frac{b_{t-1}^f}{\pi_t^f} + p_{o,t}^f Y_{o,t}/\Xi_t - p_{o,t}^f Y_{o,t}^I - (\mu + (1 - \mu) \Xi_t) Y_{I,t}/\Xi_t,$$

$$\pi_{no,t} = \pi_t \frac{p_{no,t}}{p_{no,t-1}},$$

$$\pi_{I,t} = \pi_t \frac{p_{I,t}}{p_{I,t-1}},$$

$$\frac{e_t}{e_{t-1}} = \frac{s_t}{s_{t-1}} \frac{\pi_t}{\pi_t^f},$$

$$i_t = i_{o,t} + i_{no,t},$$

$$Y_t = p_{no,t} Y_{no,t}^{va} + s_t p_{o,t}^f Y_{o,t},$$

$$Y_{no,t}^{va} = Y_{no,t} - s_t \Xi_t p_{o,t}^f \frac{Y_{o,t}^I}{p_{no,t}},$$

$$\log(R_t^f) = (1 - \rho_{R^f}) \log(R^f) + \rho_{R^f} \log(R_{t-1}^f) + \varepsilon_{R^f,t},$$

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

$$\log(P_{o,t}^f) = (1-\rho_{P_o^f})\log(P_o^f) + \rho_{P_o^f}\log(P_{o,t-1}^f) + \varepsilon_{P_o^f,t},$$

$$\log(O_t) = (1-\rho_O)\log(O) + \rho_O\log(O_{t-1}) + \varepsilon_{O,t},$$

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

$$\log(A_{o,t}) = (1-\rho_{A_o})\log(A_o) + \rho_{A_o}\log(A_{o,t-1}) + \varepsilon_{A_{o,t}},$$

$$\log(A_{no,t}) = (1-\rho_{A_{no}})\log(A_{no}) + \rho_{A_{no}}\log(A_{no,t-1}) + \varepsilon_{A_{no,t}}.$$

B.9 The Log-Linear Equilibrium System

$$\widehat{h}_t = \alpha_{ho}\widehat{h}_{o,t} + \alpha_{hno}\widehat{h}_{no,t},$$

$$\widehat{\lambda}_t = -\gamma\widehat{c}_t,$$

$$\widehat{\lambda}_t = (1+\sigma)\,\widehat{h}_t - \widehat{h}_{o,t} - \widehat{w}_{o,t},$$

$$\widehat{\lambda}_t = (1+\sigma)\,\widehat{h}_t - \widehat{h}_{no,t} - \widehat{w}_{no,t},$$

$$E_t\left(\beta\widehat{k}_{o,t+2} - \beta E_t\widehat{k}_{o,t+1} + \widehat{\lambda}_{t+1} + \overline{q}_o\widehat{q}_{o,t+1}\right) = \widehat{\lambda}_t + \psi_o\widehat{k}_{o,t+1} - \psi_o\widehat{k}_{o,t}$$

$$E_t\left(\beta\widehat{k}_{no,t+2} - \beta\widehat{k}_{no,t+1} + \widehat{\lambda}_{t+1} + \overline{q}_{no}\widehat{q}_{no,t+1}\right) = \widehat{\lambda}_t + \psi_{no}\widehat{k}_{no,t+1} - \psi_{no}\widehat{k}_{no,t}$$

$$\widehat{\lambda}_t = E_t\left(\widehat{\lambda}_{t+1} - \widehat{\pi}_{t+1}\right) + \widehat{R}_t,$$

$$\widehat{\lambda}_t + \widehat{s}_t + \widehat{\Xi}_t - \widehat{R}^f_t - \widehat{\kappa}_t = E_t\left(\widehat{\lambda}_{t+1} + \widehat{s}_{t+1} + \widehat{\Xi}_{t+1} - \widehat{\pi}^f_{t+1}\right),$$

$$\widehat{y}_{o,t} = \alpha_o\widehat{k}_{o,t} + \beta_o\widehat{h}_{o,t} + \theta_o\widehat{O}_t,$$

$$\widehat{q}_{o,t} = \widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{y}_{o,t} - \widehat{k}_{o,t},$$
$$\widehat{w}_{o,t} = \widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{y}_{o,t} - \widehat{h}_{o,t},$$
$$\widehat{p}_{O,t} = \widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{y}_{o,t} - \widehat{O}_t,$$

$$\widehat{y}_{no,t} = \alpha_{no}\widehat{k}_{no,t} + \beta_{no}\widehat{h}_{no,t} + \theta_{no}\widehat{y}^I_{o,t},$$

$$\widehat{q}_{no,t} = \widehat{y}_{no,t} - \widehat{k}_{no,t} + \widehat{mc}_{no,t},$$

$$\widehat{w}_{no,t} = \widehat{y}_{no,t} - \widehat{h}_{no,t} + \widehat{mc}_{no,t},$$

$$\widehat{p}_{o,t} = \widehat{y}_{no,t} - \widehat{y}^{I}_{o,t} + \widehat{mc}_{no,t},$$

$$\widehat{mc}_{no,t} = \alpha_{no,t}\widehat{q}_{no,t} + \beta_{no}\widehat{w}_{no,t} + \theta_{no}\widehat{p}_{o,t},$$

$$\widehat{\pi}_{no,t} = \beta E_t \pi_{no,t+1} + \frac{(1-\phi_{no})(1-\beta\phi_{no})}{\phi_{no}}\widehat{mc}_{no,t},$$

$$\widehat{\pi}_{I,t} = \beta E_t \pi_{I,t+1} + \frac{(1-\phi_I)(1-\beta\phi_I)}{\phi_I}\left[\widehat{s}_t + (1-\mu)\,\widehat{\Xi}_t\right],$$

$$\widehat{z}_t = \frac{\overline{c}}{\overline{z}}\widehat{c}_t + \frac{\overline{i}_o}{\overline{z}}\widehat{i}_{o,t} + \frac{\overline{i}_{no}}{\overline{z}}\widehat{i}_{no,t},$$

$$\widehat{mc}_{I,t} = \widehat{s}_t + (1-\mu)\,\widehat{\Xi}_t,$$

$$\widehat{y}_{no,t} = -\tau\widehat{p}_{no,t} + \widehat{z}_t,$$

$$\widehat{y}_{I,t} = -\tau\widehat{p}_{I,t} + \widehat{z}_t,$$

$$\widehat{R}_{t+1} = \mu_{\pi_{no}}\widehat{\pi}_{no,t} + \mu_{\pi}\widehat{\pi}_t + \mu_{\Delta e}\Delta\widehat{e}_t,$$

$$\widehat{p}_{o,t} = (1-\upsilon)\left(\widehat{p}_{o,t-1} - \widehat{\pi}_t\right) + \upsilon\left(\widehat{s}_t + \widehat{\Xi}_t + \widehat{p}^{f}_{o,t}\right),$$

$$\Delta\widehat{e}_t = \Delta\widehat{s}_t + \widehat{\pi}_t - \widehat{\pi}^{f}_t,$$

$$\widehat{\pi}_{no,t} = \widehat{\pi}_t + \widehat{p}_{no,t} - \widehat{p}_{no,t-1},$$

$$\widehat{\pi}_{I,t} = \widehat{\pi}_t + \widehat{p}_{I,t} - \widehat{p}_{I,t-1},$$

$$\widehat{i}_{o,t} = \frac{1}{\delta}\widehat{k}_{o,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{o,t},$$

$$\widehat{i}_{no,t} = \frac{1}{\delta}\widehat{k}_{no,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{no,t},$$

$$i_t = \frac{\overline{i}_o}{\overline{i}}\widehat{i}_{o,t} + \frac{\overline{i}_{no}}{\overline{i}}\widehat{i}_{no,t},$$

$$\widehat{y}_t = \frac{\overline{p}_{no}\overline{y}^{va}_{no}}{\overline{y}}\left(\widehat{p}_{no,t} + \widehat{y}^{va}_{no,t}\right) + \frac{\overline{p}^f_o\overline{y}_o}{\overline{y}}\left(\widehat{s}_t + \widehat{p}^f_{o,t} + \widehat{y}_{o,t}\right),$$

$$Y^{va}_{no}Y^{va}_{no,t} = Y_{no}Y_{no,t} + s\Xi p^f_o\frac{Y^I_o}{p_{no}}\left(s_t + \Xi_t + p^f_{o,t} + Y^I_{o,t} - p_{no,t}\right),$$

$$\begin{aligned}\widehat{b}^f_t - \widehat{b}^f_{t-1} &= \widehat{b}^f_t - \beta\left(\widehat{b}^f_t - \widehat{\kappa}_t - \widehat{R}^f_t\right) + \frac{\overline{p}^f_o\overline{y}_o}{\overline{b}^f}\left(\widehat{p}^f_{o,t} + \widehat{y}_{o,t} - \widehat{\Xi}_t\right) - \\ &\quad \frac{\overline{p}^f_o\overline{y}^f_o}{\overline{b}^f}\left(\widehat{p}^f_{o,t} + \widehat{y}^I_{o,t}\right) - \frac{\mu\overline{y}_I}{\overline{b}^f}\left(\widehat{y}_{I,t} - \widehat{\Xi}_t\right) + \frac{(1-\mu)\,\overline{y}_I}{\overline{b}^f}\widehat{y}_{I,t},\end{aligned}$$

$$\widehat{R}^f_t = \rho_{R^f}\widehat{R}^f_{t-1} + \varepsilon_{R^f,t},$$

$$\widehat{\pi}^f_t = \rho_{\pi^f}\widehat{\pi}^f_{t-1} + \varepsilon_{\pi^f,t},$$

$$\widehat{p}^f_{o,t} = \rho_{p^f_o}\widehat{p}^f_{o,t-1} + \varepsilon_{p^f_o,t},$$

$$\widehat{O}_t = \rho_O\widehat{O}_{t-1} + \varepsilon_{O,t},$$

$$\widehat{a}_{o,t} = \rho_{a_o}\widehat{a}_{o,t-1} + \varepsilon_{a_{o,t}},$$

$$\widehat{a}_{no,t} = \rho_{a_{no}}\widehat{a}_{no,t-1} + \varepsilon_{a_{no,t}},$$

$$\widehat{\xi}_t = \rho_\xi\widehat{\xi}_{t-1} + \varepsilon_{\xi,t}.$$

Appendix C

Appendix-Chapter 3

C.1 Figures and Tables

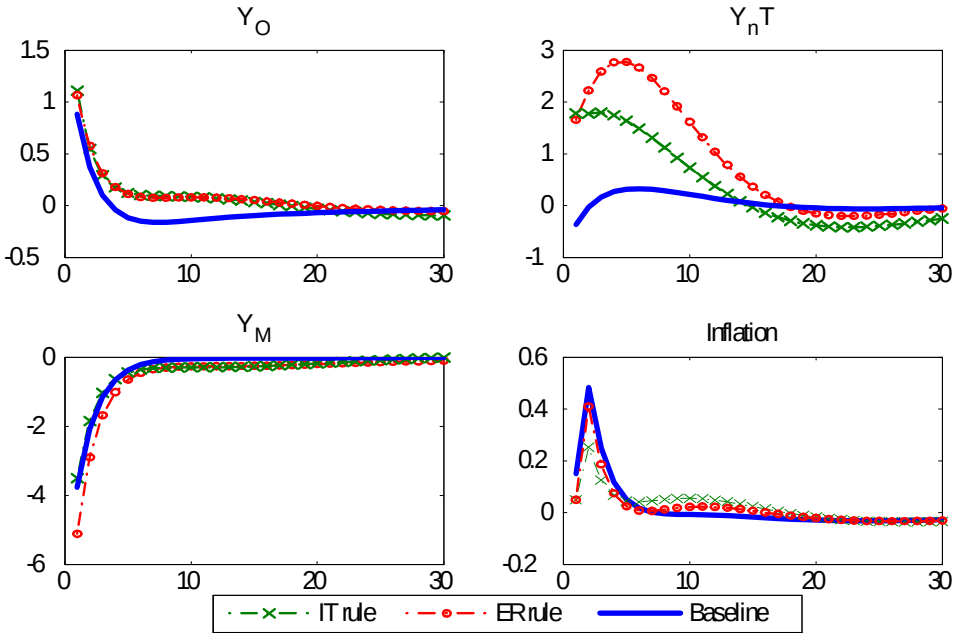


Figure 3.11: Alternative monetary policy rules (Algeria).

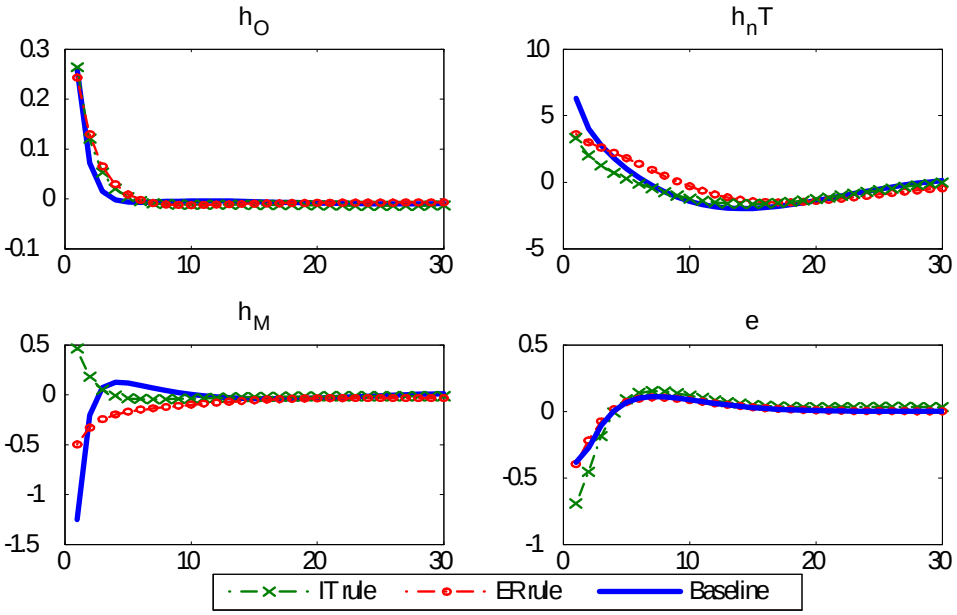


Figure 3.12: Alternative monetary policy rules (Algeria).

