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Conception et Estimation d'un Modèle DSGE pour la Prévision Macroéconomique: Un petit modèle d'économie ouverte pour le Cameroun

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A mes parents

A mes enfants

A mon épouse Awa

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Résumé

Cette thèse propose une analyse de la dynamique macroéconomique de l'économie camerounaise. On commence par une analyse quantitative générale du cycle des affaires au Cameroun, fondée sur des données macroéconomiques annuelles que nous avons nous-mêmes assemblées. Cette première exploration laisse apparaître un certain nombre de caractéristiques qui se prêtent bien à une modélisation de type néo-keynesien. Nous construisons alors un modèle dynamique stochastique d'équilibre général (DSGE) de l'économie camerounaise. Ce modèle comporte les blocs de construction de modèles DSGE néo-keynésiens standards (par exemple, la rigidité des prix et des salaires des rigidités, et des coûts d'ajustement), mais il inclut également un certain nombre de caractéristiques spécifiques (telles que l'exportation des matières premières et les revenus du pétrole entre autre) dont on montre qu'elles jouent un rôle important dans la dynamique de l'économie camerounaise. Le modèle est estimé et évalué selon une approche bayésienne. La performance du modèle DSGE en termes de prévision est comparée à celle d'un modèle de marche aléatoire, à celle d'un modèle vectoriel auto-régressif (VAR) et, enfin, à celle d'un modèle vectoriel auto-régressif de type Bayesien (BVAR). Nous trouvons que, le modèle DSGE est plus précis en matière de prévision au moins dans un horizon de court-terme. Pour ce qui est des fluctuations macroéconomiques, les chocs des prix des produits de base génèrent une expansion de la production, une augmentation de l'emploi et une baisse de l'inflation tandis que des chocs liés aux prix du pétrole ont un impact direct sur le coût marginal de production qui augmente et provoque une augmentation de l'inflation en même temps que production et emploi baissent. Notons que, les chocs extérieurs et les chocs d'offre domestiques représentent une grande part des fluctuations de la production et de l'investissement. Aussi, l'évolution de la production sur l'ensemble de l'échantillon est dominée par le choc de prix des matières premières et le choc des prix du pétrole.

Mots clés: Modèles DSGE, néo-keynésien, Méthode bayésienne, Fluctuations Macroéconomiques, Prévisions, Cameroun

Abstract

This thesis aims at analyzing the macroeconomic dynamics of the Cameroonian economy. It begins with a quantitative analysis of the business cycle in Cameroon, based on annual macroeconomic data, especially gathered for this purpose. This preliminary inquiry highlights a number of features that can be accounted for in a new-keynesian modelling framework. A dynamic stochastic general equilibrium (DSGE) model of the new-keynesian family is thus constructed as a mean of describing the salient feautures of the Cameroonian economy. It has the traditional blocks of new-keynesian DSGE models (Sticky prices and wages, adjustment costs, etc). But it also accounts for a number of characteristics of the Cameroonian economy that are shown to be influential in the dynamics of the cameroonian economy (e.g. oil revenues or primary goods exports). The model is then estimated and evaluated, based on a Bayesian approach. Its forecasting performance is also assessed through comparison to the performances of a random walk model, a vector autoregressive (VAR) model and a Bayesian VAR (BVAR) model. It turns out that, at least for short horizons, the DSGE model shows the highest perfromance. As to macroeconomic fluctuations, the estimated model suggests that commodity price shocks generate an output expansion, an increase in employment and a fall in inflation. In addition, oil price shocks have a direct impact on marginal costs which increase and provoke a rising in inflation while output and employment tend to fall. Foreign shoks and domestic supply shocks account for a large share of output and investment fluctuations. The evolution of output over the whole sample is dominated by commodity price shocks and oil price shocks as one would expect.

Keywords: DSGE Models, New-Keynesian, Bayesian Method, Macroeconomic Fluctuations, Forecasting, Cameroon

Principales Abbréviations

AR: Auto-Regressive

ARMA: Auto-Regressive Moving Average

B: Beta

BEAC: Bank of Central African States

BP: Band-Pass

BOF: Bank Of Finland

BVAR: Bayesian Vector Auto-Regressive

CEE: Central and Eastern European

CAEMC: Economic Community of Central African States)

CES: Constant Elasticity of Substitution

CFA: African Financial Community

CPI: Consumer Price Index

DGP: Data Generating Process

DSGE: Dynamic Stochastic General Equilibrium

DM: Diebold-Mariano

ECOWAS: Economic Community of West Africa States

FEVD: Forecast Error Variance Decomposition

G: Gamma

GDP: Gross Domestic Product

GMM: Generalized Method of Moment

MFE: Mean Forecast Error

HD: Historical Decomposition

HP: Hodrick-Prescott

IID: Independent and Identically Distributed

IG: Inverse Gamma

II: Indirect Inference

IMF: International Monetary Fund

IFS: International Financial Statistic

INS: Institut National de Statistique

IRF: Impuls Response Functions

IW: Inverse Wishart

LP: Likelihood Principle

MA: Moving Average

MH: Metroplis Hasting

MCMC: Markov Chain Monte Carlo

ML: Maximum Likelihood

MPC: Monetary Policy Commitee

NKM: New Keynesian Macroeconomics

NER: Nominal Exchange Rate

NR: Non Ricardian

NKDSGE: New-Keynesian Dynamic Stochastic General Equilibrium

NIW: Normal Inverse Wishart

PI: Permanent Income

RBC: Real Business Cycle

RER: real Exchange Rate

RW: Random Walk

RMSE: Root Mean Square Error

SSA: Sub-Saharan Africa

TOT: Terms Of Trade

TB: Trade Balance

U.S.: Unitate States

U.S.A: Unitate States of America

VAR: Vector Auto-Regressive

VARMA: Vector AutoRegressive Moving Average

SOMMAIRE

"After climbing a great hill, one only finds that there are many more hills to climb." Nelson Mandela

Introduction

"Dynamic equilibrium theory made a quantum leap between the early 1970s and the late 1990s. In the comparatively brief space of 30 years, macroeconomists went from writing prototype models of rational expectations (think of Lucas, 1972) to handling complex constructions like the economy in Christiano, Eichenbaum, and Evans (2005). It was similar to jumping from the Wright brothers to an Airbus 380 in one generation". Jesus Fernandez-Villaverde in "The Econometrics of DSGE Models"(2009, pag.2)

De 1940 à 1960, les modèles macro-économétriques de grande taille (3000 équation et plus) se sont imposés comme un outil naturel pour étudier les sources des fluctuations macroéconomiques. Identifier les sources des fluctuations économiques est en effet plus qu'une exigence pour la conduite de politiques économiques. Historiquement, ces modèles[1] trouvent leurs racines dans l'approche de modélisation de Tinbergen (1939), puis, Klein (1950) et les développements ultérieurs de la "Cowle's Commission".

Cependant, c'est au début des années 1970, avec l'instabilité de l'économie mondiale, à la suite de la flambée des prix du pétrole, qu'une attention particulière sera portée sur l'étude des cycles économiques. L'utilisation des modèles macro-économétriques de grande taille pour l'analyse de la politique économique (voir par exemple; Ando et

[1] Le modèle de Phillips–Bergstrom (PB), le modèle de Walras–Johansen (WJ), le modèle de Walras–Leontief (WL), le modèle de Muth–Sargent (MS), et enfin les modèles d'équilibre général calculable (EGC).

Modigliani, 1969) va être très critiquée. Sur le plan empirique, ces modèles vont être confrontés au défi de la concomitance d'un taux de chômage élevé et d'un fort taux d'inflation, ce qui était incompatible avec la courbe de Phillips, traditionnellement incluse dans ces modèles. Il était donc devenu nécessaire d'admettre une relation instable entre inflation et chômage, instabilité dont les modèles macroéconomiques traditionnels ne tenaient pas compte. Une autre critique, de nature méthodologique cette fois-ci, adressée à ces modèles est venue de Sims (1980). Celui-ci va remettre en question la pratique habituelle de conférer à certaines variables dans le modèle, le statut de variables exogènes. Cette pratique reposait ainsi sur une hypothèse ad hoc, qui consistait à exclure des mécanismes de rétroaction significative entre les variables incluses dans les modèles.

Mais la principale critique est d'ordre théorique et a été émise par Lucas (1976). Lucas soulignait que le casse-tête empirique de la stagflation n'était que le reflet d'un problème théorique plus général. Il notait que les agents économiques se comportaient selon une approche d'optimisation dynamique et faisaient des anticipations rationnelles. Cela signifiait qu'ils maximisaient leur bien-être sur toute leur durée de vie, en tenant compte non seulement de leurs conditions économiques passées et présentes, mais aussi de leurs prospectives quant à l'avenir, en utilisant toutes les informations pertinentes dont ils disposaient, et que, bien qu'ils ne puissent pas prédire totalement l'avenir, ils pouvaient construire des attentes qui n'étaient pas systématiquement biaisées. Par conséquent, si les agents devaient anticiper tout changement dans leur environnement économique, à l'exemple d'un changement dans la politique économique, ils devraient immédiatement intégrer ces attentes dans leur prise de décision et ce, en tenant compte de ces changements dans leurs comportements actuels et futurs. Étant exclusivement orientés vers le passé, les modèles traditionnels ne pouvaient pas rendre compte du rôle des attentes sur le comportement des agents économiques et par conséquent, ils souffraient d'un important manque dans la description du fonctionnement de l'économie. Ils supposaient simplement que les relations entre les variables économiques qui étaient en vigueur dans un certain contexte seraient en mesure d'expliquer l'évolution de l'économie, même si le contexte sous-jacent venait à changer et ce, sans tenir compte du fait que la prévision de ce changement par les agents peut modifier la façon dont ils réagissent et, de cette façon, invalider les relations estimées antérieurement. Par conséquent, pour prédire correctement les effets des nouvelles politiques, les modèles doivent tenir compte du rôle des attentes des agents économiques dans leurs prises de décision.

Depuis lors, beaucoup de ces modèles vont être abandonnés, et des études sur les cycles économiques internationaux vont être remises sur la table. La réponse d'un bon nombre des professionnels de l'économie sera de se tourner vers l'utilisation des modèles VAR (vecteur autorégressif) pour analyser les cycles économiques. Ces modèles sont une spécification dynamique puisque chaque variable du modèle est exprimée comme une fonction des valeurs retardées de l'ensemble des variables présentes dans le modèle. En outre, ces modèles VAR ont l'avantage sur les modèles macroéconomiques traditionnels de ne pas imposer au modélisateur l'adoption d'une structure vaste et complexe. Historiquement, Sims (1980) est le premier à avoir introduit les modèles VAR comme alternative aux anciens modèles macro-économétriques. Depuis lors, la méthodologie VAR va gagner en popularité dans la recherche en macroéconomie appliquée. Une fois de plus, notons encore que cette méthodologie est née d'une insatisfaction des professionnels de l'économie avec l'utilisation des modèles macroéconométriques traditionnels qui considéraient à la suite des travaux de la "Cowle's Commission" que le problème d'identification dans ces modèles (modèles macroéconométriques traditionnels) se résolvait en excluant certaines variables - le plus souvent des variables endogènes retardées - sans justifications théoriques ou statistiques. L'idée derrière cette façon de faire était que les variables pouvaient être classées comme des variables endogènes ou des variables exogènes. Les variables exogènes étaient déterminées à l'extérieur du système et pouvaient donc être traitées indépendamment des variables endogènes. Imposer des restrictions d'exclusion sur les retards de certaines variables était le moyen pratique de traiter ce problème d'identification. Sims (1980) s'est interrogé sur cette façon de faire, c'est à dire, développer de vastes modèles économétriques sophistiqués et y résoudre le problème d'identification par ce qu'il a appelé "d'incroyables restrictions (non justifiée) d'exclusion" qui ne sont ni anodines ni essentielles pour la construction d'un modèle qui pourrait être utilisé pour l'analyse et l'élaboration des politiques économiques. Enfin, l'absence de consensus sur le modèle structurel approprié a conduit de nombreux économistes à se pencher plus sur l'utilisation des modèles VAR pour examiner les effets de politiques économiques alternatives. Cependant, outre le fait que les modèles VAR sont sans fondement théorique et peuvent de ce fait être sujets à la critique de Lucas, tous les effets de variables omises dans la modélisation VAR sont mécaniquement incluses dans la composante résiduelle. Cela peut conduire à d'importantes distorsions dans les fonctions de réponses d'impulsion[2], ce qui les décrédibilise pour les interprétations structurales (voir par exemple Hendry, 1995), bien que le système puisse toujours être utile pour les prévisions (voir par exemple Hendry et Tournai 1997, et les références qui s'y trouvent). Enfin, toutes les erreurs de mesure ou erreurs de spécification du modèle VAR pourront également renvoyer les informations inexpliquées dans le terme d'erreur du modèle, ce qui rend l'interprétation des fonctions de réponse d'impulsion encore plus difficile pour toute intervention de politique économique.

Dans le même temps, il y a eu chez les économistes la nécessité d'une compréhension approfondie des fluctuations des cycles économiques et les corrélations dynamiques entre les variables macroéconomiques dans les économies avancées. Ce qui a conduit à l'élaboration des modèles d'équilibre général dynamique et stochastique (DSGE) (Kydland et Prescott, 1982). Contrairement aux modèles VAR, ces modèles DSGE sont des modèles micro-fondés, ce qui les met à l'abri de la critique de Lucas. Ceci est probablement la principale raison pour laquelle ils sont devenus aujourd'hui un outil puissant qui fournit un cadre cohérent pour l'élaboration des politiques économiques et les prévisions en macroéconomie. Dès lors, les modèles DSGE vont désormais être considérés comme une véritable locomotive pour les économistes dans la structuration de leur pensée afin de comprendre le fonctionnement de l'économie. Ces modèles vont ainsi être utilisés dans divers contextes, allant de l'analyse des politiques économiques à la mesure du bien-être, en passant par l'identification de chocs, l'analyse des scénarii ou la prévision économique. Ils permettent ainsi de mener à bien tous les exercices essentiellement empiriques que les modèles macro-économétriques précédents permettaient de réaliser. Ils ont en outre l'avantage d'être fortement fondés sur la théorie économique, en contraste avec la nature plus statistique des modèles VAR. Les modèles DSGE font ainsi l'objet d'une attention

[2] Une fonction de réponse d'impulsion donne la réponse d'une variable à une impulsion d'une autre variable dans un système qui peut impliquer un certain nombre d'autres variables également.

particulière non seulement dans le milieu universitaire, mais aussi dans un certain nombre d'institutions non-universitaires de prise de décision, telles les banques centrales, le fond monétaire international, etc.. En fait, les modèles DSGE sont considérés comme un cadre exceptionnel doté d'une fertilisation croisée entre le sol théorique du milieu universitaire et le sol empirique des banques centrales et d'autres institutions semblables. Ils permettent aussi 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 des modèles macroéconomiques anciens. Bien que ces modèles se soient développés assez rapidement dans les pays développés (Edge et al, 2007 pour l'économie américaine; Smets et Wouters, 2004 pour la zone euro, etc.), ils sont restés un véritable défi pour les pays en développement.

Un certain nombre de raisons justifient la timide percée des modèles DSGE dans le monde en développement: Tout d'abord, non seulement ces modèles nécessitent la maîtrise de nouvelles techniques de modélisation, mais ils sont aussi assez exigeants en termes de compétences techniques (statistiques) et informatiques. Deuxièmement, la nature complexe des modèles DSGE a peut-être également limité leur acceptation auprès des décideurs politiques dans la mesure où les notations qu'ils utilisent peuvent parfois se révéler plutôt incompréhensibles, créant ainsi une barrière naturelle pour la communication des résultats aux décideurs politiques, pour ne pas dire au public en général. Troisièmement, la compréhension du fonctionnement de ces modèles requiert que le macroéconomiste soit bien formé avec une bonne culture de modélisation et des compétences en statistique et enprogrammation très fortes. En outre, fournir au public une interprétation économique des équations n'est pas une tâche facile. En particulier, il est difficile d'expliquer les mécanismes de transmission ou d'identifier des canaux de transmission d'un choc ou d'une décision de politique dans toute l'économie. Dans la plupart des cas, les solutions analytiques sont l'exception plutôt que la règle, ce qui rend la recherche de solutions analytiques fiables un défi supplémentaire, auquel le praticien devrait faire face. Cela implique également que les banques centrales auraient à investir des ressources supplémentaires pour développer de tels modèles ; un objectif qui ne peut pas être prioritaire lorsque les ressources sont rares.