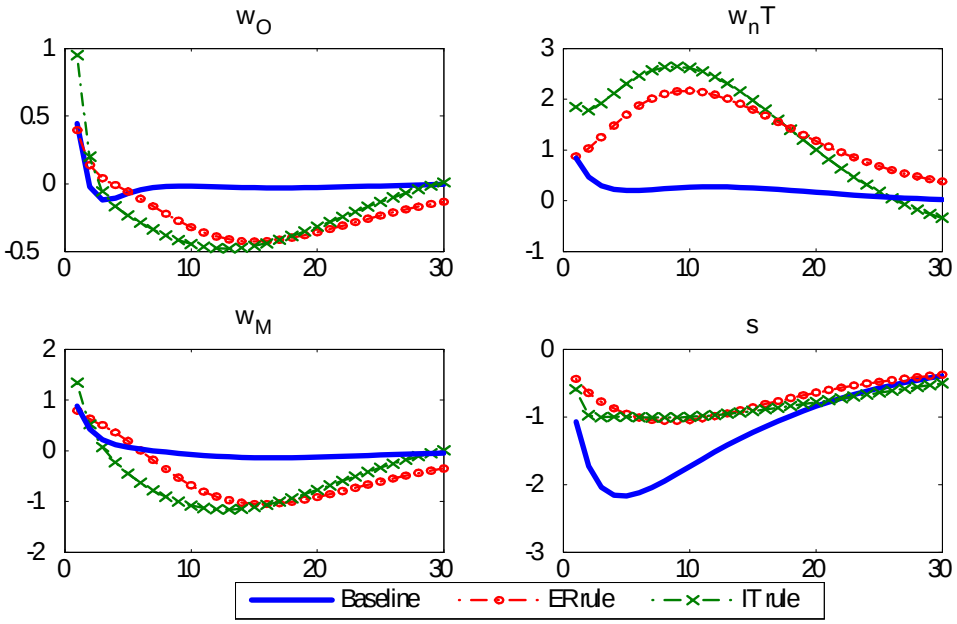


Figure 3.13: Alternative monetary policy rules (Algeria).

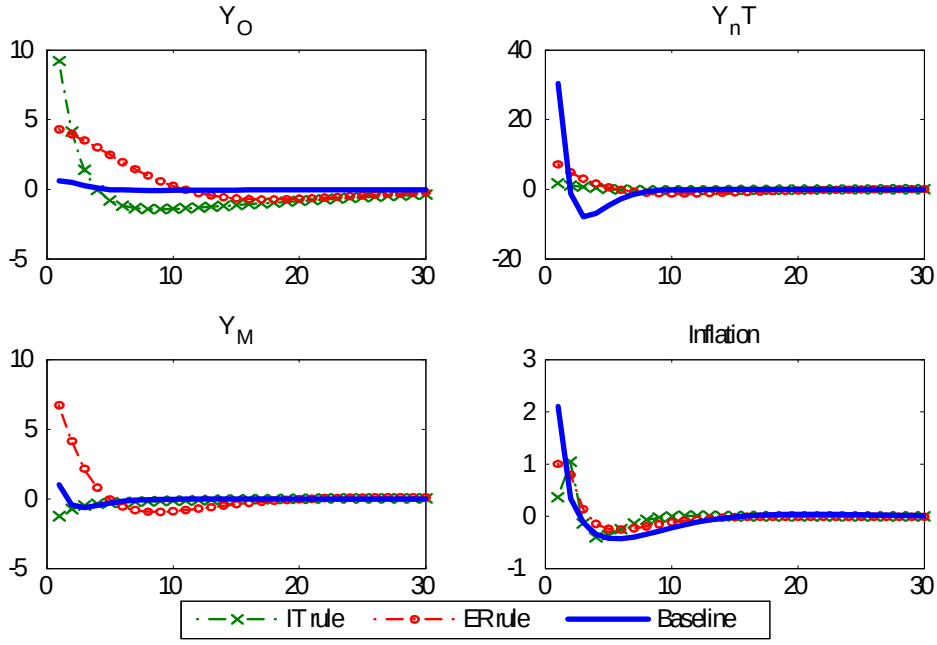


Figure 3.14: Alternative monetary policy rules (Gabon).

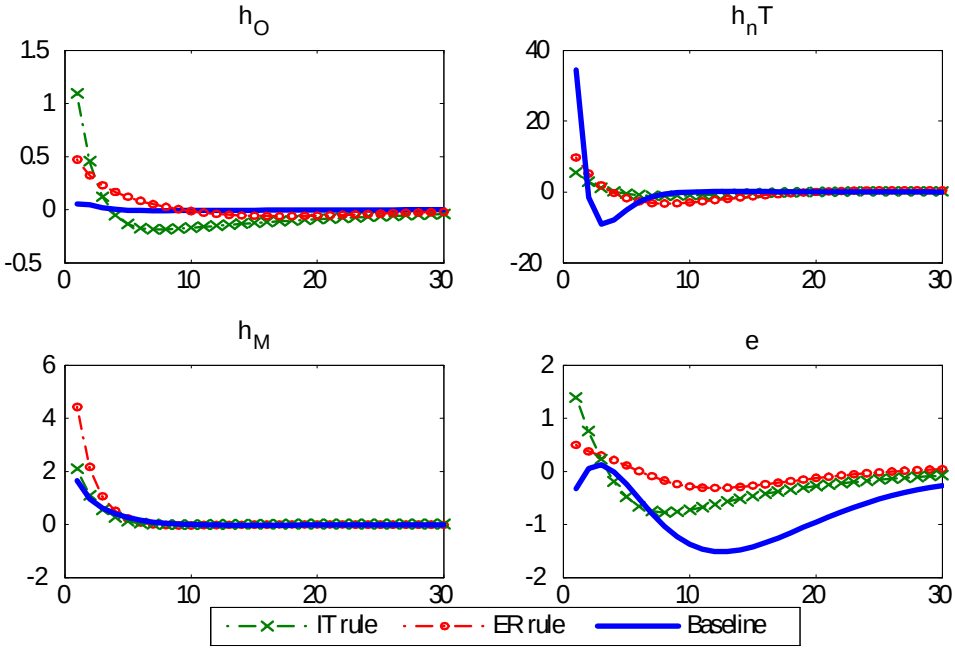


Figure 3.15: Alternative monetary policy rules (Gabon).

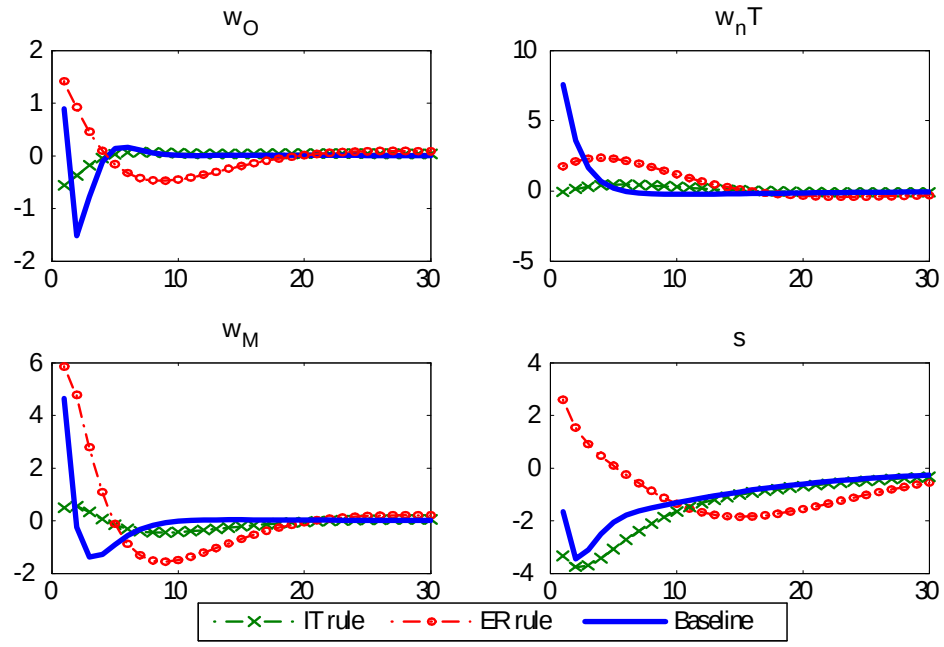


Figure 3.16: Alternative monetary policy rules (Gabon).

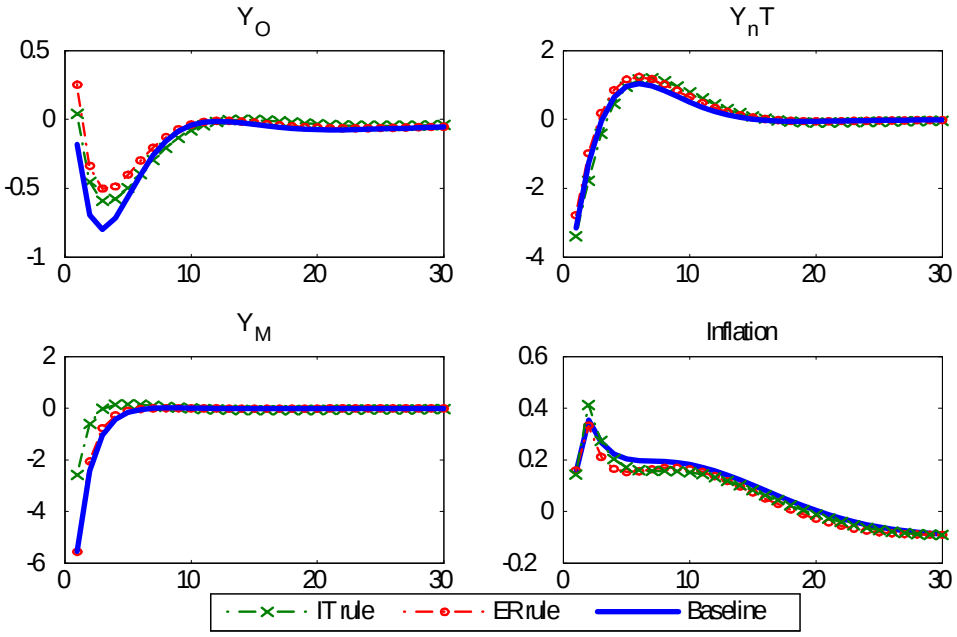


Figure 3.17: Alternative monetary policy rules (Kuwait).

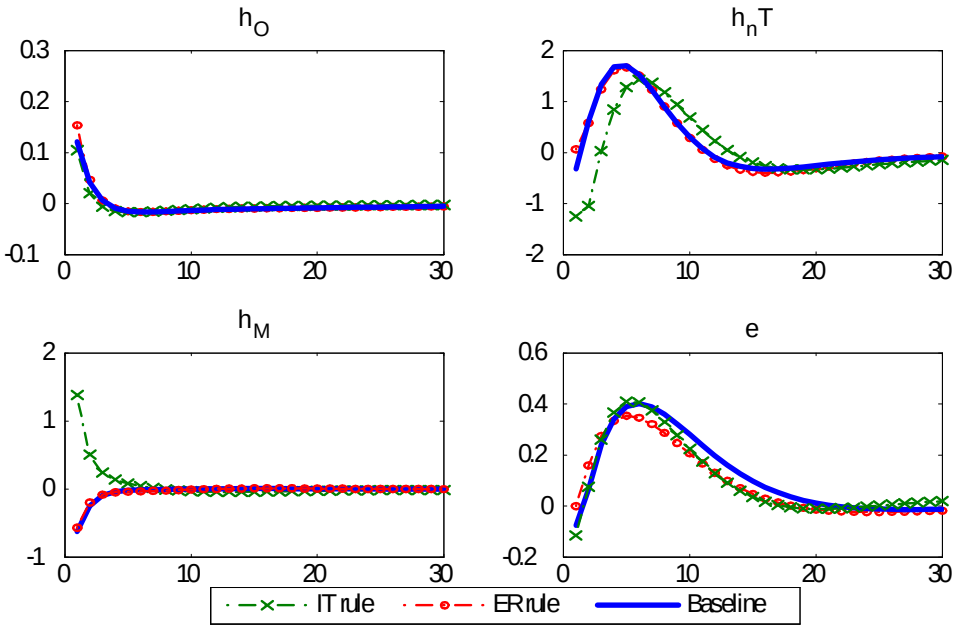


Figure 3.18: Alternative monetary policy rules (Kuwait).

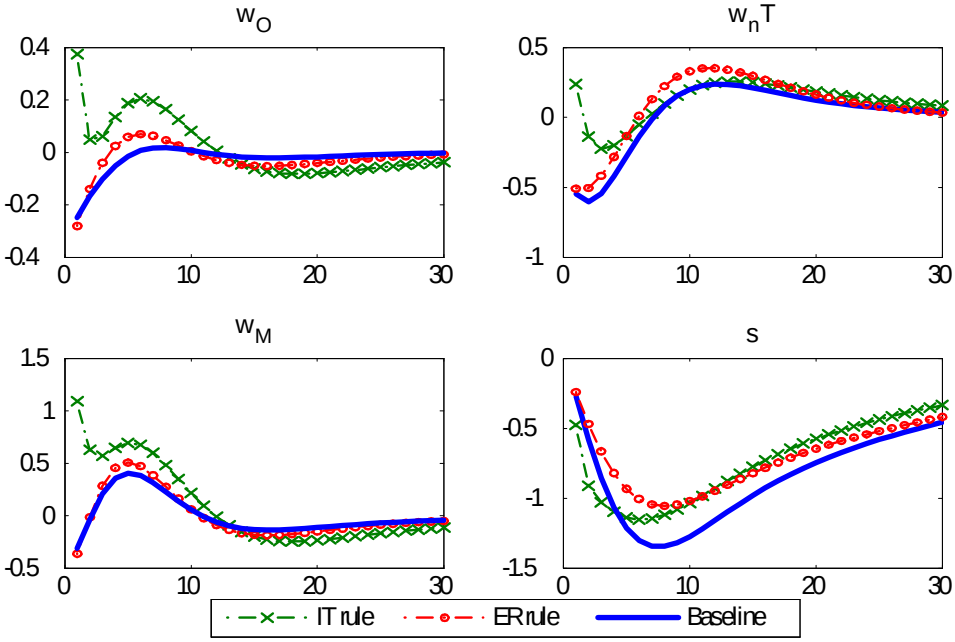


Figure 3.19: Alternative monetary policy rules (Kuwait).