Pourtant, les modèles DSGE présentent aussi un certain nombre d'avantages, hautement importants pour les pays en développement. Premièrement, les modèles DSGE ont un fondement microéconomique explicite avec des agents agissant sous anticipations rationnelles. Ces modèles spécifient explicitement les objectifs et les contraintes des secteurs privé et public, et permettent la détermination des prix et des allocations de façon optimale. Les effets décisions des agents, telles que la quantité d'offre de travail et la demande de consommation ou la demande de travail et les décisions de prix par les entreprises peuvent être analysés directement. En outre, le fondement microéconomique de ces modèles permet d'avoir des relations exactes entre les paramètres de la forme réduite et les paramètres structurels du modèle, ces derniers étant moins susceptibles de changer en réponse à des changements de régime, ce qui permet de donner un sens économique à ces paramètres. De plus, à partir de l'approximation de la fonction d'utilité de l'agent représentatif, il en résulte un critère de bien-être qui est cohérent dans le modèle. De cette façon, un modèle DSGE est un outil puissant qui fournit un cadre cohérent pour la discussion et l'analyse des politiques économiques : à l'aide du critère de bien-être, les décisions de politiques alternatives peuvent facilement être évaluées dans le cadre des hypothèses du modèle. Finalement, un certain nombre d'auteurs (Smets et Wouters, 2004, Del Negro et Schorfheide, 2004; Dib, Gammoudi et Moran, 2005; Kilponen et Ripatti, 2006 et Bord et al, 2010, entre autres) montrent que les modèles DSGE ont des performances hors échantillon plus élevées que les modèles VAR non structurels ou même VAR Bayesiens (BVAR désormais). Compte tenu de l'importance des prévisions macroéconomiques pour la conception de la politique économique, ces résultats impliquent que les pays en développement bénéficieraient également de la performance supplémentaire des modèles DSGE au-dessus de ceux de la famille des modèles VAR.

Cette thèse vise à proposer un modèle DSGE d’économie ouverte pour le Cameroun. Le premier objectif ainsi poursuivi est de fournir un cadre théorique qui tient compte de la réalité de l'économie camerounaise. Cela nécessite un examen approfondi des sources de fluctuations des cycles économiques dans cette économie. Un nombre croissant d’études a exploré les sources des fluctuations économiques dans les économies américaines et européennes. Smets et Wouters (2007) ont estimé un modèle néo-keynésien pour identifier les principales forces motrices du développement de la production aux États-Unis. Justiniano, Primiceri et Tambalotti (2010) ont constaté quant à eux que la plupart de la variabilité de la production et des heures de travail dans l'économie des États-Unis est due aux chocs d'investissement et que la concurrence imparfaite est le canal de transmission le plus important.

Le deuxième objectif est de concevoir un nouvel outil de prévision macroéconomique pour aider à l'élaboration de politiques économiques au Cameroun. Certaines des contributions les plus importantes mettant en évidence la performance de prévision des modèles DSGE sont celles de Smets et Wouters (2004), Del Negro et Schorfheide (2004), Dib, Gammoudi et Moran (2005), Kilponen et Ripatti (2006), et Edge et al. (2010). Dans cette littérature, les performances prévisionnelles de modèles DSGE sont évaluées par comparaison à un large éventail d'outils de prévision sans aucun fondement théorique, comme les modèles VAR et BVAR, et bien d'autres types de modèle.

En revenant à la modélisation DSGE, notons en effet qu'il y a deux directions essentielles qui sous-tendent ce type de modèles: la théorie néoclassique des cycles d'affaire réelle (RBC) et la théorie néo-keynésienne des cycles d'affaire. La question principale dans les modèles RBC est que, avec des prix complètement flexibles, tout changement dans le taux d'intérêt nominal (qu'il soit choisi directement par la banque centrale ou induit par des changements dans l'offre de monnaie) va toujours de pair avec les changements du taux l'inflation, laissant inchangé le taux d'intérêt réel. Cela signifie que toute action de l'autorité monétaire n'aurait pas d'impact sur les variables réelles et laisserait donc la politique monétaire neutre, un résultat en contradiction avec l'idée largement répandue (certainement parmi les banquiers centraux) selon laquelle la politique monétaire devrait influencer le côté réel de l'économie ne serait-ce qu'à court terme. En outre, du moment où les fluctuations cycliques sont la réponse optimale de l'économie aux chocs, toute politique de stabilisation ne serait pas seulement inutile, mais pourrait aussi se révéler contre-productive si elle détournait l'économie de sa réponse optimale.

Ceci est en contradiction avec le point de vue néo-keynésien selon lequel les fluctuations des cycles économiques sont principalement dues à une utilisation inefficace des ressources disponibles. En outre, le rôle principal attribué à des chocs technologiques dans les fluctuations économiques est en contradiction avec la vision traditionnelle des chocs technologiques comme étant une source de croissance à long terme, sans lien avec les cycles économiques et qui sont dans une large mesure considérés comme un phénomène axé sur la demande. Plus important encore, l'incapacité des modèles RBC à reproduire certains faits empiriques a commencé à préoccuper leurs utilisateurs, principalement universitaires. Ces caractéristiques des modèles RBC expliquent ainsi pourquoi en dépit de leur influence dans les milieux universitaires, ils ont eu une influence très limitée sur la pratique de la conception des politiques des banques centrales et d'autres institutions du même type.

Ces insuffisances des modèles RBC ont commencé à être surmontées dans les années 1990 quand les économistes, tout en gardant la structure principale de ces modèles ont commencé à y introduire de nouvelles hypothèses. Une nouvelle école de pensée (le néo-keynésianisme) va donc voir le jour. Cette école partage cette conviction <<RBCiènne>> selon laquelle la macroéconomie nécessite des fondements microéconomiques rigoureux, d'où l'utilisation des modèles DSGE comme instrument principal dans l'élaboration des politiques économiques. Partant de la théorie RBC, le raisonnement néo-keynésien consistait à reconnaître que l'économie n'est ni parfaitement souple, ni parfaitement concurrentielle et qu'elle est soumise à une variété d'imperfections et de rigidités. C'est de cette conviction qu'est née, chez les économistes néo-keynésiens, l'idée d'introduire la concurrence monopolistique et divers types de rigidités nominales et réelles dans le modèle, en plus d'un certain nombre de perturbations aléatoires. Quelques exemples notables sont l'introduction de la rigidité des prix, à la suite des études antérieures comme Calvo (1983) qui a permis de tenir compte de l'inertie des prix, brisant ainsi l'hypothèse forte de la neutralité de la monnaie dans les modèles RBC ; l'introduction des coûts d'ajustement du capital suivant King (1991) qui a permis d'appréhender, dans les modèles néo-keynésiens, l'effet de liquidité ; et enfin, l'introduction de chocs de demande avec Rotemberg et Woodford (1995).

L'idée qui sous-tend cette thèse est qu'un modèle DSGE pourrait aider à mieux comprendre et à expliquer les fluctuations économiques au Cameroun. Ainsi, si les fondements théoriques nécessaires pour conceptualiser la politique macroéconomique appropriée en réponse aux chocs exogènes sont clairement mis en place, on pourrait donc découvrir les sources les plus pertinentes des fluctuations économiques dans l'économie de ce pays. Un objectif supplémentaire de cette recherche est d'adapter le cadre dynamique standard d'équilibre général stochastique dans la littérature existante, à l'économie camerounaise. Nous conceptualisons dans cette thèse que l'économie camerounaise est une économie avec un équilibre stable ou un sentier de croissance équilibrée et que les chocs stochastiques exogènes auxquels elle est assujettie (chocs externes ou des chocs des matières premières), provoquent ainsi son déplacement de son équilibre ou de son sentier de croissance d'une part, et générent ainsi des fluctuations de certaines variables macroéconomiques d'autre part. L'économie comporte des frictions réelles, nominales, et financières, qui ralentissent l'ajustement de l'économie lors de son retour à son état d'équilibre ou de son retour à son sentier de croissance équilibrée après un départ provoqué par un choc exogène. Par conséquent, nous soulignons l'importance des chocs exogènes comme source des fluctuations économiques au Cameroun, permettant ainsi une interprétation de ces chocs comme étant une source des fluctuations économiques, ce qui reste en ligne avec la vision consensuelle de la macroéconomie moderne (Smets et Wouters, 2003, 2007; Christiano et al., 2005; Schorfheid, 2005; etc.).

Le cadre analytique que nous retenons a une structure de base de la nouvelle génération des modèles néo-keynésiens d'équilibre général stochastique dynamique. D'un point de vue méthodologique, ces modèles cherchent en général à mettre l'accent sur un grand nombre de questions dans différentes économies. Ceci est d'autant plus important que l'un des défis de cette thèse est de trouver une description raisonnable de l'économie du Cameroun tout en soulignant ses spécificités d'une part, et en tenir compte dans le modèle que nous proposons d'autre part.

L'environnement de base que nous adoptons est celui où un agent représentatif qui vit infiniment maximise sa fonction d'utilité qui dépend de sa consommation et de ses loisirs sous sa contrainte budgétaire intertemporelle; un grand nombre d'entreprises ont accès à une technologie identique et sont soumises à des chocs exogènes, l'économie est caractérisée par une concurrence monopolistique où les entreprises fixent les prix des biens qu'elles produisent afin de maximiser leurs profits d'une part, et d'autre part que ladite économie est aussi caractérisée par des rigidités nominales qui limitent la fréquence avec laquelle ces entreprises ajustent les prix des biens et services qu'elles vendent, ou la fréquence avec laquelle les travailleurs ajustent leurs salaires.

Cependant, en plus de ces traits distinctifs néo-keynésiens, le cadre d'analyse de cette recherche vise une photographie plus réaliste de l'économie camerounaise. Il vise ainsi à donner un accent spécifique aux caractéristiques structurelles susceptibles de rendre une telle économie plus vulnérable aux chocs exogènes.

Plus précisément, il y a trois caractéristiques structurelles frappantes et bien perceptibles de l'économie camerounaise, sur lesquels nous mettons un accent particulier. Tout d'abord, nous considérons un modèle qui intègre des frictions financières qui entravent le financement des investissements et qui amplifient l'effet des fluctuations des taux d'intérêt et des taux de change sur les positions réelles de la richesse nette des emprunteurs et les bilans de l'équilibre macroéconomique (Stiglitz et al., 2006, Hostland 2009; Krugman 1999, Aghion, Bacchetta, et Benerjee 2001). Deuxièmement, le modèle intègre également le canal de transmission de taux de change dès lors que la vitesse avec laquelle les chocs des taux de change atteignant le niveau des prix domestiques semble être plus élevée dans les économies en développement que dans le monde industriel (Calvo et Reinhard 2002 Choudhri et Hakura 2006 et Devereux et Yetman, 2005). Peut-être, le trait le plus distinctif de l'économie camerounaise est que les chocs exogènes ont tendance à avoir de plus grandes amplitudes. Un fait stylisé de la macroéconomie camerounaise est que les exportations et les importations sont fortement et positivement corrélées avec le PIB tandis que les exportations nettes sont, elles, négativement corrélées avec le PIB. Ce dernier résultat est compatible avec une grande partie de la littérature empirique (voir, par exemple, Aguiar et Gopinath, 2007; Backus et Kehoe, 1992; Benczur et Ratfai, 2010; Raffo, 2008). Backus et Kehoe argumentent que ce résultat peut survenir lorsqu'un pays est emprunteur des capitaux sur les marchés internationaux. En étroite ligne avec l'expérience d'autres pays, les importations sont fortement procycliques au Cameroun. Le pays étant une économie tributaire des importations, cela pourrait signifier que les biens importés jouent un rôle important dans les fluctuations de la production au Cameroun. Aussi, les exportations sont positivement corrélées avec le PIB, ce qui suggère une forte procyclicacité des exportations au Cameroun. Ce résultat serait attendu compte tenu de la forte dépendance de l'économie de l'extérieur. L'importance des chocs exogènes peut aussi être bien illustrée par celle des prix du pétrole sur le marché mondial. En fait, les changements dans les prix du pétrole ont une influence directe spécifique sur les petites économies ouvertes puisqu'ils affectent à la fois les décisions de consommation et influencent la structure de coûts des entreprises, d'où, finalement, une influence sur les prix intérieurs via ce canal.

Malheureusement, il y a d'autres caractéristiques cruciales de l'économie camerounaise dont nous ne tenons pas compte ici et que nous laissons pour les recherches futures. Un exemple de telles caractéristiques est le «dualisme économique» (Lewis 1954), qui consiste en la partition d'une seule économie en deux secteurs dissemblants. Un de ces secteurs étant généralement de forte intensité capitalistique et exportant une partie de sa production, tandis que l'autre secteur s'appuie plus sur la main d'œuvre non qualifiée mais abondante et fournit toute sa production seulement au marché intérieur. Ce dernier secteur constitue généralement un "réservoir de main-d'oeuvre".

Globalement, le modèle que nous proposons dans cette thèse est proche de celui développé par Christiano et al (2005), Altig et al. (2004), et Smets et Wouters (2003a, 2003b). Il y a trois types d'entreprises dans l'économie. Un premier type regroupe les entreprises qui produisent des variétés différenciées de biens intermédiaires échangeables. Ces entreprises produisent en utilisant le travail, le capital et le pétrole comme facteurs de production, et vendent leurs productions dans les marchés intérieurs et étrangers. Elles ont un pouvoir monopolistique sur les variétés qu'ellesproduisent et fixent les prix de leur production d'une manière échelonnée. Un deuxième type d'entreprises est celui des entreprises de la distribution des différentes variétés importées de l'étranger. Ces entreprises ont aussi un pouvoir monopolistique sur les variétés qu'elles distribuent et fixent elle aussi les prix de leur production d'une manière échelonnée. Il y a une troisième catégorie d'entreprises qui sont complètement tournées à l'exportation des matières premières (ressources naturelles) à l'étranger. Elles n'ont, en revanche, aucun pouvoir sur le marché mondial et sont preneuses de prix. Le stock de ressources naturelles est déterminé de manière exogène et est possédé par le gouvernement, ainsi que par des investisseurs étrangers. Le secteur du bois au Cameroun appartient à ce secteur d'exportation. Les produits intermédiaires locaux et étrangers sont utilisés pour fabriquer deux types de produits finis: le produit local et le produit étranger. Ces deux produits finis sont combinés avec du pétrole pour former un panier de consommation du ménage camerounais, du gouvernement camerounais, et de l'investisseur camerounais à travers l'accumulation de nouveaux biens d'équipement pour augmenter son capital-actions. Nous considérons deux types de ménages: les ménages ricardiens et les ménages non-ricardiens. Le premier adopte d'une manière prospective des décisions d'épargne et de consommation inter-temporelle en maximisant son utilité sous contrainte budgétaire. Le second consomme son revenu net d'impôt, ne constitue pas d'épargne et ne reçoit pas non plus la part du bénéfice distribué provenant des entreprises. La politique monétaire est menée par une règle de politique de taux d'intérêt tandis que l'autorité budgétaire se comporte d'une manière qui ressemble à la règle d'équilibre structurel mise en place par le gouvernement. Le modèle présente un sentier de croissance équilibrée. A côté de ces variables endogènes, différents chocs sont introduits comme sources de fluctuations, et sous une forme log-linéaire, ces chocs sont supposés suivre un processus autorégressifs d'ordre un.

Comme dans la pratique générale, les modèles DSGE n'ont pas de solution analytique claire et nous nous appuyons plutôt sur les méthodes de calcul numérique[3]. Ces méthodes de calcul reposent sur la méthode de perturbation, la résolution du modèle, et la simulation du modèle DSGE autour de la position d'équilibre de l'économie ou de sa trajectoire de croissance équilibrée afin de produire des données artificielles. Ces données artificielles décrivent les réponses des variables économiques aux chocs exogènes. Un ensemble de statistiques comme les moments théoriques pourrait résumer les contributions des différents chocs exogènes aux fluctuations économiques. Dès lors que les chocs structurels sont orthogonaux (non corrélés), il est possible de décomposer sans ambiguïté la variance de l'erreur de prévision de chaque variable macroéconomique en composantes qui reflètent la variabilité exclusivement attribuable à chaque choc spécifique. L'erreur de prévision de la variance d'une variable affectée par un choc particulier détermine l'importance relative de ce choc à expliquer les fluctuations de ladite variable. Cette méthodologie de résumer les cycles économiques par une collecte de statistiques calculées à partir des données artificielles trouve ses origines dans la littérature des cycles des affaires (voir Cooley 1995). Aujourd'hui, quatre méthodes empiriques majeures existent pour générer des

[3] Habituellement, les conditions d'optimalité impliquent un système d'équations non-linéaire d'ordre supérieur avec des espoirs de résolution mathématique très mince.

données artificielles à partir d'un modèle DSGE théorique: le calibrage, la méthode d'information complète, l'estimation basée sur la méthode de maximum de vraisemblance, et la méthode bayésienne.

Dans cette recherche, nous combinons deux de ces méthodes empiriques. Tout d'abord, nous utilisons les données macroéconomiques camerounaises[4] pour calibrer les paramètres du modèle DSGE qui sont liés à l'état stationnaire de l'économie en question. Nous résolvons le modèle étant données les valeurs de ces paramètres en utilisant les conditions d'optimalité non-linéaires évaluées à l'état stationnaire. Les paramètres structurels ainsi calibrés sont fonctions des variables endogènes évaluées à l'état d'équilibre ainsi que sur la moyenne de l'échantillon à long-terme. Nous en déduisons également les valeurs des paramètres non calibrés en estimant sous une approche bayésienne le modèle DSGE linéarisé en utilisant des données macroéconomiques camerounaises. Cette approche bayésienne nous permet d'aborder efficacement les questions auxquelles nous nous intéressons à savoir la performance du modèle pour les prévisions et les fluctuations macroéconomiques. Ainsi, nous effectuons des analyses de performances de prévisions pour déterminer quel modèle de prévision est le meilleur. Nous menons également des simulations dans le but d'analyser la dynamique de l'économie par le biais des fonctions de réponse d'impulsion. Finalement, nous décomposons les variances des erreurs de prévision afin d'identifier les principales forces motrices de l'économie camerounaise.

Le chapitre 1 de cette thèse propose une analyse générale des cycles des affaires dans l'économie camerounaise. Il vise à proposer une description globale des cycles économiques dans ce pays à travers l'évaluation statistique des principaux phénomènes caractéristiques. Ainsi dans le cadre de ce chapitre, nous fournissons une première tentative de documentation d'un large éventail de régularités dans les fluctuations macroéconomiques du Cameroun. L'analyse est effectuée à partir de trois dimensions caractéristiques des fluctuations macroéconomiques: la volatilité de la

[4] Ces données sont principalement extraites de la base de données des Statistiques financières internationales (SFI). C'est le cas de la production intérieur brut (PIB), la consommation des ménages, la croissance de la production étrangère, et le taux d'intérêt étranger. L'investissement, le taux de change réel, le taux d'intérêt national, et le taux d'inflation sont extraits dans la base de données de l'Institut National des statistiques (INS). Toutes ces données ont une fréquence annuelle allant de 1960 à 2012.

production est aussi bien un indicateur de la sensibilité de l'économie aux chocs exogènes qu'un indicateur des sources endogènes d'instabilité. Les co-mouvements des variables d'intérêt apportent une lumière sur la façon avec laquelle les fluctuations observées se rapportent à d'autres agrégats de l'économie. Plus importante encore est l'évaluation de la persistante de certains phénomènes dans les cycles des affaires camerounais. Enfin, l'analyse repose sur trois outils statistiques de base couramment utilisées dans la littérature empirique des cycles économiques. Ce sont l'écart-type utilisé comme mesure de la volatilité, les corrélations croisées comme un moyen d'analyser les co-mouvements et les auto-corrélations comme mesures de la persistance. Alors que la pratique habituelle est de s'appuyer sur des données trimestrielles pour de telles études, malheureusement pour nous, les données dont nous disposons pour le Cameroun sont seulement de périodicité annuelle. Cela est regrettable car cela peut être critiqué au motif que la fréquence annuelle ne permettrait pas de saisir pleinement la dynamique de court terme de l'économie. En outre, avec de telles données, nos résultats ne sont pas facilement comparables à ceux rapportés pour d'autres pays dans d'autres études comme celle d'Agénor et al. (2000) ou celle de Rand et Tarp (2002).

Dans le chapitre 2, nous proposons un modèle DSGE descriptif de l'économie du Cameroun. Le modèle mis en place est basé sur un cadre néo-keynésien, caractérisé par des rigidités nominales et réelles. Ce cadre nous permet d'introduire des fondements microéconomiques du comportement optimisateur des agents économiques dans le système. Les entreprises sont supposées ajuster les prix avec une fréquence irrégulière tandis que les salaires sont fixés de façon échelonnée par les travailleurs. Le modèle intègre des frictions financières qui entravent le financement des investissements et amplifient l'effet des fluctuations des taux d'intérêt et taux de change sur les valeurs réelles de la richesse nette de l'emprunteur et les bilans de l'équilibre macroéconomique. Le modèle intègre également le canal de transmission de taux de change dès lors que la vitesse avec laquelle les chocs des taux de change atteignant le niveau des prix domestiques semble être plus élevée dans les économies en développement que dans le monde industriel. Les chocs externes tels que les chocs des prix du pétrole et les chocs des prix des produits de base sont intégrés dans le modèle car le Cameroun dépend fortement de l'exportation des matières premières qui le rend si vulnérables à ces différents chocs.

Le chapitre 3, prépare le terrain pour l'exploitation du modèle DSGE développé dans le chapitre 2. Deux méthodes sont utilisées pour une évaluation empirique dudit modèle. Un premier groupe de paramètres (paramètres structurels) qui influencent l'état stationnaire de l'économie vont être calibrés. En deuxième lieu, les paramètres non calibrés vont être inférés en estimant par la méthode bayésienne le modèle DSGE linéarisé en utilisant les données macroéconomiques du Cameroun. Toujours dans le cadre de ce chapitre, nous donnons un aperçu sur les mécanismes de transmission de ces chocs qui sont générateurs des fluctuations des cycles économiques. Pour ces sources et ces mécanismes de propagation desdits chocs, il nous est impératif de revoir les opérations nécessaires pour detrender les conditions d'optimalité et d'équilibre du modèle, la technique pour construire une approximation linéaire du modèle, la stratégie visant à résoudre le modèle ainsi linéarisé, donner une représentation de cette solution sous une forme espace-état qui permet de produire des projections du filtre de Kalman. Nous utilisons un simulateur pour générer des distributions a posteriori de notre modèle DSGE. Ces distributions a posteriori donnent des statistiques sommaires des estimations bayésiennes des paramètres du modèle DSGE qui sont comparés aux résultats dans la littérature existante. En outre, ce chapitre fournit des exercices empiriques dans lesquels le modèle DSGE est estimé et évalué sur la base de nos croyances et ce, à l'instar de la littérature standard des modèles DSGE.

Finalement, c'est seulement dans le chapitre 4, que nous procédons à la prévision des fluctuations macroéconomiques au Cameroun. Nous considérons l'économie camerounaise comme un système dynamique avec un équilibre stationnaire. Nous considérons également que des chocs exogènes ont perturbé ce système et l'ont fait dévir de sa position d'équilibre et générer des fluctuations des variables macroéconomiques. Ces chocs exogènes provoquent les fluctuations du cycle économique. Sachant que le modèle DSGE du chapitre 2 doit contenir des informations utiles sur la dynamique future des cycles des affaires de l'économie camerounaise, car il est utilisé pour des fins d'évaluation de politique économique, nous évaluons ce contenu d'information en procédant à des expériences de prévision et à des comparaisons entre le modèle DSGE et ses modèles concurrents. En particulier, nous considérons les prévisions des variables observables du modèle

DSGE, et les comparons à celles générées par les modèles VAR, BVAR, et les modèles de marche aléatoire. Par la suite, nous cherchons la contribution de chaque choc à la volatilité des variables macroéconomiques observables. Ainsi, nous pouvons voir si un choc particulier est, ou non, une force motrice significative pour une variable macroéconomique. Cela pourrait être évalué à partir des données artificielles générées par simulation du modèle DSGE théorique. Dès lors que les chocs structurels sont orthogonaux (non corrélés), il devient possible de décomposer sans ambiguïté la variance de l'erreur de prévision de chaque variable macroéconomique en composantes qui reflètent la variabilité exclusivement attribuée à un choc spécifique. La contribution relative d'un choc exogène dans la variance de l'erreur de prévision d'une variable macroéconomique spécifique détermine l'importance de ce choc pour expliquer les fluctuations de cette variable d'intérêt. Les chocs exogènes ayant les plus fortes contributions dans la variance de l'erreur de prévision d'une variable macroéconomique d'intérêt sont ses principales forces motrices, ou ses principales sources de fluctuations. Enfin, grâce à la décomposition historique, des informations sur l'importance de chaque choc qui affecte les variables endogènes dans le modèle DSGE du Cameroun sont également obtenues. Ceci est fait à travers une suite de substitutions et la décomposition Wald et en écrivant les variables du modèle à chaque instant en fonction des valeurs initiales des variables d'intérêt et des chocs structurels.

CHAPTER 1: BUSINESS CYCLES IN CAMEROON: AN OVERVIEW

Abstract

In this chapter, we aim at conducting a thorough analysis of business cycles in Cameroon by statistically assessing their main characteristics. Our analysis is carried out by considering the three dimensions of macroeconomic fluctuations. By assessing output volatility, we shed light on the sensitivity of the economy to exogenous shocks as well as to endogenous sources of instability. Likewise, analysing the co-movements of aggregate variables of interest helps in understanding the extent to which the observed fluctuations relate to other aggregates in the economy and hence, the main forces driving the dynamics of that economy. Eventually, more light could be shed on macroeconomic dynamics by analysing the timing and persistence of business cycles. We conduct such analyses using basic statistical tools commonly used in the empirical literature on business cycles. These are the standard deviation as a measure of volatility, cross-correlations as a means of analysing co-movements and auto-correlations as measures of persistence. Our results indicate that many of the features of a new-Keynesian economy are present in Cameroon.

Keywords: business cycle; macroeconomic fluctuation; Cameroon

Introduction

"The role of facts in theoretical disputes is often stressed in different episodes of the history of macroeconomics. In particular, … it is central to the protagonists' narratives on how antagonists theories – new classical (and real business cycle, RBC), on the one hand, and new Keynesian, on the other – were eventually synthesized into the DSGE macroeconomics. In such narratives, mainstream

macroeconomists tend to hold loose methodological and philosophical ideas about facts falsifying theories, about paradigms being challenged, and school of thoughts winning bitter battles, all of this in favor of some type of knowledge accumulation" (Duarte 2012, 190-4)

This chapter aims at proposing an overall description of business cycles in Cameroon by statistically assessing their main characteristics. Identifying the main features of business cycles in an economy is more than a requirement when designing a DSGE model for that economy. As underlined in the main introduction to this thesis, the theory of business cycles is actually the main foundation of DSGE models. This means that for a DSGE model to provide us with a realistic description of a given economy, it necessarily has to account for, if not to replicate those salient features that govern the formation and evolution of its business cycles. A few examples might better highlight the reason why a preliminary empirical analysis of business cycles is essential for the theoretical hypotheses leading to a DSGE model to reflect the real world the model aims at describing. A strong correlation of imports and exports with GDP (Gross Domestic Product) would obviously indicate a high degree of openness of the economy as well as a high degree of dependence vis-à-vis the rest of the world and would therefore suggest that the external sector should play an important role in the DSGE model being designed. Likewise, a large volatility of output in a developing open economy may arise from a variety of events including real external shocks (such as terms of trade) or financial external shocks and natural disasters (commodity production shock), all of which have to be identified and accounted for in the model. Eventually, a high degree of persistence in prices and nominal wages would make it crucial that the model being constructed be in the New-keynesian vein, hence including mechanisms governing price and wage rigidities.

Unlike industrialized countries, little attention has been paid to the analysis of business cycles in developing countries. As argued by Agénor et al. (2000), there are at least two factors that may explain this. First, limitations in data quality and frequency could be a constraining factor in some cases. For instance, quarterly data on national accounts are available for only a handful of developing countries; and even when these are available, they are considered to be of significantly lower quality. Second, developing countries tend to be proned to sudden crises and marked gyrations in macroeconomic variables, hence making it difficult to discern any type of "cycle" or economic regularities. Thus, very helpful are the few available studies such as those by Agénor et al. (2000), Rand and Tarp (2002), Neumeyer and Perri (2005), and Arguar and Gopinath (2007). In particular, Agénor et al. (2000) established a set of stylized facts for the business cycles of developing countries and this has become the benchmark upon which most subsequent studies compare their findings.

Based on a sample of twelve middle-income developing countries (Korea, Malaysia, Mexico, Morocco, Nigeria, the Philippines, Tunisia, Turkey, and Uruguay) for the period 1978:1-1995:4, Agénor et al. (2000) found significant differences between developed and industrialised countries with respect to business cycles. Their key findings are as follows: First, output volatility varies substantially across developing countries and is on average much higher than the level typically observed in industrialised countries. However, developing countries also show higher persistence in output fluctuations as compared to industrialised countries. Second, activity in industrialised countries, as measured by the output and world real interest rate, has a significantly positive influence on output in most developing countries. Third, government expenditures and the fiscal impulse appear to be counter-cyclical while there is no distinct pattern in government revenue which seems to be acyclical in some countries and significantly countercyclical in others. Fourth, there is evidence of procyclicality in real wages as is the case in developed countries. Fifth, while prices are widely documented as being countercyclical in the industrialized countries, there appears that there are no consistent relationships between either output and prices or output and inflation in developing countries. Sixth, contemporaneous correlations between money and output are positive, but not very strong, and this contrasts with the evidence from many industrialised countries. This also suggests that there is a need to examine the key roles that are often assigned to monetary policy in stabilization programs in developing countries. Furthermore, while the velocity of broad money is weakly procyclical, in most industrialized countries, it appears to be strongly countercyclical in developing countries. Seventh, there is no robust relationship between the trade balance and output. In the countries where this relation is procyclical, this "may indicate that fluctuations of industrial output are driven by export demand and that imports are not as sensitive to domestic demand fluctuations as they are in industrial countries" (Agénor et al., 2000, p. 280). Furthermore, the terms of trade are strongly procyclical suggesting that much of the fluctuations in output in developing countries can be explained by terms of trade shocks, as has been suggested by Mendoza (1995).

In the frame of this chapter, we provide a first attempt to document a wide range of regularities in macroeconomic fluctuations in Cameroon. The analysis is carried out by considering the three dimensions of macroeconomic fluctuations. Output volatility is an indicator of the sensitivity of the economy to exogenous shocks as well as to endogenous sources of instability. The co-movements of aggregate variables of interest sheds light on the extent to which the observed fluctuations relate to other aggregates in the economy. Also important is the assessment of how persistent do observed business cycles tend to be.

The analysis relies on three basic statistical tools commonly used in the empirical literature on business cycles. These are the standard deviation as a measure of volatility, cross-correlations as a means of analysing co-movements and auto-correlations as measures of persistence. Unfortunately, while the usual practice is to rely on quarterly data, the data available to us for Cameroon are of annual periodicity. This is unfortunate as this may be criticized on the grounds that the annual frequency would not allow one to fully capture short run dynamics of the economy. In addition, our results may be less straightforwardly comparable to those reported in other studies like Agénor et al. (2000) or Rand and Tarp (2002) for other countries.