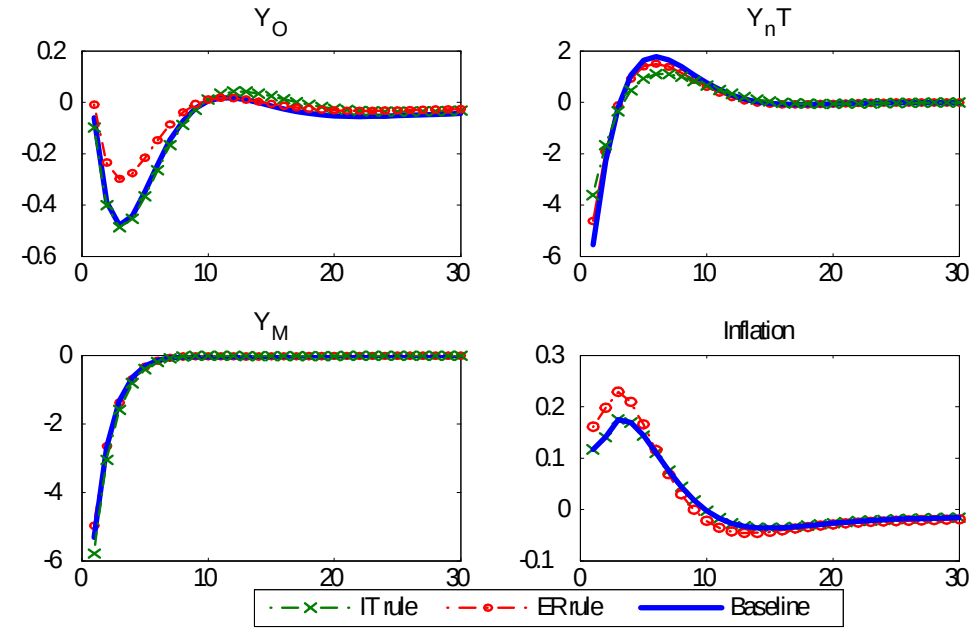
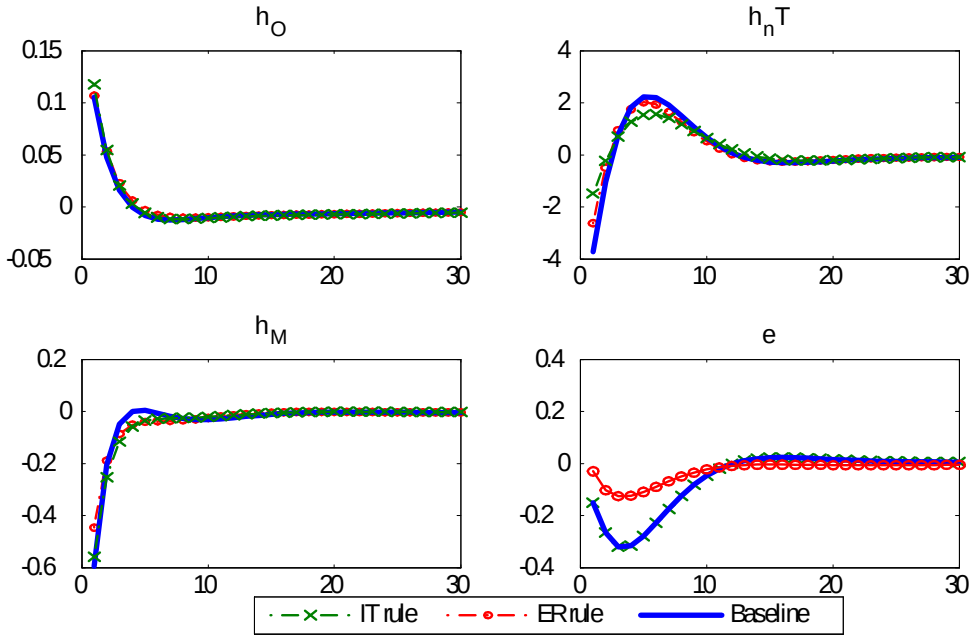


Figure 3.20: Alternative monetary policy rules (Oman).



GRAPH. C.1: Figure 3.21: Alternative monetary policy rules (Oman).

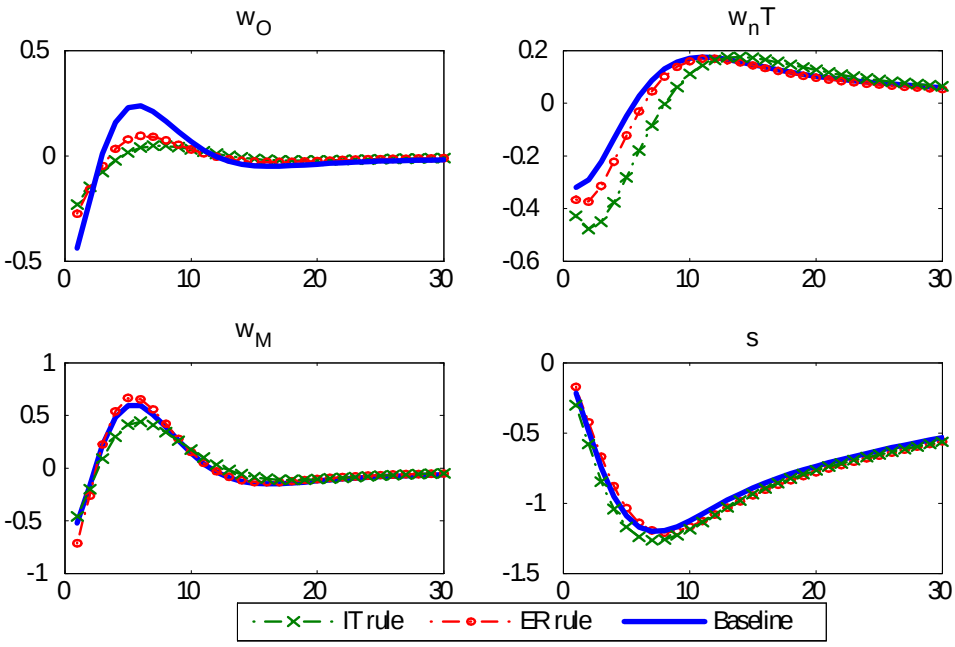


Figure 3.22: Alternative monetary policy rules (Oman).

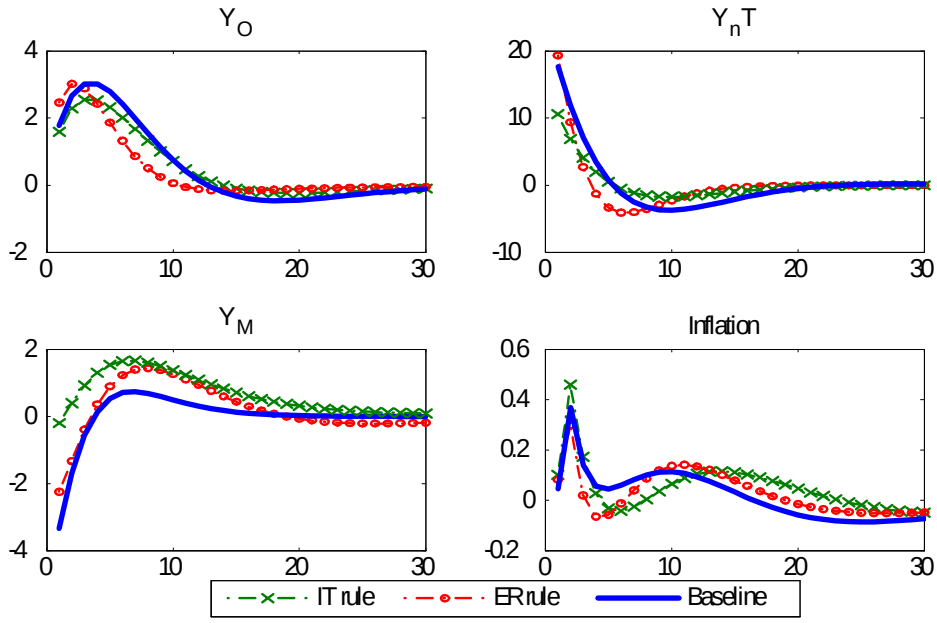


Figure 3.22: Alternative monetary policy rules (Saudi Arabia).

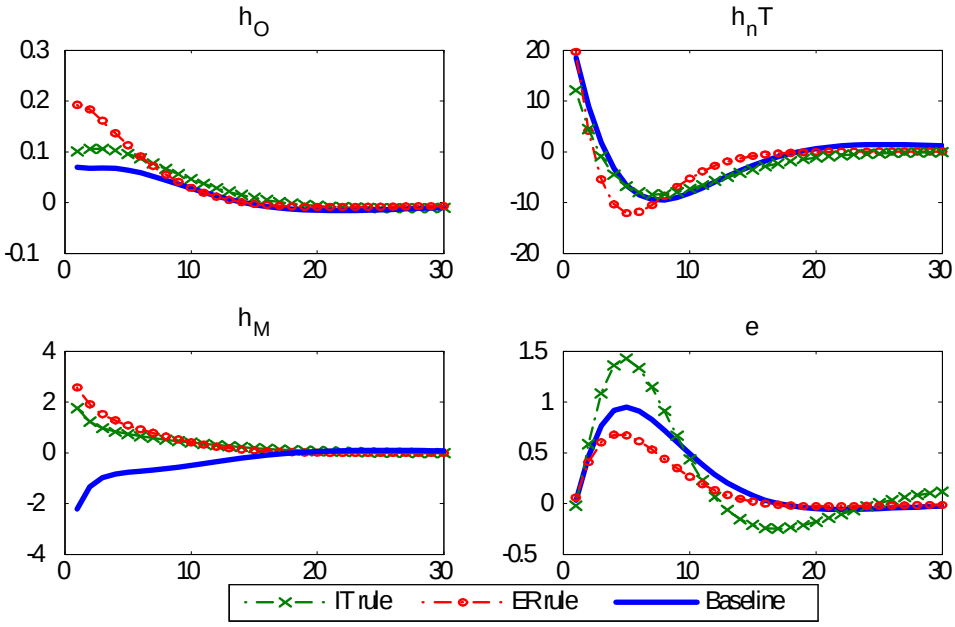


Figure 3.24: Alternative monetary policy rules (Saudi Arabia).

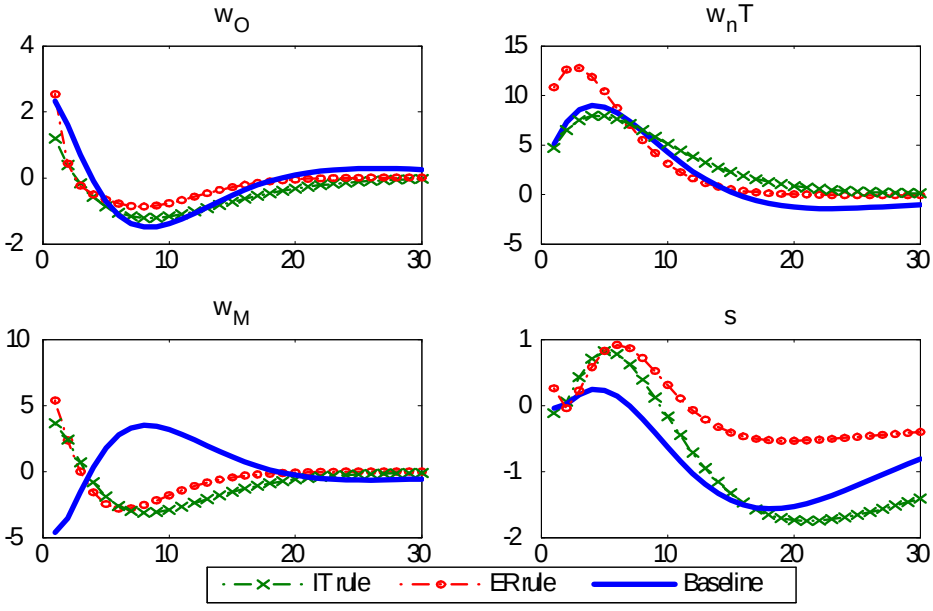
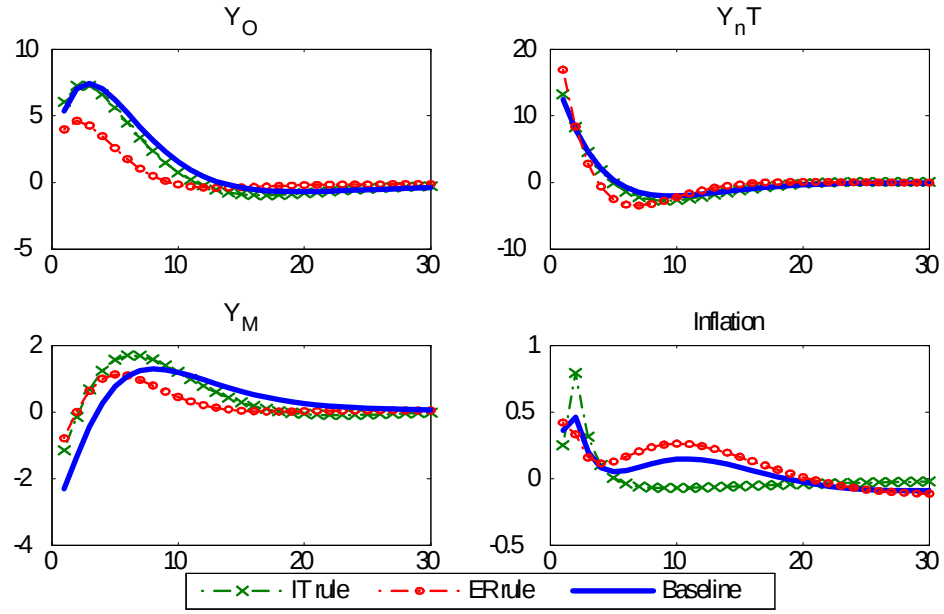


Figure 3.25: Alternative monetary policy rules (Saudi Arabia).



GRAPH. C.2: Figure 3.26: Alternative monetary policy rules (Venezuela).

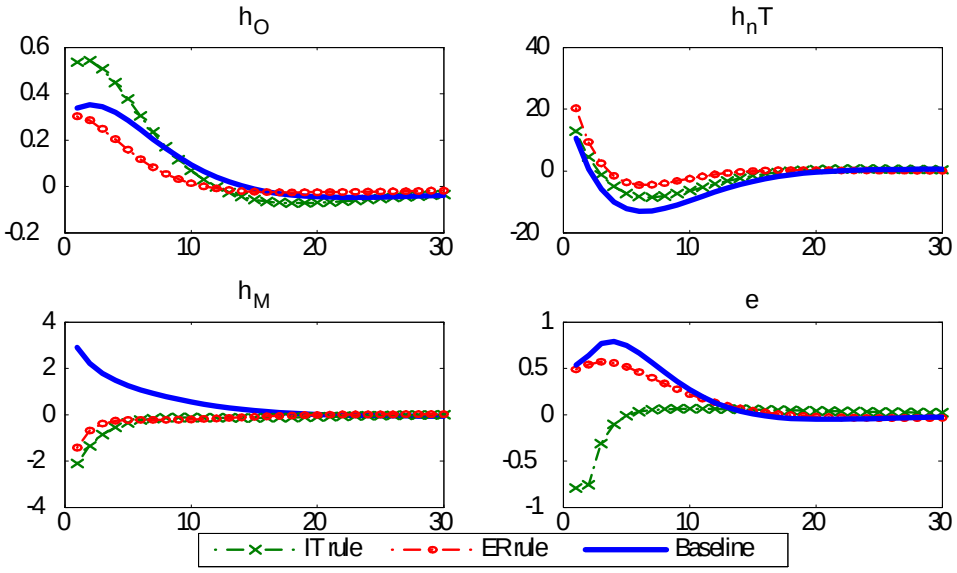


Figure 3.27: Alternative monetary policy rules (Venezuela).

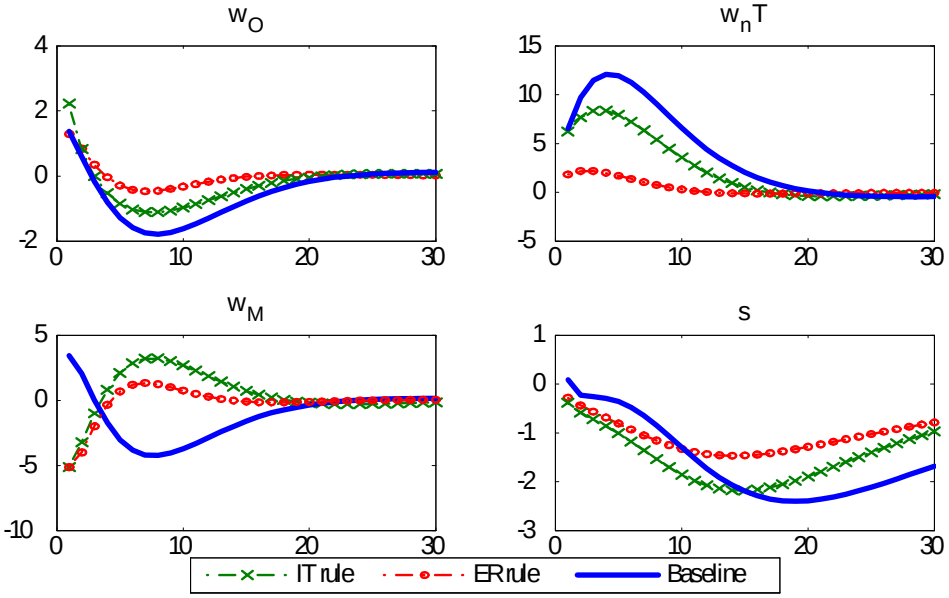


Figure 3.28: Alternative monetary policy rules (Venezuela).

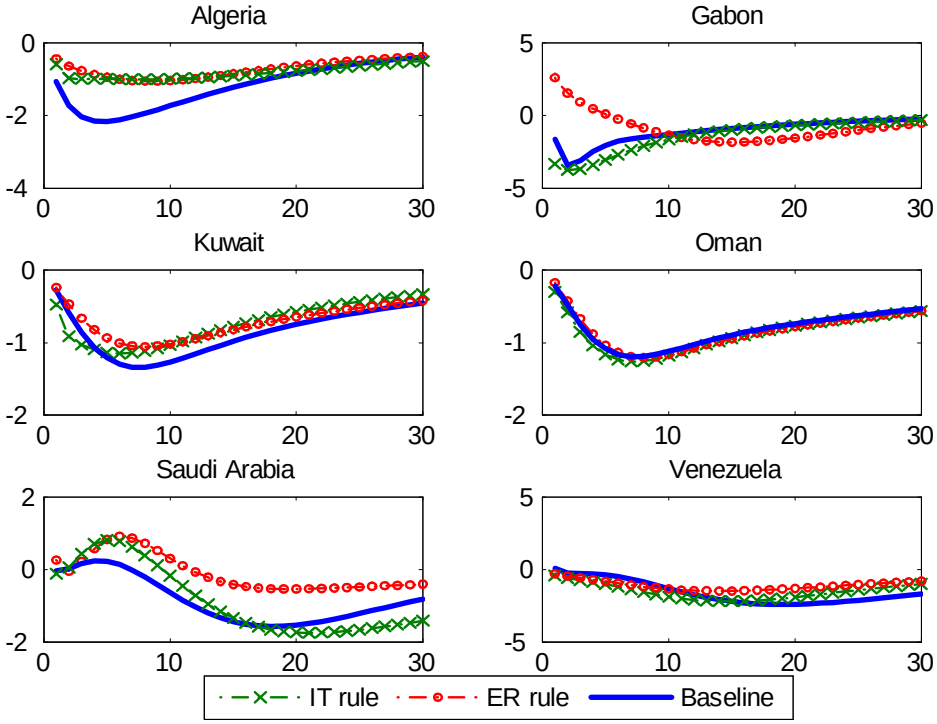


Figure 3.29**:** Real exchange rate under alternative monetary policy rules.

C.2 Household's first order conditions

Given the initial condition, the representative household chooses a consumption path and the composition of its portfolio, $\{c_t,\ h_t,\ k_{o,t+1},\ k_{M,t+1},\ k_{nT,t+1},\ B_t^d$ and $B_t^f\}$ to maximize its utility function subject to its budget constraint and the evolution of capital in the three sectors.

The function value, V_t, of the representative household is:

$$V_t = \max_{c_t\ ,\ h_t,\ k_{j,t+1}\ ,B_t^d\ ,B_t^f} \left\{ \begin{array}{c} \frac{1}{1-\gamma}\eta_t \left(\frac{c_t}{{c_{t-1}}^{\varpi}}\right)^{1-\gamma} - \varsigma_t \frac{{h_t}^{1+\sigma}}{1+\sigma} + \beta E_t V_{t+1} - \lambda_t \\ \{P_t c_t + \sum_{j=o,M,nT} P_{j,t}(k_{j,t+1} - (1-\sigma)k_{j,t} \\ + \frac{\psi_j}{2}\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right)^2 k_{j,t}) + \frac{B_t^d}{R_t} + \frac{e_t B_t^f}{R_t^f k_t} \\ - B_{t-1}^d - e_t B_{t-1}^f - \sum_{j=o,T,nT} Q_{j,t} k_{j,t} - \\ (1-\varkappa) \sum_{j=o,M,nT} W_{j,t} h_{j,t} - D_t\} \end{array} \right\}$$

The first order conditions of the household's optimization problem are:

$$\frac{\partial V_t}{\partial c_t} = 0 \rightarrow \eta_t \frac{c_t^{-\gamma}}{({c_{t-1}}^{\varpi})^{1-\gamma}} - \varpi\beta E_t \left(\eta_t \frac{c_{t+1}^{1-\gamma}}{({c_{t-1}}^{\varpi})^{(1-\gamma)+1}}\right) = \lambda_t$$

$$\frac{\partial V_t}{\partial c_t} = 0 \rightarrow \eta_t \left(\frac{c_t}{{c_{t-1}}^{\varpi}}\right)^{1-\gamma} - \varpi\beta E_t \left(\eta_t \frac{c_{t+1}^{1-\gamma}}{({c_{t-1}}^{\varpi})^{(1-\gamma)+1}\, c_t^{-1}}\right) = c_t\lambda_t$$

$$\frac{\partial V_t}{\partial c_t} = 0 \rightarrow \eta_t \left(\frac{c_t}{{c_{t-1}}^{\varpi}}\right)^{1-\gamma} - \varpi\beta E_t \left(\eta_t \frac{c_{t+1}}{{c_{t-1}}^{\varpi}}\right)^{1-\gamma} = c_t\lambda_t \qquad \text{(A.1)}$$

The equation $(A.1)$ is the marginal utility of household's consumption.

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow \beta E_t \left[\lambda_{t+1}\left(\psi_j\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)\left(-\frac{k_{j,t+2}}{k_{j,t+1}^2}\right)k_{j,t+1} + \frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)^2 - (1-\sigma) - q_{j,t+1}\right)\right]$$
$$-\lambda_t\left[\psi_j\left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right) + 1\right] = 0,$$

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow -\beta E_t \left[\lambda_{t+1} \left(\psi_j \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1 \right) \left(\frac{k_{j,t+2}}{k_{j,t+1}} \right) - \frac{\psi_j}{2} \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1 \right)^2 + 1 - \sigma + q_{j,t+1} \right) \right] + \lambda_t \left[\psi_j \left(\frac{k_{j,t+1}}{k_{j,t}} - 1 \right) + 1 \right] = 0,$$

$$\frac{\partial V_t}{\partial k_{j,t}} = 0 \rightarrow \beta E_t \left[\lambda_{t+1} \left(\psi_j \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1 \right) \left(\frac{k_{j,t+2}}{k_{j,t+1}} \right) - \frac{\psi_j}{2} \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1 \right)^2 + 1 - \sigma + q_{j,t+1} \right) \right] = \lambda_t \left[\psi_j \left(\frac{k_{j,t+1}}{k_{j,t}} - 1 \right) + 1 \right], \tag{A.2}$$

Equation $(A.2)$ corresponds to the optimal distribution of capital between the three production sectors, namely oil, manufacturing and non-tradable sectors.

$$\frac{\partial V_t}{\partial b_t^d} = 0 \rightarrow \lambda_t \left(-\frac{1}{R_t} \right) + \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) = 0,$$

with $b_t^d = \frac{B_t^d}{P_t}$,

$$\frac{\partial V_t}{\partial b_t^d} = 0 \rightarrow \frac{\lambda_t}{R_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right), \tag{A.3}$$

and for $b_t^f = \frac{B_t^d}{P_t}$,

$$\frac{\partial V_t}{\partial b_t^f} = 0 \rightarrow \lambda_t \left(-\frac{s_t}{R_t^f k_t} \right) + \beta E_t \left(\lambda_{t+1} \frac{s_{t+1}}{\pi_{t+1}^f} \right) = 0,$$

$$\frac{\partial V_t}{\partial b_t^f} = 0 \rightarrow \frac{\lambda_t s_t}{R_t^f k_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1}}{\pi_{t+1}^f} \right), \tag{A.4}$$

Equations $(A.3)$ and $(A.4)$ imply the uncovered interest rate parity, so that:

$$\frac{R_t}{R_t^f \kappa_t} = \frac{e_{t+1}}{e_t}. \tag{A.5}$$

C.3 Wage setting

In each production sector, the demand for the household's labor is given by the following maximization problem:

$$\max_{h_{j,t}} W_{j,t}h_{j,t} - \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota = 0, \tag{B.1}$$

$$s.t : h_{j,t} = \left(\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \tag{B.2}$$

with $j = [o, M, nT]$.

Note that $h_{o,t}, h_{M,t}$ and $h_{nT,t}$ that follow the standard Dixit-Stiglitz form represent the aggregate labor supplies to oil, manufacturing and non-tradable sectors respectively, and θ denotes the constant elasticity of substitution between different labor services. Note also that $W_{j,t}(\iota)$ is the wage rate set by the household ι and $W_{o,t}, W_{M,t}$ and $W_{nT,t}$ are the aggregate wage index, or the unit cost of sales the units of the labor index to the oil, manufacturing and non-tradable sectors, respectively.

The first order condition give:

$$W_{j,t} \left(\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} - \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota = 0,$$

$$\frac{\theta}{\theta-1} W_{j,t} \left(\int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1} \frac{\theta-1}{\theta} \int_0^1 h_{j,t}(\iota)^{\frac{\theta-1}{\theta}-1} - W_{j,t}(\iota) = 0,$$

$$h_{j,t}^{\frac{1}{\theta}} h_{j,t}(\iota)^{\frac{-1}{\theta}} = \frac{W_{j,t}(\iota)}{W_{j,t}},$$

finally we get:

$$h_{j,t}(\iota) = \left(\frac{W_{j,t}(\iota)}{W_{j,t}} \right)^{-\theta} h_{j,t} \tag{B.3}$$

where $W_{j,t}(\iota)$ is the nominal wage of houshold ι in each sector j.