The chapter is organized as follows. Section 2 briefly presents the data the analysis relies on as well as the empirical strategy. Section 3 discusses the main results. Section 4 concludes.

2- Data and empirical setup

We rely on annual data to analyse economic fluctuations in the Cameroonian economy. These data are drawn from the International Financial Statistics (IFS) database of the International Monetary Fund (IMF) as well as from the National Statistical Institute (INS) of Cameroon (see appendix A for more details).

The variables we use are: gdp-output; inv-investment; π-inflation; x-exports; m-imports; xn-net exports; c-private consumption; g-government consumption; b^*-external debt; rer-real exchange rate; ner-nominal exchange rate; tot-terms of trade; tb-trade balance; $M2$-broad money; $M1$-narrow money; cr-private sector credit; r-real interest rate; i-nominal interest rate; cpi-consumer price index; w-real wages; $y^{*(US)}$-US-real GDP; o^*-world oil price; r^*- real treasury bill rate.

Prior to empirical analysis, we first detrend the natural logarithm of every variable using the Hodrick-Prescott (HP) filter.

2.1- Detrending

Detrending in business cycle studies helps to decompose all macroeconomic series into non-stationary (trend) and stationary (cyclical) components. Different procedures are used in the literature (Canova, 1998) to extract trends from the observed time series. These procedures are divided into two broad categories: 'statistical' methods, which assume that the trend and the cycle are unobservable but use different statistical assumptions to identify the two components, and 'economic' methods, where the choice of trend is dictated by an economic model, by the preferences of the researcher or by the question being asked. Since only trend and cycle are assumed to exist, all the procedures implicitly assume that either data have previously been seasonally adjusted or that the seasonal and the cyclical component of the series are lumped together and that irregular (high frequency) fluctuations are negligible. Throughout this chapter, we denote the natural logarithm of the time series by x_t, its trend by x_t^g and its cyclical component by x_t^c. In choosing a detrending technique, most researchers appear to opt for 'economic methods' with either the Hodrick-

Prescott (HP) filter (Hodrick and Prescott, 1997) or the band-pass (BP) filter (Baxter and King, 1999).

2.1.1- Hodrick-Prescott filter

In the Real Business Cycle (RBC) literature the trend of a time series is not intrinsic to the data but is rather a representation of the preferences of the researcher and depends on the economic question being investigated. The popularity of the HP filter among applied macroeconomists results from its flexibility to accommodate these needs since the implied trend line resembles what an analyst would draw by hand through the plot of the data (see, e.g. Kydland and Prescott, 1990). The selection mechanism that economic theory imposes on the data via the HP filter can be justified using the statistical literature on curve fitting (see, e.g. Wabha, 1980). In this framework the HP filter optimally extracts a trend which is stochastic but moves smoothly over time and is uncorrelated with the cyclical component.

The HP filter is a linear filter designed to optimally extract a trend component, which changes smoothly over time, from an observed non-stationary time series. Assuming that the (deseasonalized) time series x_t can be decomposed into an additive cyclical component x_t^c and a trend component x_t^g, extracting the trend component will yield a stationary cyclical component, which can be used by researchers to analyse business cycles:

$$x_t = x_t^c + x_t^g \qquad \text{for} \qquad t = 1, \dots, T$$

The standard HP filter (see Hodrick and Prescott, 1997) employs an adjustment rule whereby the trend component, x_t^g, moves continuously and adjusts gradually. Formally, the trend component is extracted by solving the following minimization problem

$$\min_{\{x_t^g\}_{t=0}^{\infty}} \sum_{t=1}^{\infty} \left\{ \left(x_t - x_t^g\right)^2 + \lambda\left[\left(x_{t+1}^g - x_t^g\right) - \left(x_t^g - x_{t-1}^g\right)\right]^2 \right\} \qquad (*)$$

The first term in the expression is the sum of squared deviations between the observed data and the trend, and is a measure of the goodness of fit of the trend to the original series. The objective is to select the trend component that minimizes the sum of squared deviations from the observed series, subject to the constraint that changes in x_t^g vary gradually over time. The Lagrange multiplier λ is a positive number that penalizes changes in the trend component. The larger the value of λ, the smoother is the resulting trend series.

The HP filter has been subject to various criticisms (see Stadler, 1994, pp. 1768-69). In particular, it has been argued that it removes potentially valuable information from the time series (King and Rebelo, 1993), and so, it may impact cyclical patterns of the data (Cogley and Nason, 1995)[5]. More important in our case is the choice of the value of λ. The usual practice in the literature is to set λ to 1600 for quarterly time series, and 100 for annual time series. However, imposing this specific value (which was derived from an examination of the properties of US output data) for each series is somewhat arbitrary, and may reflect an overly stringent implicit assumption about the degree of persistence in x_t.

2.2- Volatility, Persistence, and Correlations.

Once the series have been detrended and hence the cyclical components obtained, the statistical analysis of the resulting stationary data can be carried out. As mentioned earlier, the statistical analysis in this chapter concentrates on volatility, persistence, and cross-correlations.

[5] For comparison of the HP filter with other detrending methods, also see Blackburn and Ravn (1991) and Canova (1991).

2.2.1- Volatility

Volatility reports the magnitude of fluctuations of the variables of interest. Volatility is measured by the standard deviation of the variable while relative volatility is the ratio between the volatility of the variable of interest and the volatility of industrial production. A relative volatility of one implies that the variable has the same cyclical amplitude as the aggregate business cycle (as proxied by industrial production) while a relative volatility greater than one implies that the variable has greater cyclical amplitude than the aggregate business cycle.

2.2.2- Persistence

Persistence can be broadly defined as the speed with which a variable x_t returns to its baseline (or its previous level) after, say, a shock (for instance, a macroeconomic policy measure) or an "innovation". In other words, x_t is said to be more inertial when it slowly converges (or returns) to its previous level after the occurrence of a stimulus. Persistence is thus inversely related to the concept of mean reversion.

Quantifying the response of x_t to a shock is indeed important not only because it may allow one to assess the effectiveness of economic policy measures but also because it may show at what point it is more appropriate to act in order to overcome a harmful effect of a shock to x_t. By definition, quantifying the response of x_t to shocks implies evaluating the persistence of x_t.

The implication of that definition is that the degree of persistence can be associated with both the speed with which x_t responds to a shock and the length (permanent or temporary) of the shock effects. When the value is small, x_t responds quickly to a shock and returns quickly to its trend. Conversely, when the value is high, the speed of adjustment is low, and x_t will tend to converge more slowly to its baseline. Therefore, if the degree of persistence is small, a shock tends to have temporary effects and conversely if the degree of persistence is high, a shock tends do have more long-lasting effects.

The estimate of persistence at time t is obtained via the use of autoregressive model as in Belbute and Caleiro (2013). A univariate AR(k) process is characterized by the following expression:

$$x_t = \alpha + \sum_{j=1}^{k} \beta_j x_{t-j} + \varepsilon_t$$

Where x_t is explained by a constant α, by past values up to lag *k*, and by a number of other factors whose effect is captured by the random term ε_t.

The persistence of the cyclical component of a variable is measured by its autocorrelation function:

$$r(k) = \frac{\sum_{t=k+1}^{T}(x_t - \bar{x})(x_{t-k} - \bar{x})}{\sum_{t=1}^{T}(x_t - \bar{x})^2}$$

Where *T* is the sample size and *k* is the number of lags. The significance of the persistence is validated using the Ljung-Box portmanteau (Q) test for white noise. The Ljung-Box *Q*-statistic helps to decide if the null hypothesis which states that there is no auto-correlation up to order *k* is accepted. Under this hypothesis, the Ljung-Box *Q*-statistic is given by:

$$Q = T(T+2)\sum_{j=1}^{k} \frac{r_j^2}{T-j}$$

and is asymptotically distributed as a χ^2 with k degrees of freedom[6].

2.2.3- Cyclicality

The degree of co-movement between two variables x and y is measured with their unconditional cross-correlation function

$$r_{xy}(k) = Corr(x_t, y_{t-k}) = \frac{\sum_{t=k+1}^{T}(x_t - \bar{x})(y_{t-k} - \bar{y})}{\sum_{t=1}^{T}(x_t - \bar{x})^2},\ k \in \{0, \pm 1, \pm 2, \dots\}$$

These correlations estimated for the stationary components of variables that have been detrended using the same filter. Assuming y to be an indicator and x the cyclical component of real GDP, y is considered to be procyclical, acyclical or counter-cyclical depending on whether the contemporaneous correlation coefficient $r(0)$ is positive, zero, or negative, respectively.

Following Agenor et al. (2000), the indicator is considered to be strongly contemporaneously correlated if $0.26 \leq |r(0)| < 1$, weakly contemporaneously correlated with the cycle if $0 \leq |r(0)| < 0.13$, and contemporaneously correlated if $0.13 \leq |r(0)| < 0.26$. In addition, y_t is said to lead the cycle by k period(s) if $|r(k)|$ is maximum for a negative k, to be synchronous if $|r(k)|$ is maximum for $k = 0$, and to lag the cycle if $|r(k)|$ is maximum for a positive k.

[6] [6] H_0: The data are independently distributed i.e. there is not serial correlation. If the statistic has its p-value such that, $p > 0.05$, then this is not significant and is considered to imply that there is little or no persistence in the cyclical component.

3 - Results : Business Cycles in Cameroon

In this section, we describe the main features of business cycles in Cameroon through three dimensions: volatility, cross-correlation and persistence. The results are reported in Tables 1, 2 and 3 below. However, two remarks are in order. First, whenever relevant, the variables of interest are measured in per capita terms. Second, all of the variables have been detrended using the HP filter with the smoothing parameter λ set to 100.

3.1- Volatility

We gauge the volatility and persistence of business cycle fluctuations by examining summary statistics for the stationary component of real GDP, components of aggregate demand and inflation. The second and third columns of Table 1 report the means and standard deviations of output growth rates and standard deviations of the cyclical components of output derived using the HP with λ set at 100. Output growth rates are measured as year differences of the log levels of output. The taking into account of the mineral-GDP in this study yields on the importance of the mining sector in the Cameroonian economy with an average share of 20 percent contribution to the GDP (African economic outlook, 2014, 2012).

Table 1.1: Summary statistics for output

Output measure and filter	Output						
	Mean (%)	St. dev(%)	Autocorrelations				
			Lag 1	Lag 2	Lag 3	Lag 4	Q(p-value)
Aggregate GDP							
Growth	4.8	13.75	0.45	0.17	0.00	-0.35	12.31(0.00)
HP		08.21	0.13	0.03	-0.13	-0.29	07.01(0.00)
BP		05.48	0.34	0.34	-0.25	-0.38	04.17(0.01)
Non-mineral GDP							
Growth	4.2	05.82	0.59	-0.63	-0.23	-0.37	08.47(0.00)

HP		03.44	0.41	-0.05	-0.09	-0.07	03.22(0.00)
BP		01.37	0.89	0.47	0.13	-0.17	05.36(0.00)
Non-mineral private GDP							
Growth	5.7	09.31	0.29	0.14	-0.02	-0.26	09.78(0.01)
HP		04.56	0.44	0.11	-0.01	-0.11	06.55(0.00)
BP		02.78	0.89	0.54	0.12	-0.00	03.67(0.00)
Mineral GDP							
Growth	4.2	24.78	0.22	0.13	0.07	-0.28	07.49(0.00)
HP		17.15	0.05	0.04	-0.05	-0.15	05.88(0.00)
BP		09.24	0.75	0.33	-0.08	-0.31	07.31(0.04)

Source: Author's calculations based on data obtained from the IFS database.
Mineral GDP: mineral contribution to the GDP; Non-Mineral GDP: Non-mineral contribution to the GDP; Non-Mineral private GDP: Non-mineral private contribution to the GDP.

The results reported in this table show that the mean annual growth rates during the sample period are 4.8 for aggregate output, 4.2 for mineral output and 5.7 for non-mineral output. The volatility of growth rates as measured by standard deviations indicates that mineral GDP is the most unstable, followed by aggregate GDP, and non-mineral GDP being the least volatile. The same pattern, albeit to a lesser extent, emerges from the standard deviations of the filtered cyclical components of output. Since mineral goods are considered as commodity goods whose entire production is exported, their unstability may be modelled in a DSGE model (as in chapter 2) either by introducing exogenous shocks in their production function, or by introducing commodity price shock in the international market where they are sold.

In comparison with output volatility in the USA, it is clear that output in Cameroon is 2.5 times more volatile than it is in the USA. Loayza et al. (2007) document that output in developing economies is significantly more volatile than in industrialized economies and suggest that, the excessive volatility in developing economies may arise from three key sources: The first is that developing countries are subject to greater exogenous shocks. The second is that, developing economies may be subject to greater domestic shocks arising, for example, from policy mistakes. The third and final suggestion is that external shocks have greater effects on volatility because developing economies do not possess neither the financial markets necessary to diversify risks nor the ability to perform stabilising macroeconomic policies. The latter effect has significant implications for the welfare of an economy. Hnatkovska and Loayza (2005) document a significant negative relationship between economic growth and output volatility, which is exacerbated by underdeveloped financial markets and institutions. Thus, under these conditions, external shocks have a greater effect on volatility, hence inducing lower economic growth. In particular, it is estimated in Hnatkovska and Loayza (2005) that a one-standard-deviation increase in volatility would reduce the economy's growth rate by 1.3%.

Table 2 reports measures of persistence and volatility in components of aggregate spending and inflation. Volatility is measured by the standard deviation as in Table 1 above, while the first order autocorrelation coefficient measures the persistence of series.

Table 1.2: Components of aggregate spending, inflation, external conditions, and monetary and financial variables

Variables	σ_x	σ_x/σ_y	$\rho(1)$	Q	P-value
inv: investment	0.3480	2.531	0.327	4.748	0.00
π: inflation	0.6195	4.506	0.415	3.988	0.01
cpi: consumer price index	0.4225	3.073	0.473	5.180	0.00
w: real wages	0.0412	0.300	0.571	7.550	0.00
$M2$: broad money	0.2018	1.468	0.524	6.358	0.02
$M1$: narrow money	0.2813	2.046	-0.510	6.023	0.12
cr: private sector credit	0.1790	1.302	0.393	3.576	0.03
r: real interest rate	0.2142	1.558	0.521	6.285	0.00
i: nominal interest rate	0.2525	1.837	0.490	5.559	0.09
x: exports	0.2094	1.523	-0.653	9.874	0.03
m: imports	0.1552	1.129	0.751	13.060	0.14
xn: net exports	0.1816	1.321	0.721	12.037	0.00

tot: terms of trade	0.2891	2.103	0.756	11.381	0.02
tb: trade balance	0.4525	3.291	0.622	10.203	0.00
c: private consumption	0.1438	1.045	0.535	6.628	0.03
g: govement consumption	0.1406	1.023	0.824	15.723	0.00
b^*: external debt	0.1087	0.791	0.981	22.285	0.04
rer: real exchange rate	0.1508	1.097	0.637	9.396	0.02
ner: nom exchange rate	0.1663	1.210	0.572	7.576	0.00
$y^{*(US)}$: US-real gdp	0.3437	2.5	0.761	13.410	0.04
o^*: world oil price	0.3865	2.811	0.825	15.761	0.00
r^*: real treasury bill rate	0.1842	1.34	0.636	9.366	0.01

All data are at their annual frequency, deseasonalized by the HP filter. Absolute volatility is the standard deviation of each variable. Relative volatility is measured as the ratio of standard deviation of each variable and that of real GDP. Persistence is the AR (1) coefficient following subsection 2.2.2 above.

From table 2, it appears firstly that consumption is the least volatile of all the components of aggregate spending. However, it is more volatile than aggregate output, which contradicts the predictions of the Permanent Income and Life Cycle theories of consumption smoothing behaviour. Secondly, this fact also points to a lack of consumption smoothing over the course of the business cycle. Thus, large welfare gains may be possible through reductions in consumption volatility as is argued by Loayza *et al.* (2007).