Using the zero profit condition, $W_{j,t}h_{j,t} = \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota$, and solving, we obtain the aggregate wage index W_t as follows:

$$W_{j,t}h_{j,t} - \int_0^1 W_{j,t}(\iota)\, h_{j,t}(\iota)\, d\iota = 0$$

$$W_{j,t}h_{j,t} - \int_0^1 W_{j,t}(\iota) \left(\frac{W_{j,t}(\iota)}{W_{j,t}}\right)^{-\theta} h_{j,t} d\iota = 0$$

$$W_{j,t} = \int_0^1 W_{j,t}(\iota)\, W_{j,t}(\iota)^{-\theta}\, W_{j,t}^{\theta} d\iota$$

we obtain:

$$W_{j,t} = \left(\int_0^1 W_{j,t}(\iota)^{1-\theta}\, d\iota\right)^{\frac{1}{1-\theta}} \tag{B.4}$$

where $W_{j,t}$ and $h_{j,t}$ are considered as given.

For the production sectors $i = o, M, nT$, the household ι chooses $\widetilde{W}_{j,t}(\iota)$ to maximize:

$$\max_{\widetilde{W}_{j,t}(\iota)} E_t \left[\sum_{s=0}^{\infty} (\beta\varphi_j)^s \left\{U\left(c_{t+s}(\iota), h_{t+s}(\iota)\right) + \lambda_{t+s}\pi^s \widetilde{W}_{j,t+s}(\iota)\, h_{j,t+s}(\iota)/P_{t+s}\right\}\right] \tag{B.5}$$

subject to:

$$h_{j,t+s}(\iota) = \left(\frac{\pi^s \widetilde{W}_{j,t}(\iota)}{W_{j,t+s}}\right)^{-\theta} h_{j,t+s} \tag{B.6}$$

Replacing $(B.6)$ in $(B.5)$ we obtain:

$$\max_{\widetilde{W}_{j,t}(\iota)} E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{U\left(c_{t+s}\left(\iota\right),h_{t+s}\left(\iota\right)\right)+\lambda_{t+s}\pi^s\frac{\widetilde{W}_{j,t+s}\left(\iota\right)}{P_t}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s}\right\}\right],$$

The first order condition is:

$$E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{\frac{\partial U_{t+s}}{\partial h_{j,t+s}\left(\iota\right)}\frac{\partial h_{j,t+s}\left(\iota\right)}{\widetilde{W}_{j,t}\left(\iota\right)}+(1-\theta)\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{\pi^s h_{j,t+s}}{P_{t+s}}\right\}\right]=0,$$

where $\frac{\partial h_{j,t+s}(\iota)}{\partial\widetilde{W}_{j,t}(\iota)}=-\theta\left(\frac{\pi^s\widetilde{W}_{j,t}(\iota)}{W_{j,t+s}}\right)^{-\theta-1}\frac{\pi^s h_{j,t+s}}{W_{j,t+s}}$,

Let $\Lambda_{j,t+s}=-\frac{\partial U_{t+s}}{\partial h_{j,t+s}}/\frac{\partial U_{t+s}}{\partial c_{t+s}(\iota)}$ represents the marginal rate of substitution between $c_{t+s}\left(\iota\right)$ and $h_{t+s}\left(\iota\right)$ and $\frac{\partial U_{t+s}}{\partial c_{t+s}(\iota)}=\lambda_{t+s}$ denotes the marginal utility of consumption. Thus we obtain,

$$(20)\Rightarrow E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{-\frac{\partial U_{t+s}}{\partial h_{j,t+s}\left(\iota\right)}\theta\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta-1}\frac{\pi^s h_{j,t+s}}{W_{j,t+s}}+(1-\theta)\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{\pi^s h_{j,t+}\right.\right.$$

$$\Rightarrow E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{-\theta\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s}\ \Lambda_{j,t+s}\ \lambda_{t+s}+(1-\theta)\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}\frac{\pi^s h_{j,t+s}}{P_{t+s}}\widetilde{W}_{j,t}\right.\right.$$

$$\Rightarrow\quad E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{\lambda_{t+s}\left(\frac{\pi^s\widetilde{W}_{j,t}\left(\iota\right)}{W_{j,t+s}}\right)^{-\theta}h_{j,t+s}\left(\Lambda_{j,t+s}+\frac{\theta-1}{\theta}\frac{\widetilde{W}_{j,t}\left(\iota\right)\pi^s}{P_{t+s}}\right)\right\}\right]=0,$$

$$\Rightarrow\quad E_t\left[\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\left\{\lambda_{t+s}w_{j,t+s}^{\theta}h_{j,t+s}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}\left(\Lambda_{j,t+s}+\frac{\theta-1}{\theta}\widetilde{w}_{j,t}\left(\iota\right)\prod_{k=1}^{s}\pi^s\pi_{t+k}^{-1}\right)\right\}\right]=0,$$

where $\widetilde{w}_{j,t}(\iota) = \frac{\widetilde{W}_{j,t}(\iota)}{P_t}$ and $w_{j,t+s} = \frac{W_{j,t+s}}{P_{t+s}}$ denote the real optimized wage and the real wage index in the sector j respectively.
Rearranging the last equation yields:

$$\widetilde{w}_{j,t}(\iota) = \frac{\theta}{\theta-1}\frac{E_t\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\lambda_{t+s}h_{j,t+s}\Lambda_{j,t+s}w_{j,t+s}^{\theta}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta}}{E_t\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\lambda_{t+s}h_{j,t+s}w_{j,t+s}^{\theta}\prod_{k=1}^{s}\pi^{s(1-\theta)}\pi_{t+k}^{\theta-1}}, \tag{B.7}$$

Note that for each sector j, $\Lambda_{j,t} = \alpha_{j,t}\frac{h_t^{1+\sigma}}{h_{j,t}\lambda_t}$.

C.4 Non-linear recursive procedure:

Following approach developed by Schmitt-Grohé and Uribe (2007), we rewrite equation $(B.7)$ in a recursive fashion that does away with the use of infinite sums. To do so, the real optimized wage, $\widetilde{w}_{j,t}$, in the sector j, can be written as:

$$\widetilde{w}_{j,t} = \frac{\theta}{\theta-1}\frac{x_{j,t}^1}{x_{j,t}^2},$$

where $x_{j,t}^1$ and $x_{j,t}^2$ are two auxiliary variables. Let

$$x_{j,t}^1 = E_t\sum_{s=0}^{\infty}\left(\beta\varphi_j\right)^s\lambda_{t+s}h_{j,t+s}\Lambda_{j,t+s}w_{j,t+s}^{\theta}\prod_{k=1}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta},$$

$$x_{j,t}^1 = \lambda_t h_{j,t}\Lambda_{j,t}w_{j,t}^{\theta} + E_t\left(\beta\varphi_j\right)^s(\pi^{-\theta}\pi_{t+1}^{\theta})E_t\sum_{s=1}^{\infty}\left(\beta\varphi_j\right)^s\lambda_{t+s}h_{j,t+s}\Lambda_{j,t+s}w_{j,t+s}^{\theta}\prod_{k=2}^{s}\pi^{-\theta s}\pi_{t+k}^{\theta},$$

$$x_{j,t}^1 = \lambda_t h_{j,t}\Lambda_{j,t}w_{j,t}^{\theta} + E_t\left(\beta\varphi_j\right)^s(\pi^{-\theta}\pi_{t+1}^{\theta})x_{j,t+1}^1,$$

$$x_{j,t}^1 = \lambda_t h_{j,t}\Lambda_{j,t}w_{j,t}^{\theta} + \beta\varphi_j E_t\left[\left(\frac{\pi_{t+1}}{\pi}\right)^{\theta}x_{j,t+1}^1\right], \tag{C.1}$$

Similarly, let

$$x_{j,t}^2 = E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{s(1-\theta)} \pi_{t+k}^{\theta-1},$$

$$x_{j,t}^2 \quad = \lambda_t h_{j,t} w_{j,t}^{\theta} + \beta\varphi_j E_t \left[\left(\frac{\pi_{t+1}}{\pi} \right)^{\theta-1} x_{j,t+1}^2 \right] \tag{C.2}$$

The same procedure is used in the case of price setting.

C.5 Intermediate goods producers' FOC:

C.5.1 Tradable goods producers

The maximization problem of the tradable goods producers can be written as follow:

$$\begin{array}{cc} \max\limits_{k_{o,t}, h_{o,t}, O_t} \left[e_{l,t} P_{o,t} Y_{o,t} - Q_{o,t} k_{o,t} - W_{o,t} h_{o,t} - P_{O,t} O_t \right] / P_t \\ s.t \qquad\qquad Y_{o,t} \preceq k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o} \end{array}$$

The first order conditions are:

$$\frac{\partial \Delta_t}{\partial k_{o,t}} = 0 \rightarrow \left[e_t P_{o,t} \alpha_o k_{o,t}^{\alpha_o - 1} h_{o,t}^{\beta_o} O_t^{\theta_o} - Q_{o,t} \right] / P_t = 0$$

$$\frac{\partial \Delta_t}{\partial k_{o,t}} = 0 \rightarrow s_{o,t} p_{o,t} \alpha_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta o}}{k_{o,t}} - q_{o,t} = 0$$

$$\frac{\partial \Delta_t}{\partial k_{o,t}} = 0 \rightarrow q_{o,t} = s_{o,t} p_{o,t} \alpha_o \frac{Y_{o,t}}{k_{o,t}} \tag{D.1}$$

$$\frac{\partial \Delta_t}{\partial h_{o,t}} = 0 \rightarrow \left[e_t P_{o,t} \beta_o k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o - 1} O_t^{\theta_o} - W_{o,t} \right] / P_t = 0$$

$$\frac{\partial \Delta_t}{\partial h_{o,t}} = 0 \rightarrow s_t p_{o,t} \beta_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}}{h_{o,t}} - w_{o,t} = 0$$

$$\frac{\partial \Delta_t}{\partial h_{o,t}} = 0 \rightarrow w_{o,t} = s_t p_{o,t} \beta_o \frac{Y_{o,t}}{h_{o,t}}, \tag{D.2}$$

$$\frac{\partial \Delta_t}{\partial O_{o,t}} = 0 \rightarrow \left[e_t P_{o,t} \theta_o k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o - 1} - P_{O,t} \right] / P_t = 0$$

$$\frac{\partial \Delta_t}{\partial h_{o,t}} = 0 \rightarrow s_t p_{o,t} \theta_o \frac{k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o}}{O_t} - p_{O,t} = 0$$

$$\frac{\partial \Delta_t}{\partial h_{o,t}} = 0 \rightarrow p_{o,t} = s_t p_{o,t} \theta_o \frac{Y_{o,t}}{O_t}. \tag{D.3}$$

where $q_{o,t} = \frac{Q_{o,t}}{P_t}, w_{o,t} = \frac{W_{o,t}}{P_t}, p_{o,t} = \frac{P_{o,t}}{P_t}$, $p_{O,t} = \frac{P_{O,t}}{P_t}$ and $s_t = e_t \frac{P_t^f}{P_t}$ denote respectively the real capital return, the real wage and the real oil price, oil price resource and real exchange rate.

C.5.2 Manufactured and Non-tradable goods producers

The following is the lagrangian associated:

$$\begin{aligned} \Lambda \quad = \quad & \pi^s \widetilde{P}_{nT,t}(i) Y_{nT,t+s}(i) - Q_{nT,t+s} k_{nT,t+s}(i) - W_{nT,t+s} h_{nT,t+s}(i) - P_{o,t} Y_{o,t}^{I_{nT}}(i) \\ & + \lambda_t \left(Y_{nT,t}(i) - A_{nT,t} k_{nT,t}^{\alpha_{nT}}(i) h_{nT,t}^{\beta_{nT}}(i) {Y_{o,t}^{I_{nT}}}^{\theta_{nT}}(i) \right) \end{aligned}$$

where λ_t denotes the lagrangian multiplier which can be defined as the marginal cost, $MC_{nT,t}$, of the non-tradable firm.

$$\frac{\partial \Lambda_t}{\partial k_{nT,t}(i)} = 0 \rightarrow -Q_{nT,t} - MC_{nT,t} \alpha_{nT} \left(A_{nT,t} k_{nT,t}^{\alpha_{nT}-1}(i) h_{nT,t}^{\beta_{nT}}(i) {Y_{o,t}^{I_{nT}}}^{\theta_{nT}}(i) \right) = 0$$

$$\frac{\partial \Lambda_t}{\partial k_{nT,t}(i)} = 0 \rightarrow -Q_{nT,t} - MC_{nT,t} \alpha_{nT} \frac{Y_{nT,t}(i)}{k_{nT,t}(i)} = 0$$

$$\frac{\partial \Lambda_t}{\partial k_{nT,t}(i)} = 0 \rightarrow q_{nT,t} = \alpha_{nT} \frac{Y_{nT,t}(i)}{k_{nT,t}(i)} mc_{nT,t}. \tag{D.4}$$

$$\frac{\partial \Lambda_t}{\partial h_{nT,t}(i)} = 0 \rightarrow -W_{nT,t} - MC_{nT,t}\beta_{nT}\left(A_{nT,t}k_{nT,t}^{\alpha_{nT}}(i)\, h_{nT,t}^{\beta_{nT}-1}(i)\, Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i)\right) = 0,$$

$$\frac{\partial \Lambda_t}{\partial h_{nT,t}(i)} = 0 \rightarrow -W_{nT,t} - MC_{nT,t}\beta_{nT}\frac{Y_{nT,t}(i)}{h_{nT,t}(i)} = 0,$$

$$\frac{\partial \Lambda_t}{\partial h_{nT,t}(i)} = 0 \rightarrow w_{nT,t} = \beta_{nT}\frac{Y_{nT,t}(i)}{h_{nT,t}(i)}mc_{nT,t}. \tag{D.5}$$

$$\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I_{nT}}(i)} = 0 \rightarrow -P_{o,t} - MC_{nT,t}\theta_{nT}\left(A_{nT,t}k_{nT,t}^{\alpha_{nT}}(i)\, h_{nT,t}^{\beta_{nT}}(i)\, Y_{o,t}^{I_{nT}{}^{\theta_{nT}-1}}(i)\right) = 0,$$

$$\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I_{nT}}(i)} = 0 \rightarrow -P_{o,t} - MC_{nT,t}\theta_{nT}\frac{Y_{nT,t}(i)}{Y_{o,t}^{I_{nT}}(i)} = 0,$$

$$\frac{\partial \Lambda_t}{\partial Y_{o,t}^{I_{nT}}(i)} = 0 \rightarrow p_{o,t} = \theta_{nT}\frac{Y_{nT,t}(i)}{Y_{o,t}^{nT}(i)}mc_{nT,t}. \tag{D.6}$$

where $q_{nT,t} = \frac{Q_{nT,t}}{P_t}, w_{nT,t} = \frac{W_{nT,t}}{P_t}, mc_{nT,t} = \frac{MC_{nT,t}}{P_t}$ and $p_{o,t} = \frac{P_{o,t}}{P_t}$ denote respectively the real capital return, the real wage, the real marginal cost, and the real domestic oil price.

C.5.3 Final good producer

The maximization problem of the final good producer is given by:

$$\max_{Y_{I,t},Y_{T,t}^d,Y_{nT,t}} P_t z_t - P_{I,t}Y_{I,t} - P_{T,t}Y_{M,t}^d - P_{nT,t}Y_{nT,t},$$

$$s.t: \qquad \left[\chi_T^{\frac{1}{\tau}}Y_M^{d\,\frac{\tau-1}{\tau}} + \chi_{nT}^{\frac{1}{\tau}}Y_{nT}^{\frac{\tau-1}{\tau}} + \chi_I^{\frac{1}{\tau}}Y_I^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}} = 1$$

we get:

$$P_{I,t} - \lambda_{1,t}\chi_I^{\frac{1}{\tau}}Y_{I,t}^{-\frac{1}{\tau}}z_t^{\frac{1}{\tau}} = 0,$$

$$P_{M,t} - \lambda_{1,t}\chi_M^{\frac{1}{\tau}} Y_{M,t}^{d(-\frac{1}{\tau})} z_t^{\frac{1}{\tau}} = 0,$$

$$P_{nT,t} - \lambda_{1,t}\chi_{nT}^{\frac{1}{\tau}} Y_{nT,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}} = 0,$$

Combining the three expressions, we obtain:

$$P_{I,t} + P_{M,t} + P_{nT,t} - \lambda_{1,t}\left[\chi_I^{\frac{1}{\tau}} Y_{I,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}} + \chi_M^{\frac{1}{\tau}} Y_{M,t}^{d(-\frac{1}{\tau})} z_t^{\frac{1}{\tau}} + \chi_{nT}^{\frac{1}{\tau}} Y_{nT,t}^{-\frac{1}{\tau}} z_t^{\frac{1}{\tau}}\right] = 0,$$

$$P_{I,t}^{1-\tau} + P_{M,t}^{1-\tau} + P_{nT,t}^{1-\tau} - \lambda_{1,t}^{1-\tau}\left[\chi_I^{\frac{1-\tau}{\tau}} Y_{I,t}^{\frac{\tau-1}{\tau}} + \chi_M^{\frac{1-\tau}{\tau}} Y_{M,t}^{d(\frac{\tau-1}{\tau})} + \chi_{nT}^{\frac{1-\tau}{\tau}} Y_{nT,t}^{\frac{\tau-1}{\tau}}\right] = 0,$$

$$\chi_I P_{I,t}^{1-\tau} + \chi_M P_{M,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau} - \lambda_{1,t}^{1-\tau}\left[\chi_I^{\frac{1}{\tau}} Y_{I,t}^{\frac{\tau-1}{\tau}} + \chi_T^{\frac{1}{\tau}} Y_{M,t}^{d(\frac{\tau-1}{\tau})} + \chi_{nT}^{\frac{1}{\tau}} Y_{nT,t}^{\frac{\tau-1}{\tau}}\right] = 0,$$

we find:

$$\lambda_{1,t} = \left[\chi_I P_{I,t}^{1-\tau} + \chi_M P_{M,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau}\right]^{\frac{1}{1-\tau}} = P_t$$

this equation implies that $P_t = \lambda_{1,t}$. Thus, replacing $\lambda_{1,t}$ by P_t we get:

$$P_{I,t} - P_t \left(\frac{z_t}{Y_{I,t}}\right)^{\frac{1}{\tau}} \chi_I^{\frac{1}{\tau}} = 0,$$

$$P_{M,t} - P_t \left(\frac{z_t}{Y_{M,t}^d}\right)^{\frac{1}{\tau}} \chi_M^{\frac{1}{\tau}} = 0,$$

$$P_{nT,t} - P_t \left(\frac{z_t}{Y_{nT,t}}\right)^{\frac{1}{\tau}} \chi_{nT}^{\frac{1}{\tau}} = 0,$$

we find finally, the following demand function:

$$Y_{I,t} = \chi_I \left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t, \quad Y_{M,t} = \chi_M \left(\frac{P_{M,t}}{P_t}\right)^{-\tau} z_t, \quad Y_{nT,t} = \chi_{nT} \left(\frac{P_{nT,t}}{P_t}\right)^{-\tau} z_t \quad \text{(D.7)}$$

The zero-profit condition implies that:

$$P_t z_t - P_{I,t} Y_{I,t} - P_{M,t} Y_{M,t}^d - P_{nT,t} Y_{nT,t} = 0,$$

$$P_t z_t = P_{I,t} \chi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\tau} z_t + P_{M,t} \chi_M \left(\frac{P_{M,t}}{P_t} \right)^{-\tau} z_t + P_{nT,t} \chi_{nT} \left(\frac{P_{nT,t}}{P_t} \right)^{-\tau} z_t,$$

$$P_t = P_{I,t} \chi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\tau} + P_{M,t} \chi_M \left(\frac{P_{M,t}}{P_t} \right)^{-\tau} + P_{nT,t} \chi_{nT} \left(\frac{P_{nT,t}}{P_t} \right)^{-\tau},$$

we obtain finally the following price index:

$$P_t = \left[\chi_I P_{I,t}^{1-\tau} + \chi_M P_{M,t}^{1-\tau} + \chi_{nT} P_{nT,t}^{1-\tau} \right]^{\frac{1}{1-\tau}} \tag{D.8}$$

C.6 Price setting

The non-tradable firms' maximization problem can be written as follow:

$$\max_{k_{nT,t}(i), h_{nT,t}(i), P_{nT,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta \phi_{nT})^s \lambda_{t+s} D_{nT,t+s}(i) / P_{t+s}], \tag{E.1}$$

subject to the production function $(E.1)$ and the demand function $(E.2)$:

$$Y_{nT,t}(i) \preceq A_{nT,t} k_{nT,t}^{\alpha_{nT}}(i) \, h_{nT,t}^{\beta_{nT}}(i) \, Y_{o,t}^{I_{nT}{}^{\theta_{nT}}}(i) \tag{E.2}$$

$$Y_{nT,t+s}(i) = \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}} \right)^{-\vartheta} Y_{nT,t+s}, \tag{E.3}$$

where $D_{nT,t+s}(i)$ is the profit function:

$$D_{nT,t+s}(i) = \pi^s \widetilde{P}_{nT,t}(i) \, Y_{nT,t+s}(i) - Q_{nT,t+s} k_{nT,t+s}(i) - W_{nT,t+s} h_{nT,t+s}(i) - P_{o,t} Y_{o,t}^{I_T}(i),$$

where $\beta^s \lambda_{t+s}$ the producer's discount factor and λ_{t+s} the marginal utility of consumption in period $t+s$.

The optimal pricing condition is given by the maximization of $(E.1)$:

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} = 0 \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s}[\pi^s \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta} Y_{nT,t+s} - \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta-1}$$
$$\frac{\pi^s Y_{nT,t+s}}{P_{nT,t+s}} \pi^s \widetilde{P}_{nT,t}(i) + \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta-1} \frac{\pi^s Y_{nT,t+s}}{P_{nT,t+s}} MC_{nT,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-\vartheta} Y_{nT,t+s}[\pi^s - \vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-1} \frac{\pi^s}{P_{nT,t+s}} \pi^s \widetilde{P}_{nT,t}(i)$$
$$+\vartheta \left(\frac{\pi^s \widetilde{P}_{nT,t}(i)}{P_{nT,t+s}}\right)^{-1} \frac{\pi^s}{P_{nT,t+s}} MC_{nT,t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta} [(1-\vartheta)\pi^s + \vartheta \frac{mc_{nT,t+s}}{\widetilde{p}_{nT,t}(i)} \pi_{t+s}] = 0,$$

$$\frac{\partial \prod_t}{\partial \widetilde{P}_{nT,t}(i)} \Rightarrow E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta} [(1-\vartheta)\widetilde{p}_{nT,t}(i) \prod_{k=1}^{s} \pi^s \pi_{t+s}^{-1} + \vartheta mc_{nT,t+s}] = 0,$$

we get finally:

$$\widetilde{p}_{nT,t}(i) = \left(\frac{\vartheta}{\vartheta-1}\right) \frac{E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} mc_{nT,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta\phi_{nT})^s \lambda_{t+s} Y_{nT,t+s} p_{nT,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}}$$

where $p_{nT,t+s} = \frac{P_{nT,t+s}}{P_{t+s}}, mc_{nT,t+s} = \frac{MC_{nT,t+s}}{P_{t+s}}, \widetilde{p}_{nT,t}(i) = \frac{\widetilde{P}_{nT,t}(i)}{p_t}$ and $\pi_{t+s} = \frac{P_{t+s}}{P_t}$denote respectively the relative price of non-tradable goods, the real marginal cost in non-

tradable sector, the real optimized price for non-tradable goods and the CPI inflation rate.
The same procedure is used in the imports sector.

C.7 Current account

Combining the households' budget constraint, the single period profit functions of manufactured and non-tradable goods producing firms and foreign good importers and the first order conditions of the three sectors and applying the market clearing conditions yields the following current account equation:

$$P_t\left(c_t+i_t\right)+\frac{B_t^d}{R_t}+\frac{e_t B_t^f}{R_t^f \kappa_t} \preceq B_{t-1}^d+e_t B_{t-1}^f+\sum_{j=o,M,nT} Q_{j,t}k_{j,t}+\left(1-\varkappa\right)\sum_{j=o,M,nT} W_{j,t}h_{j,t}+\varpi P_{O,t}O_t+D_t,$$

In a symmetric equilibrium, $B_t^d=0$. This implies that:

$$\frac{e_t B_t^f}{R_t^f \kappa_t}-e_t B_{t-1}^f=\sum_{j=o,M,nT} Q_{j,t}k_{j,t}+\left(1-\varkappa\right)\sum_{j=o,M,nT} W_{j,t}h_{j,t}+P_{O,t}O_t+D_t-P_t\left(c_t+i_t\right),$$

In real term:

$$\frac{s_t b_t^f}{R_t^f \kappa_t}-s_t\frac{b_{t-1}^f}{\pi_t^f}=\sum_{j=o,M,nT} q_{j,t}k_{j,t}+\left(1-\varkappa\right)\sum_{j=o,M,nT} w_{j,t}h_{j,t}+p_{O,t}O_t+D_M+D_{nT}+D_I-\left(c_t+i_t\right),$$

Replacing the first order conditions of the three sectors in the household' budget constraint, we get:

$$\begin{aligned}\frac{s_t b_t^f}{R_t^f \kappa_t}-s_t\frac{b_{t-1}^f}{\pi_t^f} &= \left(\alpha_o+\beta_o\right)s_t p_{o,t}Y_{o,t}+\left(\alpha_M+\beta_M\right)Y_{M,t}mc_{M,t}+\left(\alpha_{nT}+\beta_{nT}\right)Y_{nT,t}mc_{nT,t}+\\ &\quad \varkappa\sum_{j=o,M,nT} w_{j,t}h_{j,t}+\theta_o s_t p_{o,t}Y_{o,t}+D_M+D_{nT}+D_I-\left(c_t+i_t\right),\end{aligned}$$

combining the single period profit functions and the market clearing conditions:

$$\begin{aligned}\frac{s_t b_t^f}{R_t^f \kappa_t} - s_t \frac{b_{t-1}^f}{\pi_t^f} &= \left(\alpha_o + \beta_o\right) s_t p_{o,t} Y_{o,t} + \left(\alpha_M + \beta_M\right) Y_{M,t} mc_{M,t} + \left(\alpha_{nT} + \beta_{nT}\right) Y_{nT,t} mc_{nT,t} + \\ &\varkappa \sum_{j=o,M,nT} w_{j,t} h_{j,t} + \theta_o s_t p_{o,t} Y_{o,t}, - \pi^s \widetilde{p}_{M,t} Y_{M,t} + q_{M,t} k_{M,t} + w_{M,t} h_{M,t} + p_{o,t} Y_{o,t}^M - \\ &\pi^s \widetilde{p}_{nT,t} Y_{nT,t} + q_{nT,t} k_{nT,t} + w_{nT,t} h_{nT,t} + p_{o,t} Y_{o,t}^{nT} - \pi^s \widetilde{p}_{I,t} Y_{I,t} + s_{t+s} Y_{I,t} - \left(c_t + i_t\right),\end{aligned}$$

this implies:

$$\begin{aligned}\frac{s_t b_t^f}{R_t^f \kappa_t} - s_t \frac{b_{t-1}^f}{\pi_t^f} &= \left(\alpha_M + \beta_M + \theta_M\right) Y_{M,t} mc_{M,t} + \left(\alpha_{nT} + \beta_{nT} + \theta_{nT}\right) Y_{nT,t} mc_{nT,t} \\ &+ s_t p_{o,t} Y_{o,t}^{ex} - Y_{M,t} mc_{M,t} - Y_{nT,t} mc_{nT,t} - s_{t+s} Y_{I,t} + p_{M,t} Y_{M,t}^{ex},\end{aligned}$$

knowing that $\alpha_M + \beta_M + \theta_M = 1$ and $\alpha_{nT} + \beta_{nT} + \theta_{nT} = 1$, we find the following current account equation:

$$\frac{b_t^f}{R_t^f \kappa_t} = \frac{b_{t-1}^f}{\pi_t^f} + p_{o,t} Y_{o,t}^{ex} + \frac{p_{M,t}}{s_t} Y_{M,t}^{ex} - Y_{I,t},$$