Exports are more volatile than those reported in most studies (Male, 2010; Rand and Tarp, 2002). Note that this instability may come from export earnings, export prices, and export quantities following Herrmann (1989). In the case of Cameroon, its exportations are concentrated in a narrow range of primary commodities (cofee, cocoa, wood, iron, diamond, bauxite, cobalt, etc.) and are destined to few markets. This implies that total export earnings are highly sensitive to changes in the prices and/or quantities of the dominant export commodities, with the elasticity of earnings with respect to prices/quantities accounting for a significant share of the total sum.

We can therefore argue that as the country diversifies its exports more and more, the elasticity of each export commodity will get smaller and smaller.

Government expenditures are more volatile. It is 1.023 times more volatile than output. Since government expenditure is importantly financed by tax revenues, it is clear that tax revenues in developing countries increase with the rise of commodity prices but that they are hurt by the volatility of these prices. More specifically, increased prices on imported commodities, lead to increased trade taxes and (to a smaller extent) consumption taxes being collected. Export prices are also positively associated with tax revenue collection, in large commodity-exporting countries, but the channel is through income taxes and non-tax revenues rather than international trade taxes. However, the volatility of commodity prices, both of imported and exported commodities, is negatively affecting tax revenues. These findings point at the detrimental effect of commodity price volatility on the public finance of developing countries and highlight further the importance of finding ways to limit this price volatility and its adverse effects.

Previous analyses of business cycles (e.g. Agénor et al. 2000, Rand and Tarp, 2002; Mâle, 2010) suggest that investments are highly volatile in developing countries. Our results suggest that Cameroon is no exception as investment seems to be 2.531 times more volatile than output in this country.

Examination of absolute volatility also reveals that the real interest rate is more volatile in Cameroon than it is in the US economy. The volatility of the real interest rate is significantly greater than the volatility of output. As discussed in Agénor *et al.* (2000), this may be due to private sector credit having a significant influence on economic activities in countries where equity markets are weakly capitalised.

Examining the exchange rate volatility, the Cameroonian economy displays significant exchange rate volatility. Both the nominal and real exchange rates are more volatile than output. This is a significant finding as one of the key features of international business cycles that has gained macroeconomists' interest is the volatility and persistence of real exchange rates. Flood and Rose (1995) suggest that while the choice of exchange rate regimes affects the volatility of the exchange rate, the volatility of output is stable across regimes. In the cameroonian context, since the country has opted for a flexible exchange rate of its money (franc CFA) against the US-dollar, the cameroonian authorities will refrain from intervening in the foreign exchange market and will permit the currency to depreciate. This depreciation makes exports more competitive in world markets and thereby increases demand. Rising demand then stimulates activity in the export industries, cushioning the adverse impact of the terms-of-trade shock on output. However, where economies maintain a fixed exchange rate regime, exchange rates will be less volatile than output, and the authorities will require to intervene in the foreign exchange market to keep the value of the two currencies in line. Thus, they will sustain the value of the local currency by purchasing it for dollars. This move will in turn drain the local currency out of the money market, reducing the amount of money and credit available for business investment and expansion. Because the authorities' actions are equivalent in their effects to a tightening of monetary policy, this response to the decline in export prices can lead to a costly contraction in output. This is consistent with the Asian experience for Hong Kong, Malaysia and Pakistan; all of which have held fixed, or pegged, exchange rates for significant durations.

3.2- Persistence

The persistence of business cycle fluctuations is assessed by examining the autocorrelations of the filtered series and the results are presented in Table 1, columns 4-7 and in Table 2 the fourth column of which reports the first autocorrelation. In the case of aggregate GDP and mining GDP, the autocorrelations from growth rates and HP-filtered series are weakly positive, but statistically insignificant. Autocorrelations for non-mineral GDP and non-mineral private GDP are relatively stronger and statistically significant indicating some persistence in the cyclical components. The autocorrelations from the BP-filtered series are the most strongly positive and statistically significant. One can therefore view Cameroon's non-mineral output as having short-term fluctuations that could be reasonably characterized as business cycles. These business cycles are characterized by low magnitude and low intensity compared to those of the developing countries studied by

Agénor et al. (2000) and to the Central and Eastern European countries (CEE) and the EU countries investigated by Benczur and Ratfai (2010). The large gyrations in mineral GDP and aggregate GDP suggest that it will be difficult to discern any type of cycle or economic regularity on these aggregates. Moreover, the autocorrelations of their growth rates and HP-filtered series are statistically insignificant.

Another important result from table 3 is the significant persistence of prices and nominal wages in Cameroon. This result is important as it makes it even more crucial to allow for staggered prices and wages when modelling business cycles within a DSGE model for Cameroon. Not only would this result important in a more realistic model, but it also implies a stronger trade-off between inflation and output fluctuations (see Erceg et al., 2000, and Blanchard and Gali, 2005)[7].

3.3- Cyclicality

The degrees of co-movement between real output and other variables are summarized in Table 3 below.

Table 1.3: Cross-correlations: Real output, monetary and financial variables, components of aggregate demand and external conditions (x_t, y_{t-k})

Variables	**-8**	**-4**	**-2**	**-1**	**0**	**1**	**2**	**4**	**8**
inv: investment	-0.37	0.03	0.51	0.63	0.62	0.67	0.54	0.35	-0.24
π: inflation	0.11	0.15	-0.20	0.19	0.27	-0.34	-0.23	0.06	0.17
cpi: consumer price index	0.16	0.19	0.07	-0.11	-0.21	-0.24	-0.19	-0.01	0.13
w: real wages	-0.24	0.23	0.11	0.32	-0.25	-0.18	-0.22	-0.19	0.00

[7] Blanchard and Galí emphasize that price rigidities alone does not imply a conflict between output gap and inflation stabilization: what they call the divine coincidence. They show that adding wage rigidities breaks down this divine coincidence.

$M2$: broad money	-0.04	0.55	0.71	0.67	0.42	0.19	-0.04	-0.53	-0.37
$M1$: narrow money	-0.18	-0.04	0.38	0.57	0.62	0.63	0.52	0.07	-0.29
cr: private sector crdit	-0.31	-0.42	-0.06	0.11	0.18	0.27	0.31	0.37	0.03
r: real interest rate	-0.17	-015	0.28	0.43	0.46	0.38	-0.22	-0.19	-0.31
i: nominal interest rate	-0.07	0.11	0.21	0.22	0.20	0.05	0.01	-0.18	-0.18
x: exports	0.40	0.59	-0.36	0.51	0.65	0.54	0.41	-0.31	0.18
m: imports	0.14	-0.05	0.32	0.40	0.59	0.36	0.28	0.03	-0.17
xn: net exports	0.35	0.00	-0.36	-0.44	-0.37	-0.24	-0.27	-0.19	-0.18
tot: terms of trade	-0.27	-0.32	0.03	0.19	0.69	0.13	0.08	-0.18	-0.24
tb: trade balance	-0.34	0.00	-0.08	0.23	0.57	0.27	0.13	-0.09	-0.23
c: private consumption	-0.22	-0.20	-0.19	-0.06	0.24	0.38	0.53	0.42	0.00
g: government consumption	0.05	-0.25	-0.08	-0.05	0.02	0.17	0.30	0.27	-0.27
b^*: external debt	-0.47	-0.35	-0.25	-0.34	0.27	0.01	0.11	0.35	-0.36
rer: real exchange rate	-0.53	-0.25	-0.17	-0.13	-0.37	-0.00	0.15	0.33	0.27
ner: nominal exchange rate	-0.45	0.37	0.61	0.43	0.57	0.39	0.22	-0.33	-0.19
$y^{*(US)}$: US-real gdp	0.22	-0.17	-0.07	-0.18	-0.15	-0.14	-0.10	-0.06	-0.22
o^*: world oil price	0.59	-0.26	-0.78	-0.54	-0.74	-0.26	-0.06	0.20	0.17
r^*: real treasury bill rate	0.37	0.29	0.32	0.15	-0.17	-0.40	-0.72	-0.56	-0.02

All data are at their annual frequency, deseasonalized by the band-pass filter. Absolute volatility is the standard deviation of each variable. Relative volatility is measured as the ratio of standard deviation of each variable and that of real GDP. Persistence is the AR (1) coefficient.

3.3.1- Correlations with external conditions

We first analyse correlations between real output and a set of variables representing the external environment. Real output is represented by real GDP, while the variables representing the external environment are US real GDP, world oil prices and the US real Treasury bill rate. This helps to give a specific accent to structural characteristics susceptible to make such an economy more vulnerable to external shocks such as the financial shock, the terms of trade shock, the export demand shock, the foreign inflation shock, the foreign commodity price shock, the oil price shock, the price of imports shock, and the foreign output shock. These shocks are introduced into various structural equations in the DSGE model of Cameroon in the frame of chapter 2 of this thesis.

The contemporaneous correlation function indicates a negative and weak association between the US-GDP and the Cameroon real-GDP. This weak and countercyclical relationship is not surprising because Cameroon has weak trade links with the US. Agenor et al (2000) also found that Morocco's, Nigeria's and Turkey's cycles are weakly and negatively related to the US cycle.

Second, we note that the world business cycle conditions could also influence fluctuations in a developing country through changes in real interest rates. In particular, Agénor *et al.* (2000) suggest that the relationship with the world real interest rate could be important because it is likely to affect economic activity in developing countries by both affecting domestic interest rates and by reflecting credit conditions in international capital markets. However, the results show that the contemporaneous correlation is weakly negative, suggesting that US real interest rates do not influence output in Cameroon.

A further channel through which world events could affect macroeconomic fluctuations is that of changes in oil prices. As expected, the results for world oil prices indicate a strong negative contemporaneous correlation. Since oil is an important input in the production process, an increase in its price is expected to raise production costs and dampen economic activity. We use these results to focus on the international oil price shock in the DSGE model of Cameroon (chapter 2). This may be done by introducing oil in the household consumption, and/or by introducing it also as a factor of production in the domestic production firm's function as it is the case in the next chapter.

3.3.2- Components of aggregate demand

Correlation coefficients between real output and components of aggregate spending are reported in column 4.

Household consumption: The contemporaneous correlation between consumption and real GDP is positive, suggesting that private consumption in Cameroon is procyclical. The magnitude of the correlation functions seems to be smaller than those found in industrial and other developing countries as reported by Rand and Tarp (2002) and by Mâle (2010).

Government consumption: The Government plays a central role in the country as it is the main link between the export stability (commodity) and the rest of the economy. The Government levies royalties and tax revenues from the oil and mineral sectors and channels the funds to other sectors through budgetary allocations. Cross correlations indicate weakly procyclical Government consumption. However, this does not necessarily signal any efficacy of the fiscal policy since Government consumption does not lead the cycle. This result is similar to those reported by Alpher (2003) for Mexico and Turkey. Benczur and Ratfai (2010) also found similar relationships for five out of twelve CEE countries, namely Croatia, Latvia, Lithuania, Poland and Slovakia. Other studies that found no clear cyclical pattern include Fiorito and Kollintzas (1994) for G-7 countries. Fiorito and Kollintzas (1994) argue that the relationship between Government consumption and output depends on a variety of factors, such as military expenditures in the total budget, the existence of stabilization programmes and the evolution of institutions.

Investment: Investment is strongly procyclical and close to being synchronous. In fact, this is the component of aggregate spending most strongly associated with output. This is consistent with evidence from other studies reported in the literature (e.g., Benczur and Ratfai, 2010).

Net exports: Particularly, the procyclicality of the trade balance can be explained by the strong positive relationship between the business cycle and exports and the acyclicality of imports, which in combination will result in a positive trade balance during expansions and a negative trade balance during recessions. This contrasts with developed countries where expansionary business cycle phases result in an increased demand for imports and thus a negative trade balance. The close relationship between exports and the business cycle in these countries may extend from the implementation of export-led or outward-looking development strategies. According to table 3 the contemporaneous correlation coefficient between net exports and GDP is negative. This is consistent with much of the empirical literature (see, e.g., Aguiar and Gopinath, 2007; Backus and Kehoe, 1992; Benczur and Ratfai, 2010; Raffo, 2008). Backus and Kehoe (1992) contend that this counter-cyclicality arises because countries borrow from international capital markets. This result is exploited to introduce the risk premium in the household's budget constraint in the model of the next chapter of this thesis.

Imports: As expected, and in line with the experience of other countries (Agénor et al. 2000; Rand and Tarp, 2002; and Mâle, 2010), imports are strongly pro-cyclical. The phase shifts show that imports lead activity production. As an import-dependent economy the strong pro-cyclicality of imports in the case of Cameroon could mean that, imported inputs play an important role in Cameroon output fluctuations. We exploit this result to introduce in our DSGE model for Cameroon afirm that import and distribute different varieties of foreign goods in the domestic market.

Exports: Exports are positively correlated with real GDP, suggesting a strong pro-cyclicality with the business cycle. As an export-dependent economy, this could mean that export and more precisely, export commodities play an important role in Cameroon output fluctuations. Once again, this result is exploited to introduce in the DSGE model for Cameroon a firm that produces a commodity good which is completely exported abroad, and also a firm that produces exportable goods that are consumed domestically.

Terms of trade: It appears from table 3 hat terms of trade are strongly pro-cyclical in Cameroon. This result is similar to the findings of both Agénor *et al*. (2000) and Rand and Tarp (2002). Agénor *et al*. (2000) suggest that, under the assumption that developing economies are too small to affect world prices, the pro-cyclical relationship may reflect demand shifts that yield simultaneous increases in world prices and demand for the country's exports. As such, both the economy's terms of trade and output would increase.

3.3.3- Correlations with monetary and financial variables

Correlation coefficients between real output, monetary and financial variables are consistent with the evidence from other countries.

Money: The views on whether monetary aggregates influence output in industrial countries are varied. However, many authors (King and Plosser, 1984) agree that the monetary mechanism could still play an important stabilizing role in middle income countries. The correlations between real GDP and both definitions of money, M1 and M2, show that money is highly cyclical and rather leading or synchronous. These results are consistent with those reported in Backus and Kehoe (1992) using data for industrial countries and suggest that monetary policy could play an important role in short-term output fluctuation. However, this relationship may simply be reflective of the endogenous response of money to output fluctuations that are driven by non-monetary shocks as suggested by King and Plosser (1994).

Private sector credit: Another monetary variable which has been found by Agénor *et al*. (2000) and Rand and Tarp (2002) to have an important influence on the business cycle in some developing countries is the real domestic private sector credit. Since equity markets are weakly capitalised in developing countries relative to industrialised countries, domestic private sector credit is thought to fulfil an important role in determining investment and hence economic activity in these countries. To examine whether credit influences output and vice versa, it is necessary to examine whether credit leads or lags the business cycle. For the majority of countries credit lags the business cycle, thus suggesting that it is fluctuations in output that influence credit. The contemporaneous correlation between output and credit in the case of Cameroon is weakly positive suggesting that credit is procyclical. However, the phase shifts do not show any clear and interpretable pattern between the two variables.

Consumer price index and inflation: Next we turn to the correlations between prices and output. A substantial body of literature documents the countercyclical behaviour of prices in industrialised countries. It provides support for supply-driven models of the business cycle (see, e.g., Alper 2003). However, Chadha and Prasad (1994) argue that the appropriate correlation to discriminate between demand-driven and supply-driven models of the business cycle is between inflation and cyclical output. We therefore examined the cyclical behaviour of both the price level and inflation rate. The contemporaneous correlation between output and consumer price level is negative, indicating countercyclical variation of the price level. Similarly, the inflation rate is countercyclical and synchronous, indicating that appropriate models for Cameroon would be supply-driven as opposed to the more conventional demand-driven models. Similar findings are reported by Alper (2003) for Mexico and Turkey.

Real wages: The correlation between output and real wages shows much more consistency. In the case of Cameroon, the contemporaneous correlation is positive suggesting procyclical real wages. As discussed in Agénor *et al.* (2000), the identification of whether real wages are procyclical or countercyclical has important implications for the choice of theoretical models to represent developing countries business cycles. The procyclical wages in this case suggest the application of either a New Keynesian model with imperfect competition and countercyclical markup, or a real business cycle model. This result may support the idea of New-Keynesian framework for a DSGE model of Cameroon (see chapter 2).