C.8 The Non-Linear Equilibrium System

$$h_t = {h_{o,t}}^{\alpha_{ho}} {h_{nT,t}}^{\alpha_{hnT}} {h_{M,t}}^{\alpha_{hM}},$$

$$\kappa_t = \exp\left(-\phi \frac{e_t \widetilde{B_t^f / P_t^f}}{P_t Y_t}\right),$$

$$\eta_t \left(\frac{c_t}{{c_{t-1}}^{\varpi}}\right)^{1-\gamma} - \varpi\beta E_t \left(\eta_t \frac{c_{t+1}}{{c_{t-1}}^{\varpi}}\right)^{1-\gamma} = c_t \lambda_t$$

$$\beta E_t \left[\lambda_{t+1} \left(\psi_j \left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)\left(\frac{k_{j,t+2}}{k_{j,t+1}}\right) - \frac{\psi_j}{2}\left(\frac{k_{j,t+2}}{k_{j,t+1}} - 1\right)^2 + 1 - \delta + q_{j,t+1}\right)\right]$$
$$= \lambda_t \left[\psi_j \left(\frac{k_{j,t+1}}{k_{j,t}} - 1\right) + 1\right], \quad \text{for } j = o, M, nT$$

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

$$\frac{\lambda_t s_t}{R_t^f \kappa_t} = \beta E_t \left(\frac{\lambda_{t+1} s_{t+1}}{\pi_{t+1}^f}\right),$$

$$\widetilde{w}_{j,t} = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} \Lambda_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{-\theta s} \pi_{t+k}^{\theta}}{E_t \sum_{s=0}^{\infty} \left(\beta\varphi_j\right)^s \lambda_{t+s} h_{j,t+s} w_{j,t+s}^{\theta} \prod_{k=1}^{s} \pi^{s(1-\theta)} \pi_{t+k}^{\theta-1}}.$$

$$\left(w_{j,t}\right)^{1-\theta} = \varphi_j \left(\pi \frac{w_{j,t-1}}{\pi_t}\right)^{1-\theta} + \left(1 - \varphi_j\right) \left(\widetilde{w}_{j,t}\right)^{1-\theta},$$

$$Y_{o,t} = A_{o,t} k_{o,t}^{\alpha_o} h_{o,t}^{\beta_o} O_t^{\theta_o},$$

$$q_{o,t} = \alpha_o s_t p_{o,t} \frac{Y_{o,t}}{k_{o,t}},$$

$$w_{o,t} = \beta_o s_t p_{o,t} \frac{Y_{o,t}}{h_{o,t}},$$

$$p_{O,t} = \theta_o s_t p_{o,t} \frac{Y_{o,t}}{O_t},$$

$$Y_{M,t} = A_{M,t} k_{M,t}^{\alpha_M} h_{M,t}^{\beta_M} Y_{o,t}^{M^{\theta_M}},$$

$$q_{M,t} = \alpha_M \frac{Y_{M,t}}{k_{M,t}} mc_{M,t}$$

$$w_{M,t} = \beta_M \frac{Y_{M,t}}{h_{M,t}} mc_{M,t}$$

$$s_t p_{o,t} = \theta_M \frac{Y_{M,t}}{Y_{o,t}^M} mc_{M,t}$$

$$\widetilde{p}_{M,t} = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{s=0}^{\infty} (\beta \phi_M)^s \lambda_{t+s} Y_{M,t+s} p_{M,t+s}^{\vartheta} mc_{M,t+s} \prod_{k=1}^{s} \pi^{-s\vartheta} \pi_{t+k}^{\vartheta}}{E_0 \sum_{s=0}^{\infty} (\beta \phi_M)^s \lambda_{t+s} Y_{M,t+s} p_{M,t+s}^{\vartheta} \prod_{k=1}^{s} \pi^{s(1-\vartheta)} \pi_{t+k}^{\vartheta-1}},$$

$$(p_{M,t})^{1-\vartheta} = \phi_M \left(\pi \frac{p_{M,t-1}}{\pi_t} \right)^{1-\vartheta} + (1 - \phi_M) (\widetilde{p}_{M,t})^{1-\vartheta}$$

$$mc_{M,t} = \frac{q_{M,t}^{\alpha_M} w_{M,t}^{\beta_M} p_{o,t}^{\theta_M}}{\alpha_M^{\alpha_M} \beta_M^{\beta_M} \theta_M^{\theta_M}}.$$

$$Y_{nT,t} = A_{nT,t} k_{nT,t}^{\alpha_{nT}} h_{nT,t}^{\beta_{nT}} Y_{o,t}^{nT^{\theta_{nT}}},$$

$$q_{nT,t} = \alpha_{nT} \frac{Y_{nT,t}}{k_{nT,t}} mc_{nT,t}$$

$$w_{nT,t} = \beta_{nT} \frac{Y_{nT,t}}{h_{nT,t}} mc_{nT,t}$$

$$s_t p_{o,t} = \theta_{nT} \frac{Y_{nT,t}}{Y_{o,t}^{nT}} mc_{nT,t}$$

$$mc_{nT,t} = \frac{q_{nT,t}^{\alpha_{nT}} w_{nT,t}^{\beta_{nT}} p_{o,t}^{\theta_{nT}}}{\alpha_{nT}^{\alpha_{nT}} \beta_{nT}^{\beta_{nT}} \theta_{nT}^{\theta_{nT}}}.$$

$$(p_{nT,t})^{1-\vartheta} = \phi_{nT}\left(\pi\frac{p_{nT,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_{nT})\left(\widetilde{p}_{nT,t}\right)^{1-\vartheta}$$

$$\widetilde{p}_{nT,t} = \frac{\vartheta}{\vartheta-1}\frac{E_0\sum_{s=0}^{\infty}(\beta\phi_{nT})^s\,\lambda_{t+s}Y_{nT,t+s}p_{nT,t+s}^{\vartheta}mc_{nT,t+s}\prod_{k=1}^{s}\pi^{-s\vartheta}\pi_{t+k}^{\vartheta}}{E_0\sum_{s=0}^{\infty}(\beta\phi_{nT})^s\,\lambda_{t+s}Y_{nT,t+s}p_{nT,t+s}^{\vartheta}\prod_{k=1}^{s}\pi^{s(1-\vartheta)}\pi_{t+k}^{\vartheta-1}},$$

$$(p_{I,t})^{1-\vartheta} = \phi_I\left(\pi\frac{p_{I,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_I)\left(\widetilde{p}_{I,t}\right)^{1-\vartheta},$$

$$\widetilde{p}_{I,t} = \frac{\vartheta}{\vartheta-1}\frac{E_0\sum_{s=0}^{\infty}(\beta\phi_I)^s\,\lambda_{t+s}Y_{I,t+s}p_{I,t+s}^{\vartheta}mc_{I,t+s}\prod_{k=1}^{s}\pi^{-s\vartheta}\pi_{t+k}^{\vartheta}}{E_0\sum_{s=0}^{\infty}(\beta\phi_I)^s\,\lambda_{t+s}Y_{I,t+s}p_{I,t+s}^{\vartheta}\prod_{k=1}^{s}\pi^{s(1-\vartheta)}\pi_{t+k}^{\vartheta-1}},$$

$$\begin{aligned}
Y_{I,t} &= \chi_I\left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t,\\
Y_{M,t}^{d} &= \chi_M\left(\frac{P_{M,t}}{P_t}\right)^{-\tau} z_t,\\
Y_{nT,t} &= \chi_{nT}\left(\frac{P_{nT,t}}{P_t}\right)^{-\tau} z_t
\end{aligned}$$

$$\Lambda_{o,t} = \alpha_{ho}\left(\frac{h_t^{1+\sigma}}{h_{o,t}\lambda_t}\right),$$

$$\Lambda_{T,t} = \alpha_{hT}\left(\frac{h_t^{1+\sigma}}{h_{T,t}\lambda_t}\right),$$

$$\Lambda_{nT,t} = \alpha_{hnT}\left(\frac{h_t^{1+\sigma}}{h_{nT,t}\lambda_t}\right),$$

$$z_t = c_t + i_{o,t} + i_{T,t} + i_{nT,t}$$

$$i_t = i_{o,t} + i_{T,t} + i_{nT,t}$$

$$\pi_{nT,t} = \pi_t \frac{p_{nT,t}}{p_{nT,t-1}}$$

$$\pi_{I,t} = \pi_t \frac{p_{I,t}}{p_{I,t-1}}$$

$$\frac{e_t}{e_{t-1}} = \frac{s_t}{s_{t-1}} \frac{\pi_t}{\pi_t^f}$$

$$mc_{I,t} = s_t$$

$$i_{o,t} = k_{o,t+1} - (1-\delta)k_{o,t} + \frac{\psi_o}{2}\left(\frac{k_{o,t+1}}{k_{o,t}} - 1\right)^2 k_{o,t},$$

$$i_{M,t} = k_{M,t+1} - (1-\delta)k_{M,t} + \frac{\psi_M}{2}\left(\frac{k_{M,t+1}}{k_{M,t}} - 1\right)^2 k_{M,t},$$

$$i_{nT,t} = k_{nT,t+1} - (1-\delta)k_{nT,t} + \frac{\psi_{nT}}{2}\left(\frac{k_{nT,t+1}}{k_{nT,t}} - 1\right)^2 k_{nT,t},$$

$$\log\left(\frac{R_t}{R}\right) = \rho_R \log\left(\frac{R_{t-1}}{R}\right) + (1-\rho_R)\left[\upsilon_\pi \log\left(\frac{\pi_t}{\pi}\right) + \upsilon_e \log\left(\frac{\Delta e_t}{\Delta e}\right) + \upsilon_y \log\left(\frac{Y_t}{Y}\right)\right] + \varepsilon_{R,t}.$$

$$Y_{o,t} = Y_{o,t}^d + Y_{o,t}^{ex},$$

$$\begin{aligned} Y_{o,t}^{ex} &= \nu_o \left(\frac{e_t P_{o,t}}{P_t^f}\right)^{-\omega_o} Y_{o,t}^f \\ Y_{M,t}^{ex} &= \nu_M \left(\frac{e_t P_{M,t}}{P_t^f}\right)^{-\omega_M} Y_{M,t}^f \end{aligned}$$

$$Y_t = p_{M,t}Y^{va}_{M,t} + p_{nT,t}Y^{va}_{nT,t} + s_t p_{o,t}Y_{o,t},$$

$$Y^{va}_{M,t} = Y_{M,t} - s_t p_{o,t}\frac{Y^{M}_{o,t}}{p_{M,t}},$$

$$Y^{va}_{nT,t} = Y_{nT,t} - s_t p_{o,t}\frac{Y^{nT}_{o,t}}{p_{nT,t}}.$$

$$\frac{b^f_t}{R^f_t \kappa_t} = \frac{b^f_{t-1}}{\pi^f_t} + p_{o,t}Y^{ex}_{o,t} + \frac{p_{M,t}}{s_t}Y^{ex}_{M,t} - Y_{I,t},$$

$$\log(\eta_t) = (1-\rho_\eta)\log(\eta) + \rho_\eta \log(\eta_{t-1}) + \varepsilon_{\eta_t},$$

$$\log(\varsigma_t) = (1-\rho_\varsigma)\log(\varsigma) + \rho_\varsigma \log(\varsigma_{t-1}) + \varepsilon_{\varsigma_t},$$

$$\log(R^f_t) = (1-\rho_{R^f})\log(R^f) + \rho_{R^f}\log(R^f_{t-1}) + \varepsilon_{R^f_t},$$

$$\log(\pi^f_t) = (1-\rho_{\pi^f})\log(\pi^f) + \rho_{\pi^f}\log(\pi^f_{t-1}) + \varepsilon_{\pi^f_t},$$

$$\log(P_{o,t}) = (1-\rho_{P_o})\log(P_o) + \rho_{P_o}\log(P_{o,t-1}) + \varepsilon_{P_{o,t}},$$

$$\log(O_t) = (1-\rho_O)\log(O) + \rho_O \log(O_{t-1}) + \varepsilon_O,$$

$$\log(A_{o,t}) = (1-\rho_{A_o})\log(A_o) + \rho_{A_o}\log(A_{o,t-1}) + \varepsilon_{A_{o,t}},$$

$$\log(A_{M,t}) = (1-\rho_{A_M})\log(A_M) + \rho_{A_M}\log(A_{M,t-1}) + \varepsilon_{A_{T,t}},$$

$$\log(A_{nT,t}) = (1-\rho_{A_{nT}})\log(A_{nT}) + \rho_{A_{nT}}\log(A_{nT,t-1}) + \varepsilon_{A_{nT,t}},$$

$$\log(Y_{o,t}^{f}) = (1 - \rho_{Y_o^f}) \log(Y_o^f) + \rho_{Y_o^f} \log(Y_{o,t-1}^{f}) + \varepsilon_{Y_{o,t}^f},$$

$$\log(Y_{M,t}^{f}) = (1 - \rho_{Y_M^f}) \log(Y_M^f) + \rho_{Y_M^f} \log(Y_{M,t-1}^{f}) + \varepsilon_{Y_{M,t}^f},$$