Nominal effective exchange rate: The contemporaneous correlation indicates that nominal exchange rate is strongly procyclical and almost synchronous. This exchange rate behaviour could be explained by the high import-dependence of economic activities in Cameroon. A currency appreciation lowers the prices of imported inputs which may in turn stimulate production, especially where most of the output is for domestic consumption.

Real exchange rate: The real effective exchange rate is weakly countercyclical with a contemporaneous correlation coefficient equal to -0.37. The weak relationship between the exchange rate and the rest of the economy is well documented in the literature, and is known as the exchange rate disconnect puzzle following Obstfeld and Rogoff (2000). Thus, it is unlikely that there will be a clear pattern of correlations between output and exchange rates for a given sample of developing countries. However, for completeness, this relationship is considered.

Nominal and real interest rates: when considering the impact of monetary policy on business cycles, it is also necessary to examine the relationship between output and interest rates. Most theoretical models suggest that interest rates are not key determinants of business cycles fluctuations[8]. At the empirical level, the link between interest rates and business cycles is not clear. Neumeyer and Perri (2005) found real interest rates to be mildly procyclical in developed countries and countercyclical in developing countries. This is based on results for Argentina, Brazil, Korea, Mexico, and the Philippines. Similarly, Uribe and Yue (2005) found real interest rates to be countercyclical in five developing economies: Argentina, Brazil, Ecuador, Mexico and Peru. Theoretically, because firms have to pay for factors of production before production takes place, working capital needs to make labour demand sensitive to interest rates fluctuations. When interest rates increase, working capital becomes more expensive and firms tend to reduce their demand for labour. Correlations reported in Table 3 indicate that both nominal and real interest rates are procyclical, with the latter being strongly so and coincidental. The positive and synchronous correlation between output and real interest rates can be explained by the dominance of non-mineral output, by the financial services and the contribution of interest income to banks profits. That is, an increase in interest rates increases the interest income of the financial sector, especially commercial banks, because they hold central bank Certificates. Since financial services account for a large proportion of non-mineral output, this shows up as an increase in economic activity.

Conclusion

In this chapter, we statistically highlighted the main characteristics of business in Cameroon. While the primary purpose of the analysis is to highlight those salient

[8] This relationship was not considered in either Agénor *et al*. (2000) or Rand and Tarp (2002).

features of the Cameroonian economy that need to be accounted for in the design of the DSGE model we aim at presenting in chapter 2 of this thesis. It could also be seen as a contribution to the rather burgeoning empirical literature on business cycles in developing countries. While part of the results of this chapter are in line with those reported for other developing countries, the other part is novel as it points to a variety of aspects that seem to be specific to the Cameroonian economy.

Our results could be summarized as follows. Volatilities of the cyclical component of real output are much higher than those in developed countries. Consumption expenditure is more volatile than real output, which contrasts with predictions of the Permanent Income and Life Cycle theories of consumption smoothing behaviour. This may be due to the age pattern of the population of Cameroon where the share of the youth is relatively high. Exports are the most volatile component of national income, owing to the undiversified nature of Cameroon exports.

Both US real output and interest rates are negatively associated with the Cameroonian business cycle. However, these relationships are weak, suggesting that economic activities in the US should not be a major concern for output fluctuations in Cameroon. In contrast, world oil prices are strongly procyclical and suggests that oil prices boost economic activities as expected.

Government consumption is weakly procyclical but does not lead the cycle, indicating that unexpected shocks to fiscal policy cannot be blamed for the sources of business cycles. This also suggests a limited role for fiscal policy in managing fluctuations in output.

Money supply is strongly procyclical and either leads the cycle or is synchronous at best. Private sector credit is weakly procyclical, but does not lead the cycle. These findings suggest that restrictive monetary policy is not likely to be costly in terms of output loss. As such central bank can continue to focus on inflation control without fear of dampening economic activities.

Nominal exchange rate is procyclical and leads the cycle suggesting that the exchange rate could be used to influence short-term macroeconomic dynamics. However, the real exchange rate does not show any clear pattern.

Price variables in levels and in annual growth rates are countercyclical, giving support to the view that supply-side determined business cycle models are more relevant for Cameroon than the conventional demand-driven models. Therefore appropriate models for the analysis of non-mineral output fluctuations should incorporate supply-side variables.

Finally, the highlighted persistence of prices and wages suggests the Cameroonian economy is better describable by models with staggered prices and wages. In general, the results we reported in this chapter provide us with the framework within which the formulation of the main assumptions underlying the dynamic stochastic general equilibrium model to be constructed in the next chapter for of the small open economy of Cameroon.

While further studies on business cycles in developing countries in general and in Cameroon in particular are clearly awaited, future research may encounter one of the main limitations we encountered in this chapter:

- First, annual data used in this study have a number of shortcomings that make the use of higher-frequency information more desirable. In fact, lower-frequency data means smaller samples, which may weaken the efficiency of the results as well as their informational content, especially when it comes to short-term dynamics. This is the main reason why we have had to compare every result we reported in this study to those reported in the literature for other developing countries. Though such comparisons are obviously not likely to improve the precision of our estimates, they improved our confidence in their potential relevance in the sense that none of the results we reported contradicted the main findings from the available literature.

- Second, potential weakness of our results would relate to the use of an economic approach (HP) to detrending the macroeconomic series. This may be problematic since dynamic economic theory does not indicate the type of economic trends that series may display, nor the exact relationship between secular and cyclical components. In other words, without a set of statistical facts pinning down the properties of the secular components of a time series, the theoretical relationship between trend and cycle is unknown and the choice among various economic decompositions is arbitrary.

- Third, another potential limitation of this study may relate to measurement errors in the raw data. This is potentially a serious problem since the data collected by statistical agencies is massaged in so many ways that spurious results may obtain.

- Finally, this study did not take into account the informal sector while it is argued in Schneider (2010) that this sector contributes nearly 70% in the GDP of developing economies. Note that, as unrecorded economy, an informal sector consists of those economic activities that circumvent the institutional rules that define the reporting requirements of government statistical agencies. A summary measure of the unrecorded economy is the amount of unrecorded income, namely the amount of income that should (under existing rules and conventions) be recorded in national accounting systems (e.g National Income and Product Accounts) but is not recorded. In the literature, Ferreira-Tiryaki (2008) is one of the first to provide evidence suggesting that a larger informal sector is associated with higher volatility in consumption, investment, and output using a sample of developed and developing countries. Since then, the theoretical literature has followed suit by analyzing how the informal sector and business cycle volatility are related, most papers have ignored whether the determinants of informality play a role in this relationship. In fact, while the quality of institutions appears to have a uniform effect on the size of the informal sector in the data, institutional quality can manifest itself in different ways, work through different channels and hence lead to contrasting effects on long-run and short-run aggregate economic activity. This implies that the relationship between informality and macroeconomic performance is not clear-cut and may depend on the root cause of informality in the economy. So, what about the cameroonian context? That is the question.

The main challenge for future research could be to take into account these different problems for further improvements.

Appendix A: Data Sources and Unit Root Tests

The primary source of data used in this study is the IMF's International Financial Statistics. Other sources are also used to serve as supplemented sources. We provide below a description of the series, together with their IFS codes. All the data are available upon request.

- Real output is the manufacturing production index (series 66 ey).
- The consumer price index (*CPI*) is series 64.
- The nominal wage index is obtained from national institusion (INS); and the real wage index is obtained by deflating the nominal wage series by the CPI.
- The monetary base (or reserve money) is series 14. Narrow money is series 34 and broad money the sum of serie 34 and 35. Velocity for each monetary indicator is calculated first by transforming the monetary aggregate into an index, and then dividing by the product of the CPI and the real output index, which is used as a proxy for nominal output.
- Private sector credit is series 32d. The real credit variable is obtained by deflating the nominal aggregate by the CPI.
- Government expenditures in nominal terms are obtained from national institution (INS). The expenditure index is derived first by transforming the nominal series into an index. It is divided by the same proxy for nominal output used to derive velocity indicators.
- The trade ratio is measured as the ratio of marchandise exports at current prices (series 70) to merchandise imports at current prices (series 71), with both variables measured in US. dollar terms.
- Trade-weighted measures of nominal and real effective exchange rates are obtained from the IMF's Information Notice System.
- The terms of trade data are measured by the ratio of export unit values (serie 74) to import unit values (series 75).

- World output is proxied by the industrial production index for US. (series 66, code 110). The world real interest rate is proxied by the difference between the nominal Eur-dollar rate in London (series 60d, country code 112), and the rate of inflation in consumer price in US (series 64, code 110).

We performed a set of standard unit root tests, including the ADF test and the Phillips-Perron tests, on our raw data series (all of which were converted into logarithms for the empirical analysis except for the world real interest rate). These tests indicated virtually that the series were non-stationary in levels over the relevant sample period and, therefore, that computing correlations using the raw data would not be appropriate. We also use similar unit root tests to confirm that the cyclical components obtained with the filters employed in this work were indeed stationary.

Chapter 2: A Small Open Economy New-Keynesian DSGE model for Cameroon

Abstract

We propose an open economy dynamic stochastic general equilibrium (DSGE) model based on New-Keynesian micro-foundations for Cameroon. The model combines the building blocks of standard New-Keynesian DSGE models (e.g., price and wage rigidities, and adjustment costs) to a number of features of the Cameroonian economy: There are four types of firms in the economy. Domestic firms producing intermediate goods have monopoly power over the varieties they produce and set prices in a staggered way. Firms that import varieties of goods also have monopoly power over the varieties they distribute, and set prices in a staggered fashion. Commodity firms have no market power. They take the international price of the commodity good as given. Finally, the role of capital good firms in the economy consists in repairing depreciated capital goods and building new ones. Ricardian households make inter-temporal consumption and savings decisions in a forward looking manner by maximizing their utility subject to their inter-temporal budget constraint. Non-ricardian households consume their after-tax disposable income. The monetary policy is conducted through a policy rule for the interest rate while the fiscal authority behaves in a manner that resembles the current structural balance rule implemented by the Government.

Keywords: DSGE model; New-Keynesian; Cameroon

Introduction

Unlike developed countries for which DSGE models have been initially designed, Cameroon is characterized by a number of phenomena our model should account for. First, most of the population in Cameroon lives in rural areas, participates in primary production, be in agriculture or mining, and earns subsistence income. Even when income is higher than current consumption expenditures, savings take the form of non-financial assets or what De Soto (2000) refers to as "dead capital"; that is, assets that cannot easily be converted into liquid assets for consumption due to institutional hurdles or to the imperfections of financial markets, not to say their mere absence. Furthermore, due to the nature of their livelihood and the economic environment, households face credit constraints. This implies that low income (mainly close to sufficient for bare subsistence) reinforced by the absence of well-functioning financial markets (leading to the unavailability of different financial assets) makes inter-temporal resource transfer very difficult.

Second, many developing countries have capital controls that makes it difficult for households to hold foreign assets. Hence, any assumption (as in standard models) of international risk sharing by households through international asset markets is untenable. In addition to the existence of capital controls, there is the issue of attracting foreign investors in the case of low-income countries such as those in Sub-Saharan Africa (SSA henceforth). In general, governments and firms in low-income countries have limited access to international asset markets. For example, a recent study by Hostland (2009) finds that low-income countries have less access to global private debt markets, which induces heavier dependence on official development assistance and concessional loans.

Third, the most distinctive trait of the Cameroonian economy is its high sensitivity to exogenous shocks. As underlined in chapter 1, a remarkable characteristic of the Cameroon is that while GDP is highly and positively correlated with both exports and imports, it is negatively correlated with net exports. That is, the negative contemporaneous correlation coefficient between net exports and GDP is consistent with much of the empirical literature (see, e.g., Aguiar and Gopinath, 2007; Backus and Kehoe, 1992; Benczur and Ratfai, 2010; Raffo, 2008). Backus and Kehoe argued that this counter cyclicality may arise whenever a country borrows from international capital markets during high income periods. In line with the experience of other countries, imports are strongly procyclical and approximately coincidental in Cameroon. The country being an import-dependent economy, this could mean that imported inputs play an important role in Cameroon’s output fluctuations. Likewise, that exports be positively correlated with GDP suggests that they are also strongly procyclical. This is what one would expect given the strong dependence of this economy on foreign markets. The importance of exogenous shocks may be importantly illustrated by the foreign oil price shock. In fact, changes in oil prices have a specific direct influence on small open economies as they simultaneously affect consumption decisions and influence the cost structure of firms, hence ultimately influencing domestic prices via this channel.

In addition to these distinguishing traits of the Cameroonian economy, the basic environment we adopt is one where nominal rigidities constrain the frequency with which firms adjust the prices of the goods and services they sell, and workers, the frequency of wages at which they supply labour. But unfortunately, there are other crucial characteristics of the Cameroonian economy we do not account and for which we leave for future research. One such characteristic is "economic dualism" (Lewis 1954), which refers to the partition of a single economy into two sectors that seem at a very dissimilar level of development; one sector is generally capital intensive and exports its entire output, while the other is labour intensive and merely supplies the domestic market, and an abundant unskilled labour force generally engendering a "reservoir of labour force". Simplifying the analytical framework is the prime reason of excluding such distortions, and to some extent, the desirability of a framework that could explain data from the specific case study rather than a more generic framework that falls short in that dimension.

This chapter proposes a small open economy New-Keynesian DSGE model for Cameroon. It aims to describe a small open economy that produces two types of goods: a tradable good, which is consumed domestically and exported on world markets at an exogenous price, the small open economy considered being price-taker, and commodity goods which are only consumed abroad. The model emphasizes structural characteristics that may make the economy of Cameroon more vulnerable to exogenous shocks. The first emphasis is on financial frictions that hinder investment financing in developing economies in general. As forcefully documented by a widespread literature on the "credit channel of monetary policy"; Carlstrom and Fuerst (1997); Bernanke, Gertler and Gilchrist (1999); Cespedes, Chang and Velasco (2002a, b); Cook (2004); Cook and Devereux (2006); and Devereux, Lane and Xu

(2006); financial frictions or financial market imperfections affect the real macroeconomic equilibrium and the transmission mechanism through which exogenous shocks spread to the real economy. Specifically, Krugman (1999), Aghion, Bacchetta and Benerjee (2001) argue that foreign interest rate and exchange rate fluctuations have large impacts on borrowers' real net worth positions in developing countries and, through the balance sheet constraint that affects investment spending, have larger effects on the real macroeconomic equilibrium than they have in industrial economies. The second relevant feature of the Cameroonian economy is the exchange rate pass-through, or the speed at which exchange rate shocks feed into the domestic price level. Calvo and Reinhard (2002), Choudhri and Hakura (2006), and Devereux and Yetman (2005) document that exchange rate shocks tend to feed into the aggregate inflation at a much faster pace in developing economies than they do in industrial economies. Engel (1999) pushes the idea further and provides substantive evidence that deviations from the law of one price determine the real exchange rate in developing economies. The DSGE model built in this chapter takes these features into account and introduces an incomplete exchange rate pass-through to capture the underlying implication of such phenomena on the dynamic process the Cameroonian economy follows as it adjusts to exogenous shocks.

The model also accounts for domestic and external shocks since the impact of these on growth is of utmost importance in developing countries where such shocks may push millions of people into abject poverty and deprivation. Four distinct types of shocks that may affect the performance of a given open economy are considered. The first group contains domestic supply shocks: productivity shocks, commodity production shocks, investment adjustment cost shocks, and labour supply shocks[9]. The second group includes the domestic demand side shocks of the economy: preference and government expenditure shocks. The third group is constituted only by monetary policy shocks. Eventually, the fourth group contains shocks that are associated with external factors: commodity-price shocks, international oil price shocks, foreign demand shocks, foreign interest rate shocks, foreign inflation shocks, and imported good price shocks.

[9] Investment shocks are classified as supply shocks because they correspond to changes in the technology used to transform new capital goods into installed capital. Alternatively, these shocks could be classified as demand shocks since they capture movement in the incentives to investment not captured by the monetary policy rate and the marginal productivity of capital.