C.9 The Log-Linear Equilibrium System

$$(\varpi\beta-\gamma)\,\widehat{c}_t-\frac{1}{(\overline{c}^{1-\varpi})^{1-\gamma}}E_t\widehat{c}_{t+1}+\left(\frac{1}{(\overline{c}^{1-\varpi})^{1-\gamma}}-(1-\gamma)\right)\varpi\widehat{c}_{t-1}=(1-\varpi\beta)\,\widehat{\lambda}_t$$

$$E_t\left(\beta\widehat{k}_{o,t+2}-\beta E_t\widehat{k}_{o,t+1}+\widehat{\lambda}_{t+1}+\overline{q}_o\widehat{q}_{o,t+1}\right)=\widehat{\lambda}_t+\psi_o\widehat{k}_{o,t+1}-\psi_o\widehat{k}_{o,t}$$

$$E_t\left(\beta\widehat{k}_{M,t+2}-\beta\widehat{k}_{M,t+1}+\widehat{\lambda}_{t+1}+\overline{q}_M\widehat{q}_{M,t+1}\right)=\widehat{\lambda}_t+\psi_M\widehat{k}_{M,t+1}-\psi_M\widehat{k}_{M,t}$$

$$E_t\left(\beta\widehat{k}_{nT,t+2}-\beta\widehat{k}_{nT,t+1}+\widehat{\lambda}_{t+1}+\overline{q}_{nT}\widehat{q}_{nT,t+1}\right)=\widehat{\lambda}_t+\psi_{nT}\widehat{k}_{nT,t+1}-\psi_{nT}\widehat{k}_{nT,t}$$

$$\widehat{h}_t=\alpha_{h_o}\widehat{h}_{o,t}+\alpha_{hM}\widehat{h}_{M,t}+\alpha_{hnT}\widehat{h}_{nT,t},$$
$$\widehat{\lambda}_t-\widehat{R}_t=E_t\left(\widehat{\lambda}_{t+1}-\widehat{\pi}_{t+1}\right),$$

$$\widehat{\lambda}_t+\widehat{s}_t-\widehat{R}_t^f-\widehat{k}_t=E_t\left(\widehat{\lambda}_{t+1}+\widehat{s}_{t+1}-\widehat{\pi}_{t+1}^f\right),$$

$$\widehat{\pi}_t^{w_o}=\beta\pi_{t+1}^{w_o}+\frac{(1-\varphi_o)\,(1-\beta\varphi_o)}{\varphi_o}\left[\widehat{\Lambda}_{o,t}-\widehat{w}_{o,t}\right],$$

$$\widehat{\pi}_t^{w_M}=\beta\pi_{t+1}^{w_M}+\frac{(1-\varphi_M)\,(1-\beta\varphi_M)}{\varphi_M}\left[\widehat{\Lambda}_{M,t}-\widehat{w}_{M,t}\right],$$

$$\widehat{\pi}_t^{w_{nT}}=\beta\pi_{t+1}^{w_{nT}}+\frac{(1-\varphi_{nT})\,(1-\beta\varphi_{nT})}{\varphi_{nT}}\left[\widehat{\Lambda}_{nT,t}-\widehat{w}_{nT,t}\right],$$

$$\widehat{\kappa}_t=\left(\frac{\phi sb^f}{y}\right)\left(\widehat{s}_t+\widehat{b}_t^f-\widehat{y}_t\right),$$

$$\widehat{Y}_{o,t}=\widehat{A}_{o,t}+\alpha_o\widehat{k}_{o,t}+\beta_o\widehat{h}_{o,t}+\theta_o\widehat{O}_t,$$

$$\widehat{q}_{o,t}=\widehat{s}_t+\widehat{p}_{o,t}+\widehat{Y}_{o,t}-\widehat{k}_{o,t},$$

$$\widehat{w}_{o,t} = \widehat{s}_t + \widehat{p}_{o,t} + \widehat{Y}_{o,t} - \widehat{h}_{o,t},$$

$$\widehat{p}_{O,t} = \widehat{s}_t + \widehat{p}_{o,t} + \widehat{Y}_{o,t} - \widehat{O}_{o,t},$$

$$\widehat{Y}_{M,t} = \widehat{A}_{M,t} + \alpha_M \widehat{k}_{M,t} + \beta_M \widehat{h}_{M,t} + \theta_M \widehat{Y}^M_{o,t},$$

$$\widehat{q}_{M,t} = \widehat{Y}_{M,t} - \widehat{k}_{M,t} + \widehat{mc}_{M,t},$$

$$\widehat{w}_{M,t} = \widehat{Y}_{M,t} - \widehat{h}_{M,t} + \widehat{mc}_{M,t},$$

$$\widehat{s}_t + \widehat{p}_{o,t} = \widehat{Y}_{M,t} - \widehat{Y}^M_{o,t} + \widehat{mc}_{M,t},$$

$$\widehat{Y}_{nT,t} = \widehat{A}_{nT,t} + \alpha_{nT} \widehat{k}_{nT,t} + \beta_{nT} \widehat{h}_{nT,t} + \theta_{nT} \widehat{Y}^{nT}_{o,t},$$

$$\widehat{q}_{nT,t} = \widehat{Y}_{nT,t} - \widehat{k}_{M,t} + \widehat{mc}_{nT,t},$$

$$\widehat{w}_{nT,t} = \widehat{Y}_{nT,t} - \widehat{h}_{nT,t} + \widehat{mc}_{nT,t},$$

$$\widehat{s}_t + \widehat{p}_{o,t} = \widehat{Y}_{nT,t} - \widehat{Y}^{nT}_{o,t} + \widehat{mc}_{nT,t},$$

$$\widehat{\pi}_{M,t} = \beta E_t \pi_{M,t+1} + \frac{(1-\phi_M)(1-\beta\phi_M)}{\phi_M} \widehat{mc}_{M,t},$$

$$\widehat{\pi}_{nT,t} = \beta E_t \pi_{nT,t+1} + \frac{(1-\phi_{nT})(1-\beta\phi_{nT})}{\phi_{nT}} \widehat{mc}_{nT,t},$$

$$\widehat{\pi}_{I,t} = \beta E_t \pi_{I,t+1} + \frac{(1-\phi_I)(1-\beta\phi_I)}{\phi_I} \widehat{mc}_{I,t},$$

$$\widehat{mc}_{nT,t} = \alpha_{nT}\widehat{q}_{nT,t} + \beta_{nT}\widehat{w}_{nT,t} + \theta_{nT}\widehat{p}_{o,t},$$

$$\widehat{mc}_{M,t} = \alpha_{M}\widehat{q}_{M,t} + \beta_{M}\widehat{w}_{M,t} + \theta_{M}\widehat{p}_{o,t},$$

$$\widehat{y}_{I,t} = -\tau\widehat{p}_{I,t} + \widehat{z}_t,$$

$$\widehat{y}_{M,t} = -\tau\widehat{p}_{M,t} + \widehat{z}_t,$$

$$\widehat{y}_{nT,t} = -\tau\widehat{p}_{nT,t} + \widehat{z}_t,$$

$$\widehat{\Lambda}_{o,t} = (1+\sigma)\,\widehat{h}_t - \widehat{h}_{o,t} - \widehat{\lambda}_t,$$

$$\widehat{\Lambda}_{M,t} = (1+\sigma)\,\widehat{h}_t - \widehat{h}_{M,t} - \widehat{\lambda}_t,$$

$$\widehat{\Lambda}_{nT,t} = (1+\sigma)\,\widehat{h}_t - \widehat{h}_{nT,t} - \widehat{\lambda}_t,$$

$$\widehat{mc}_{I,t} = \widehat{s}_t,$$

$$\widehat{z}_t = \frac{\overline{c}}{\overline{z}}\widehat{c}_t + \frac{\overline{i}_o}{\overline{z}}\widehat{i}_{o,t} + \frac{\overline{i}_T}{z}\widehat{i}_{T,t} + \frac{\overline{i}_{nT}}{z}\widehat{i}_{nT,t},$$

$$i_t = \frac{i_o}{\overline{i}}\widehat{i}_{o,t} + \frac{i_M}{\overline{i}}\widehat{i}_{M,t} + \frac{i_{nT}}{\overline{i}}\widehat{i}_{nT,t},$$

$$\widehat{R}_t = \rho_R\widehat{R}_{t-1} + (1-\rho_R)\left[\upsilon_\pi\widehat{\pi}_t + \upsilon_e\Delta\widehat{e}_t + \upsilon_y\widehat{Y}_t\right] + \varepsilon_{R,t}$$

$$\overline{Y}_o\widehat{Y}_{o,t} = \overline{Y}_o^d\widehat{Y}_{o,t}^d + \overline{Y}_o^{ex}\widehat{Y}_{o,t}^{ex},$$

$$\overline{Y}_o^d \widehat{Y}_{o,t}^d = \overline{Y}_o^M \widehat{Y}_{o,t}^M + \overline{Y}_o^{nT} \widehat{Y}_{o,t}^{nT},$$

$$\overline{Y}_M \widehat{Y}_{M,t} = \overline{Y}_M^d \widehat{Y}_{M,t}^d + \overline{Y}_M^{ex} \widehat{Y}_{M,t}^{ex},$$

$$\widehat{\pi}_{M,t} = \widehat{\pi}_t + \widehat{p}_{M,t} - \widehat{p}_{M,t-1},$$

$$\widehat{\pi}_{nT,t} = \widehat{\pi}_t + \widehat{p}_{nT,t} - \widehat{p}_{nT,t-1},$$

$$\widehat{\pi}_{I,t} = \widehat{\pi}_t + \widehat{p}_{I,t} - \widehat{p}_{I,t-1},$$

$$\widehat{i}_{o,t} = \frac{1}{\delta}\widehat{k}_{o,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{o,t},$$

$$\widehat{i}_{M,t} = \frac{1}{\delta}\widehat{k}_{M,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{M,t},$$

$$\widehat{i}_{nT,t} = \frac{1}{\delta}\widehat{k}_{nT,t+1} - \frac{(1-\delta)}{\delta}\widehat{k}_{nT,t},$$

$$\overline{Y}_T^{va} \widehat{Y}_{T,t}^{va} = \overline{Y}_T \widehat{Y}_{T,t} - \overline{sp}_o^f \frac{\overline{Y}_o^{I_M}}{\overline{p}_T} \left(\widehat{s}_t + \widehat{p}_{o,t}^f + \widehat{Y}_{o,t}^{I_M} - \widehat{p}_{T,t} \right),$$

$$\overline{Y}_{nT}^{va} \widehat{Y}_{nT,t}^{va} = \overline{Y}_{nT} \widehat{Y}_{nT,t} - \overline{sp}_o^f \frac{\overline{Y}_o^{I_{nT}}}{\overline{p}_{nT}} \left(\widehat{s}_t + \widehat{p}_{o,t}^f + \widehat{Y}_{o,t}^{I_{nT}} - \widehat{p}_{nT,t} \right),$$

$$\widehat{Y}_t = \frac{\overline{p}_M \overline{Y}_M^{va}}{\overline{Y}} \left(\widehat{p}_{M,t} + \widehat{Y}_{M,t}^{va} \right) + \frac{\overline{p}_{nT} \overline{Y}_{nT}^{va}}{\overline{Y}} \left(\widehat{p}_{nT,t} + \widehat{Y}_{nT,t}^{va} \right) + \frac{\overline{sp}_o^f \overline{Y}_o}{\overline{Y}} \left(\widehat{s}_t + \widehat{p}_{o,t}^f + \widehat{Y}_{o,t} \right),$$

$$i_t = \frac{i_o}{\bar{i}} \widehat{i}_{o,t} + \frac{i_M}{\bar{i}} \widehat{i}_{M,t} + \frac{i_{nT}}{\bar{i}} \widehat{i}_{nT,t},$$

$$\widehat{Y}_{M,t}^{ex} = -\omega_M \left(\widehat{s}_t + \widehat{p}_{M,t}\right) + \widehat{Y}_{M,t}^{f},$$

$$\widehat{Y}_{o,t}^{ex} = -\omega_o \left(\widehat{s}_t + \widehat{p}_{o,t}\right) + \widehat{Y}_{o,t}^{f},$$

$$\frac{b^f}{\kappa R^f}\left(\widehat{b}_t^f - \widehat{\kappa}_t - \widehat{R}_t^f\right) = b^f\left(\widehat{b}_{t-1}^f - \widehat{\pi}_t^f\right) + \overline{p}_M \overline{Y}_M^{ex}\left(\widehat{p}_{M,t} + \widehat{Y}_{M,t}^{ex}\right) + \overline{p}_o \overline{Y}_o^{ex}\left(\widehat{p}_{o,t} + \widehat{Y}_{o,t}^{ex}\right) - \overline{Y}_I \widehat{Y}_{I,t},$$

$$\widehat{\pi}_{nT,t} = \widehat{\pi}_t + \widehat{p}_{nT,t} - \widehat{p}_{nT,t-1},$$

$$\widehat{\pi}_{I,t} = \widehat{\pi}_t + \widehat{p}_{I,t} - \widehat{p}_{I,t-1},$$

$$\widehat{e}_t - \widehat{e}_{t-1} = \widehat{s}_t - \widehat{s}_{t-1} + \widehat{\pi}_t - \widehat{\pi}_t^f,$$

$$\widehat{mc}_{I,t} = \widehat{s}_t,$$

$$\widehat{\eta}_t = \rho_\eta \widehat{\eta}_{t-1} + \varepsilon_{\eta_t},$$

$$\widehat{\varsigma}_t = \rho_\varsigma \widehat{\varsigma}_{t-1} + \varepsilon_{\varsigma_t},$$

$$\widehat{\pi}_t^f = \rho_{\pi^f} \widehat{\pi}_{t-1}^f + \varepsilon_{\pi_t^f},$$

$$\widehat{P}_{o,t} = \rho_{P_o} \widehat{P}_{o,t-1} + \varepsilon_{P_{o,t}},$$

$$\widehat{O}_t = \rho_O \widehat{O}_{t-1} + \varepsilon_O,$$

$$\widehat{A}_{o,t} = \rho_{A_o} \widehat{A}_{o,t-1} + \varepsilon_{A_{o,t}},$$

$$\widehat{A}_{M,t} = \rho_{A_M} \widehat{A}_{M,t-1} + \varepsilon_{A_{M,t}},$$

$$\widehat{A}_{nT,t} = \rho_{A_{nT}} \widehat{A}_{nT,t-1} + \varepsilon_{A_{nT,t}},$$

$$\widehat{Y}^f_{o,t} = \rho_{Y^f_o} \widehat{Y}^f_{o,t-1} + \varepsilon_{Y^f_{o,t}},$$

$$\widehat{Y}^f_{M,t} = \rho_{Y^f_M} \widehat{Y}^f_{M,t-1} + \varepsilon_{Y^f_{M,t}},$$