Any satisfactory analysis of these shocks has to provide an answer to the following questions: What are the sectors where these shocks originate? What are the intermediate variables that are affected by these shocks and that in turn pass on these effects to the production (growth) sector of the economy? What are the equilibrating variables in the economy that adjust to the disequilibrium created by these shocks? How do we quantify all these effects that originate in one sector and then spread to the rest of the economy through multiple channels? How do we differentiate between the short term and long term effects of these shocks? What are the worst-case scenarios in the eventuality of multiple shocks simultaneously affecting the economy? How do we assess the ability of public policy interventions in mitigating these shocks? The DSGE model we aim at constructing should allow answering these questions.

The rest of the chapter is organized as follows. Section 2 gives a description of the model. Section 3 yields on the structure of the model. Section 4 concludes.

2- Model description

The analytical framework we rely on has a core structure of the new generation of New Keynesian dynamic stochastic general equilibrium models. From a methodological point of view, the bulk of New Keynesian dynamic stochastic general equilibrium models developed over the past decades could in principle cover and investigate a large number of issues in various economies. This is worth recalling as one of the challenges we face in this chapter is to come up with a reasonable description of the economy of Cameroon while highlighting its specificities.

The basic environment we adopt is one where an infinitely lived representative agent maximizes the utility from consumption and leisure, subject to an intertemporal budget constraint. A large number of firms have access to an identical technology, subject to exogenous shocks and evolve in a monopolistic competition environment where private agents set the prices of goods in order to maximize their objectives. Nominal rigidities constrain the frequency with which firms adjust the prices of the goods and services they sell, or workers, the wages at which they supply labour.

However, in addition to these New-Keynesian distinguishing traits, the analytical framework we adopt in this chapter seeks a more realistic picture of the Cameroonian economy. It gives a specific accent to structural characteristics susceptible to make such an economy more vulnerable to exogenous shocks[10]. Thus, by taking account of basic features of the Cameroonian economy, this research's analytical framework is more likely to minimize the conflict between theoretical predictions and empirical evidence, or between normative implications and policy practice.

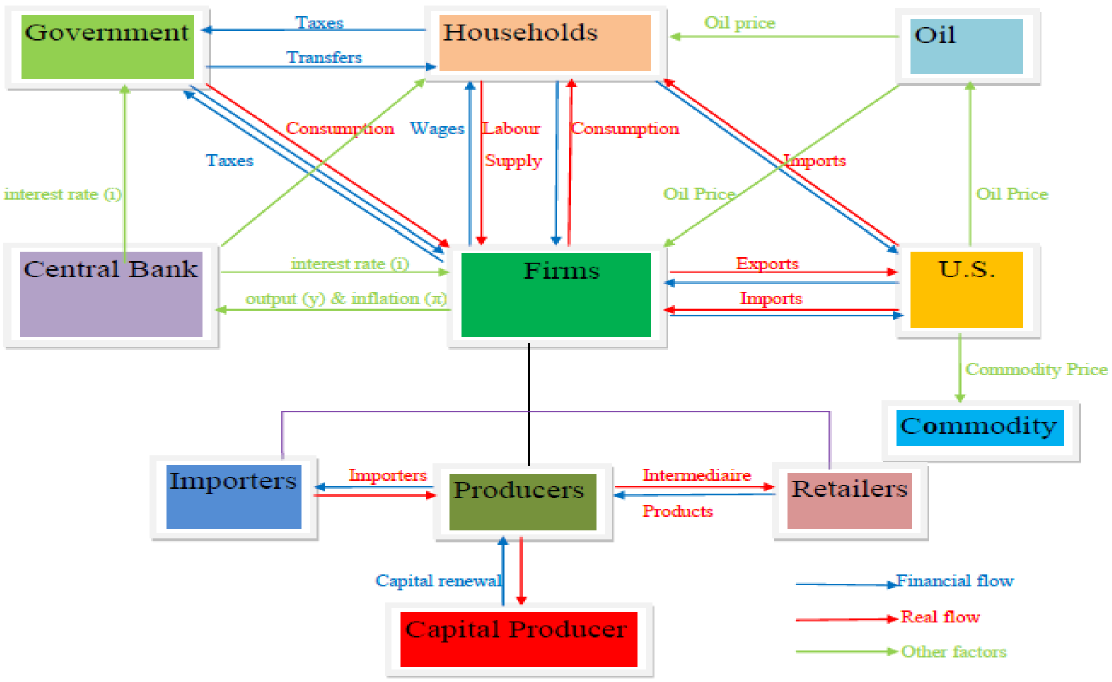
Overall, the model is closely in spirit to the ones developed by Christiano et al (2005), Altig et al. (2003, 2004), and Smets and Wouters (2003, 2007). There are four types of firms in the economy. A first type consists of firms producing differentiated varieties of intermediate tradable goods. These firms produce using labour, capital and oil as inputs, and sell their varieties in the domestic and foreign markets. They have monopoly power over the varieties they produce and set prices in a staggered way. A second type of firms is that of importers domestically distributing different varieties of foreign intermediate varieties. These firms also have monopoly power over the varieties they distribute, and set prices in a staggered fashion. A third type consists of capital goods producers who combine old capital and purchased investment to produce new capital. A final single firm is that which produces a commodity good which is completely exported abroad. This firm has no market power. It takes the international price of the commodity good as given and produces using natural resources only. The stock of natural resources is determined exogenously and is owned by the government as well as by foreign investors. This commodity-export sector is meant to characterize the wood sector in Cameroon.

[10] Structural shocks (both domestic and external) such as the productivity shock, the financial shock, the preferences and labour shocks, the terms of trade shock, the export demand shock, the foreign inflation shock, the investment adjustment cost shock, the commodity production shock, the foreign commodity price shock, the oil price shock, the price of imports shock, and the foreign output shock are introduced into various structural equations in the model.

Domestic and foreign intermediate varieties are used to assemble two final goods: home and foreign goods. These two final goods are combined together with oil into a bundle consumed by households, another bundle consumed by the government and a third bundle that corresponds to new capital goods that are accumulated to increase the capital stock. We consider two types of households: Ricardian households and non-Ricardian households. The former group make inter-temporal consumption and savings decisions in a forward looking manner by maximizing their utility subject to their inter-temporal budget constraint. The latter group consume their after-tax disposable income. They receive no profits from firms and have no savings. The monetary policy is conducted through a policy rule for the interest rate while the fiscal authority behaves in a manner that resembles the current structural balance rule implemented by the Government. The model exhibits a balanced growth path. Beside these endogenous variables, different shocks are introduced as sources of fluctuations, and in a log-linear form, these shocks are assumed to follow an orthogonal autoregressive processes of order one.

Overall, 54 equations are used to describe the economy including 38 non-linear optimality conditions that define the decisions that dictate economic agent's behaviours in their decision-making. The uncertainty economic agents confront in decision-making is characterized by exogenous processes introduced in the DSGE model. These exogenous shocks drive the economy away from its stationary state (or equivalently the balanced growth path) and trigger business cycles fluctuations. Figure 1 below provides a picture of the economy so described.

Figure 1: A bird's eye view of the model



3- Model's Structure

The model's structure is as follows:

3.1- Households

There is a continuum of households indexed by $h \in [0,1]$. A share $1- \omega$ of this continuum of households is referred to as Ricardian households type and is indexed by $i \in (0,1-\omega)$. These households have access to financial markets, where they buy and sell government bonds, and accumulate physical capital, the services of which they rent out to firms. The remaining share ω of households is referred to as non-Ricardian households type and is indexed by $j \in (1- \omega,1)$. These households do not trade in asset markets and simply consume their disposable income.

3.1.1- Ricardian Households

Each Ricardian household i maximizes its lifetime utility which depends positively on the difference between the current, individually chosen level of consumption, C_{Rt}, and the average consumption level that was chosen in the previous period by the Ricardian peer group, $C_{R,t-1}$, and negatively on labour supply, L_{Rt}. Two serially correlated shocks enter the utility function: $\varepsilon_{C,t} = \rho_C \varepsilon_{C,t-1} + \eta_{C,t}$ is a preference shock that affects the Ricardian household's willingness to smooth consumption over time, and $\varepsilon_{L,t} = \rho_L \varepsilon_{L,t-1} + \eta_{L,t}$ represents a shock to labour supply. The utility function is given by

$$U(C_{Rt}, L_{R,t}) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\varepsilon_{C,t} \frac{(C_{Rt} - hC_{Rt-1})^{1-\sigma}}{1-\sigma} - \varepsilon_{L,t} \frac{L_{Rt}^{1+\varphi}}{1+\varphi} \right) \quad (1)$$

E_0 denotes mathematical expectation, conditional on the information set available at time 0. The discount factor β is subject to the constraint that $0 < \beta < 1$. The instantaneous utility function is additively separable in consumption and leisure, and the function $U(.)$ is strictly concave and continuously differentiable. The household total available time is normalized to one and allocated between work and leisure. The household's leisure is given by $l_{Rt} = 1 - L_{Rt}$, where L_{Rt} denotes the household's hours worked. The parameter σ is the coefficient of the relative risk aversion or the inverse of the elasticity of inter-temporal substitution in consumption, while the parameter φ is the inverse of the elasticity of work effort with respect to real wage. Here, preferences display habit formation in consumption governed by the h parameter.

We assume that international asset markets are incomplete and that home residents who are able to do so, trade two nominal riskless bonds denominated in the domestic and foreign currencies. These bonds are issued by residents in both countries in order to finance their consumption expenditure. Among these two nominal bonds, home bonds are only nationally traded.

The interest rate bearing debt B_t denominated in domestic currency at an exogenous gross interest rate is defined as $\varepsilon_{b,t}(1+\ i_t)$. As in Smet and Wouters (2007), $\varepsilon_{b,t}$ is an exogenous premium on the gross return to debt denominated in domestic currency versus the risk free interest rate i_t controlled by the central bank. The exogenous premium characterizes the risk premium that households require to hold the one-period government bonds, or it reflects the aggregate imperfections and inefficiencies of the domestic financial market. These aggregate imperfections and inefficiencies in the domestic financial market arise from information asymmetries (adverse selection, moral hazard, monitoring cost, agency cost)[11]. They may affect the nature of financial contracts households receive, widen the wedge between the cost of internal and external financing, or induce a rationing equilibrium whereby only a limited number of agents have access to external financing. We assume that the household's risk premium follows a first order autoregressive process given by:

$$ln\varepsilon_{b,t} = \ (1-\ \rho_b)ln\varepsilon_b + \ \rho_b ln\varepsilon_{b,t-1} + \ \eta_{b,t} \tag{2}$$

where $0 < \rho_b < 1$, and the structural financial-market-shock $\eta_{b,t}$ is serially uncorrelated, independently and identically distributed as $\eta_{b,t} \sim N(0, \sigma_b^2)$.

On the other hand, foreign residents can allocate their wealth only in bonds D_t denominated in the foreign currency. When borrowing D_t, which is denominated in the foreign currency, households pay i_t^* which is the foreign fixed interest rate. Note that borrowing operations of D_t by households are subject to a premium that domestic households have to pay as they borrow from abroad[12]. This premium is a function of the net foreign asset position relative to GDP, D_t, which is given by

[11] See Walsh (2003), chapter 7 for more details.

[12] This premium is introduced mainly as a technical device to ensure stationarity (see Schmitt-Grohé and Uribe, 2003)

$$\mathcal{D}_t = \frac{S_t D_t}{P_{Y,t} Y_t} \qquad (3)$$

where $P_{Y,t}Y_t$ is nominal GDP, D_t, the aggregate net asset position of the economy, and S_t the nominal exchange rate[13].

The fact that the premium depends on the aggregate net asset position (and not the individual position) implies that Ricardian households take it as an exogenous variable when optimizing.

Since the domestic bond market and the international bond market are integrated, the structural financial-market-shock drives the (gross) foreign interest rate, which is assumed to follow an Auto-Regressive Moving Average model of order (1,1) ($ARMA(1,1)$) stochastic process given by

$$ln(1 + i_t^*) = (1 - \rho_R) ln(1 + i_{ss}^*) + \rho_R ln(1 + i_{t-1}^*) + \eta_{b,t} + \mu_R \eta_{b,t-1} \qquad (4)$$

The moving average (MA) term captures the frequency of the financial-market-shock on the foreign interest rate.

Households own monopolistically competitive firms and receive all the profits Π_t. Capital goods producing firms operate on competitive markets, and have their profits equal to zero. A government lump sum tax (or subsidy) T_t is levied (or allocated) to households at each period t. When supplying labour to intermediate goods firms, households receive W_t.

At each period t, the representative household's real budget constraint is given by.

[13] $D_t = \int_\lambda^1 D_t(j)\,dj$

$$(1+\tau_t^c)C_{R,t} + \frac{B_t}{P_t} + \frac{S_t D_t}{(1+i_t^*)\Theta(D_t)} \leq \varepsilon_{b,t}(1+i_{t-1})\frac{B_{t-1}}{P_t} + S_t D_{t-1} + (1-\tau_t^d)w_t L_t - T_t + \Pi_t \qquad (5)$$

where B_t and D_t are the aggregated holdings of domestic and foreign nominal risk-less bonds denominated in the local currency and S_t is the nominal exchange rate defined as the price of the foreign currency unit in terms of the domestic currency. At the steady-state, we assume that $\Theta(.) = \Theta$ and $\frac{\Theta'}{\Theta}\mathcal{D} = \rho$. When the country is a net debtor, ρ corresponds to the elasticity of the upward-sloping supply of international funds. τ_t^c and τ_t^d, denote respectively consumption and labour income tax rates.

Equation (5) expresses a conventional budget constraint. It simply states that cash expenditure on consumption, new borrowing on domestic and/or international financial markets, and portfolio adjustment costs must not exceed cash revenue from labour supply, transfer from the government, profits from monopolistically competitive firms, and repayment from last period loans.

The Ricardian household's decision problem consists in maximizing the inter-temporal utility function (1) subject to the resource constraint (5).
The Lagrangian associated with this household's decision problem is given by:

$$L_t = E_t \sum_{k=0}^{\infty} \beta^k \Bigg[\frac{(C_{t+k} - hC_{t+k-1})^{1-\sigma}}{1-\sigma} - \frac{L_{t+k}^{1+\varphi}}{1+\varphi} + \Lambda_{t+k}\Bigg(\varepsilon_{b,t+k}(1+i_{t+k-1})\frac{B_{t+k-1}}{P_{t+k}} + S_{t+k}D_{t+k-1} + (1-\tau_t^d)w_{t+k}L_{t+k} - T_{t+k} + \Pi_{t+k} - \bigg((1+\tau_t^c)C_{t+k} + \frac{B_{t+k}}{P_{t+k}} + \frac{S_{t+k}D_{t+k}}{(1+i_{t+k}^*)\Theta(D_{t+k})}\bigg)\Bigg)\Bigg]$$

where Λ_{t+k} is the Lagrange multiplier.

The first order condition with respect to consumption is:
$(C_t - hC_{t-1})^{-\sigma} - \Lambda_t = 0.$

Likewise, the first order condition with respect to bonds denominated in domestic currency B_t is given by:

$$-\Lambda_t\left(\frac{1}{P_t}\right) + \beta E_t\left[\varepsilon_{b,t}(1 + i_t)\left(\frac{1}{P_{t+1}}\right)\Lambda_{t+1}\right] = 0$$

Combining these two equations, one obtains the household's optimal consumption-saving allocation given by:

$$(C_t - hC_{t-1})^{-\sigma} = \beta E_t\left[\varepsilon_{b,t}(1 + i_t)\frac{P_t}{P_{t+1}}(C_{t+1} - hC_t)^{-\sigma}\right] \qquad (6)$$

Equation (6) is a classical Euler equation for the optimal inter-temporal allocation of consumption and savings. The dynamics of the household's aggregate consumption explicitly depend on external habit formation. When there is no external habit formation in consumption, $h = 0$, equation (6) reduces to the traditional forward-looking consumption equation. With external habit formation in household preferences, the percentage deviation of consumption from its steady-state level depends on a weighted average of past and future consumption.

The real interest rate also affects consumption. The interest rate elasticity of consumption depends on both the inter-temporal elasticity of substitution and the habit persistence parameter. A low degree of persistence tends to increase the marginal impact of the real interest rate on consumption at a given elasticity of substitution. The last factor that affects consumption is the premium $\varepsilon_{b,t}$, which corresponds to the wedge between the risk free interest rate controlled by the central bank and the return on assets held by households. Thus, a positive shock on this wedge increases the return on assets held by households and reduces consumption. It is worth observing that the exogenous risk premium induces on consumption qualitative and quantitative effects that are similar to those of the preference shock (see Smets and Wouters, 2003).

The first order condition with respect to bonds denominated in the foreign currency is given by:

$$-\Lambda_t\left(\frac{S_t}{(1+i_t^*)\Theta(D_t)}\right)+\ \beta E_t[\Lambda_{t+1}S_{t+1}]=0$$

From the first order condition with respect to bonds denominated in the domestic currency, we can obtain the relation $E_t\left(\frac{\Lambda_t}{\Lambda_{t+1}}\right)=\ \beta E_t\left(\varepsilon_{b,t}(1+\ i_t)\frac{P_t}{P_{t+1}}\right)$, which one can use to simplify the optimal choice of bonds denominated in the foreign currency. This yields:

$$E_t\left[\varepsilon_{b,t}(1+\ i_t)\frac{P_t}{P_{t+1}}\right]=\ E_t\left[(1+\ i_t^*)\Theta(\mathcal{D}_t)\frac{S_{t+1}}{S_t}\right] \tag{7}$$

Equation (7) provides the interest rate parity condition for households' choice of debt as denominated in the domestic currency and in the foreign currency. In equilibrium, both domestic currency denominated debt and foreign currency debt must have the same expected return.

Equation (7) provides some helpful insights on the international bond market, especially on the integration between domestic and foreign bond markets. Not only does the stochastic process, induced by aggregate financial imperfections on the domestic credit market, translate into a wedge between the risk free (domestic) interest rate controlled by the central bank and the return on assets held by the households, but it also widens the interest rate differential between home and abroad. A positive financial market shock then raises the expected real interest differential between the domestic economy and the rest of the world, which increases capital inflows and appreciates the domestic currency (decrease in S_t). A solution of the spot exchange rate can be derived by performing a forward-looking iteration of equation (7). That forward-looking solution shows that the exchange rate responds instantaneously and negatively to expected premium shocks as well as to any new information about expected future real interest rate differentials. Eventually, the initial appreciation of the domestic currency following a financial market shock induces its future expected depreciation (increase in $\hat{S}_{t+1}$) as the equilibrium in the international household debt market needs to be restored.

3.1.2- Non-Ricardian households

Non-Ricardian households are modeled as non-optimizing agents following the original assumption in Campbell and Mankiw (1989) and Gali et al. (2007). Since the members of non-Ricardian households do not have access to financial markets, they simply consume all of their after-tax disposable income. Denoting consumption and labour input of non-Ricardian households as $C_{NR,t}$ and $L_{NR,t}$, the period-by-period budget constraint they face is given by (expressed in real terms):

$$(1+\tau_t^c)C_{NRt} = \left(1-\tau_t^d\right)w_t L_{NRt} \tag{8}$$

3.1.3- Structure of consumption

Household's composite consumption index C_t is a nested constant elasticity of substitution (CES) given by

$$C_t = \left[(1-\omega)^{\frac{1}{\eta}} Z_t^{\frac{\eta-1}{\eta}} + \omega^{\frac{1}{\eta}} O_{C,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \ \omega \in (0,1) \text{ and } \eta > 0. \tag{9}$$

ω is the share of oil consumption in the composite consumption C_t, and θ is the elasticity of intra-temporal substitution between non-oil consumption (core consumption), Z_t, and oil consumption, $O_{C,t}$, and the overall price index is:

$$P_t = \left[(1-\omega)P_{z,t}^{1-\eta} + \omega P_{o,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{10}$$

According to (10), any change in oil prices has a direct impact on the price level of the economy. It affects intra/inter-temporal consumption decisions and labour decisions, and also influences the cost structure of firms and through this channel, it has a second-round effect on domestic prices. The presence of oil in the total consumer price index (CPI) opens the question of whether monetary authorities should react to fluctuations in total CPI inflation (including fuels) or just core inflation.

The composition of the non-oil consumption is given by

$$Z_t = \left[\gamma^{\frac{1}{\theta}}(C_{F,t})^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}}(C_{H,t})^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{11}$$

where $C_{H,t}$ represents the bundle of domestic produced goods, and $C_{F,t}$, the bundle of imported goods. Here, θ, is the intra-temporal elasticity of substitution between home and foreign goods.

For any level of consumption, each household purchases a composite of home and foreign goods, and oil in order to minimize the total cost of its consumption basket (see Appendix C1 for the detailed procedure). Hence, each household minimizes $P_{o,t}O_{C,t} + P_{z,t}Z_t$, subject to (9), $P_{o,t}$ and $P_{z,t}$ denoting the price of oil and the price of core consumption, respectively. The demand for oil consumption and core consumption are then given by:

$$Z_t = (1-\omega)\left(\frac{P_{z,t}}{P_t}\right)^{-\eta} C_t \tag{12}$$

and

$$O_{c,t} = \omega\left(\frac{P_{o,t}}{P_t}\right)^{-\eta} C_t \tag{13}$$

Likewise, each household determines the optimal composition of core consumption by minimizing the cost of the core consumption basket, $P_{H,t}C_{H,t} + P_{F,t}C_{F,t}$, subject to (11), $P_{H,t}$ and $P_{F,t}$ denoting the price of domestically produced goods, and the price of imported goods, respectively.

The demand functions for home goods and foreign goods are given by:

$$C_{H,t} = (1-\gamma)\left(\frac{P_{H,t}}{P_{Z,t}}\right)^{-\theta} C_t \tag{14}$$

and

$$C_{F,t} = \gamma\left(\frac{P_{F,t}}{P_{Z,t}}\right)^{-\theta} C_t \tag{15}$$

The consumer price index for non-oil goods is given by:

$$P_{z,t} = \left[(1-\gamma)P_{H,t}^{1-\theta} + \gamma P_{F,t}^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{16}$$

3.1.4- Household Labour Supply Decisions

Labour supply decisions and wage setting in this model are the outcome of a two-step process. In the first step and following Erceg et al. (2006), and essentially Coenen and Straub (2005), we assume that households (Ricardian and non-Ricardian) act as wage setters for their differentiated labour services $L_{R,t}(i)$ and $L_{NR,t}$ in monopolistically competitive markets. Nominal wages for differentiated labour services $W_{R,t}(i)$ and $W_{NR,t}$ are determined by staggered contracts as in Calvo (1983). This assumption is in line with the stylized fact we highlighted in chapter 1, that nominal wages in Cameroon are indeed persistent. Because all households face the same labour demand schedule, both wages and labour hours will be equal for every household type, i.e.,

$W_{R,t}(i) = W_{NR,t}(j) = W_t(n)$ and $L_{R,t}(i) = L_{NR,t}(j) = L_t(n)$.

An independent and perfectly competitive employment agency bundles differentiated labour $L_t(n)$ into a single type of effective labour input L_t using the following technology:

$$L_t = \left[\int_0^1 \left(L_t(n)\right)^{\frac{1}{1+\lambda_{w,t}}} dn\right]^{1+\lambda_{w,t}}$$

where an i.i.d. normal shock $\eta_{w,t}$ is assumed for the wage markup $\lambda_{w,t} = \lambda_w + \eta_{w,t}$: The employment agency solves:

$$\max_{L_t(n)} W_t L_t - \int_0^1 L_t(n) W_t(n) dn$$

where $W_t \equiv w_t P_t$ is an aggregate nominal wage index. The labour demand schedule for each differentiated labour service is then expressed as:

$$L_t(n) = \left(\frac{W_t(n)}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t$$

Putting the labour demand in the bundler technology of the employment agency gives:

$$W_t = \left[\int_0^1 \left(W_t(n)\right)^{-\frac{1}{\lambda_{w,t}}}\right]^{-\lambda_{w,t}}$$

Labour unions are also subject to nominal rigidities; and at each period, they can adjust wages following the Calvo (1983) mechanism of adjustment with probability $1-\theta_w$. For labour unions that can set wages optimally, the problem consists in choosing $\widetilde{W}_{jt}$ that maximizes the labour incomes in all state of nature they are stuck with in the future. For the remaining θ_w, labour union that cannot adjust wage at a period $t+k$, wages increase at the labour augmenting deterministic growth rate g and the weighted average of the steady-state (gross) inflation π_* and the last period inflation such that their wage is given by

$$W_{jt+k} = g\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\theta_w} \pi_*^{1-\theta_w} \tilde{W}_{jt}$$

where θ_w is the degree of wage indexation in the small open economy.

The maximization problem by optimizing labour unions is given by

$$\max_{\tilde{W}_{jt}} E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k \frac{P_t \Lambda_{t+k}}{P_{t+k}\Lambda_t}\left[g\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\theta_w} \pi_*^{1-\theta_w} \tilde{W}_{jt} - w_{t+k}\right] L_{jt+k}$$

subject to the labour demand

$$L_{jt+k} = \left(\frac{g\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\theta_w} \pi_*^{1-\theta_w} \tilde{W}_{jt}}{W_{t+s}}\right)^{\frac{1+\epsilon_w}{\epsilon_w}} L_{t+k}$$

The first order necessary condition for this optimization problem is given by

$$E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k \frac{P_t \Lambda_{t+k}}{P_{t+k}\Lambda_t} N_{jt+k}\left[\left(\frac{1+\epsilon_w}{\epsilon_w}\right) w_{t+k} - \frac{1}{\epsilon_w}\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\theta_w} \pi_*^{1-\theta_w} \tilde{W}_{jt}\right] = 0$$

which yields the solution

$$\widetilde{W}_{jt} = \frac{E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k \frac{P_t A_{t+k}}{P_{t+k} A_t} N_{jt+k} \left[\left(\frac{1+\epsilon_w}{\epsilon_w} \right) w_{t+k} \right]}{E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k \frac{P_t A_{t+k}}{P_{t+k} A_t} N_{jt+k} \left[\frac{1}{\epsilon_w} g \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{l_w} \pi_*^{1-l_w} \widetilde{W}_{jt} \right]} \qquad (*)$$

At each period t, the $1-\theta_w$ optimizing labour unions choose the wage $\widetilde{W}_{jt}$; and the remaining fraction θ_w adjust wage to $\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\theta_w} \pi_*^{1-\theta_w} W_{t-1}$. The aggregate wage expression is then given by

$$W_t = \left[\theta_w \left(g \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{l_w} \pi_*^{1-l_w} W_{t-1} \right)^{-\frac{1}{\epsilon_w}} + (1-\theta_w) \widetilde{W}_t^{-\frac{1}{\epsilon_w}} \right]^{-\epsilon_w} \qquad (**)$$

Equations (*) and (**) give the households' wage dynamics.

3.2- Firms

As mentioned earlier, there are four types of firms: (i) capital goods producers who combine old capital and purchased investment to produce new capital, (ii) domestic retailers who collect from intermediate goods producers to sell on the domestic market, $Y_{H,t}$, (iii) intermediate goods firms who combine factors of production to produce domestic goods, $Y_{H,t}(i)$ and (iv) import goods retailers who buy $Y_{F,t}$ on the foreign market to sell on domestic market. Domestic retailers firms are net buyers of domestic intermediate varieties produced by domestic intermediate goods producing firms and assemble them as final home goods. These firms sell a quantity of home goods, in the domestic goods market and also export the remaining quantity abroad. Import goods retailers on the other hand purchase foreign goods at world market prices, and sell their output to domestic consumers. These firms charge a markup over their cost, which creates a wedge between domestic and import prices of foreign goods, when both are measured in the same currency.

3.2.1- Capital goods producers

The activity pertaining to the role of capital producers in the economy consists in repairing depreciated capital goods and building new ones, all this being carried over in a competitive way. The production of new capital is subject to adjustment costs while the repair of old capital goods is not, as in Eisner and Strotz (1963), Lucas (1967) and Gertler et al. (2006). It is also assumed that there is no possibility of substitution between old capital and new capital. The argument is that only when repaired is the old capital likely to be productive.

Both activities (old capital maintenance and production of new capital) use the same input: a composite investment good that is composed of domestic and foreign final goods:

$$I_t = \left[(1-\gamma)^{\frac{1}{\theta}}\left(I_{H,t}\right)^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}}\left(I_{F,t}\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}$$

The capital stock evolves according to the law of motion

$$K_t = (1-\delta)K_{t-1} + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t \tag{17}$$

where δ is the depreciation rate of capital, I_t is the economy gross investment, and K_{t-1} is the installed capital of the sector. $S(*)$ is a convex adjustment cost function, which, at the steady-state, satisfies the properties $S(*) = 0$ and $S'(*) = 0$.

At each period, capital producers combine the installed capital K_{t-1} and the purchased investment I_t to produce the new installed capital K_t. This transformation is done according to the technology given by the law of motion (17). The new installed capital K_t is available at the beginning of period $t+1$, and is sold on a competitive market.

As indicated previously, the capital utilization rate u_t links the capital service K_t^* to the installed capital goods K_{t-1}. Capital producing firms choose the optimal capital utilization rate in the economy. This optimization process allows capital goods producing firms to "recover" the cost associated with the variable capital utilization in the economy[14]. These costs, measured in terms of consumption goods, are equal to $J(u_t)K_{t-1}$. As in Christiano, Eichenbaum and Evans (2005), or Smets and Wouters (2003, 2007), the cost of adjusting the capital utilization rate at the steady-state is zero, which implies $J(1) = 0$.

The capital producing firms minimize the real cost of producing the new installed capital K_t. The firm's real cost minimization problem is recursive because of the convex adjustment cost function $S(*)$ that describes the cost of adjusting the capital stock as a function of the change in investment. Ultimately, all firms belong to individual households, and the firm discount rate is $\Gamma_{t,k} = \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}}$, which is the discount rate of shareholders-households.

The capital producing firm's real cost minimization problem is formulated as follows:

$$\min_{I_t, K_t, u_t} E_t \sum_{k=0}^{\infty} \beta^k . \frac{\Lambda_{t+k}}{\Lambda_t} (I_{t+k} + R_{Kt+k} u_{t+k} K_{t+k-1} - J(u_{t+k}) K_{t+k-1})$$

subject to the constraint of the capital law of motion given by equation (17). The Lagrangian associated with this optimization problem is given by

[14] Note that the recovering of those costs associated with the capital utilization rate might be viewed as the benefit from recycling used capital.

$$L_t = \min_{I_t, K_t, u_t} E_t \sum_{k=0}^{\infty} \beta^k . \frac{\Lambda_{t+k}}{\Lambda_t} \Big[I_{t+k} + R_{Kt+k} u_{t+k} K_{t+k-1} - J(u_{t+k}) K_{t+k-1} + Q_{t+k} \left(K_{t+k} - (1-\delta) K_{t+k-1} - \left(1 - S\left(\frac{I_{t+k}}{I_{t+k-1}}\right)\right) I_{t+k} \right) \Big]$$

The Lagrange multiplier associated with this real cost minimization problem is Q_t at period t. Because of the competitive market structure, Q_t is the market value of capital in terms of consumption goods, and Q_t consequently denotes the economy's "Tobin's Q"[15]. The first order condition with respect to the new installed capital goods is given by:

$$Q_t - \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \left(R_{Kt+1} u_{t+1} - J(u_{t+1}) + (1-\delta) Q_{t+1} \right) = 0 \qquad (18)$$

Equation (18) expresses the value of the installed capital as a function of its expected value, net of the depreciation and the expected real return. The first order condition with respect to the investment I_t is the following

$$1 - Q_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right) \right] - \beta E_t \left[\frac{\Lambda_{t+k}}{\Lambda_t} Q_{t+1} S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)^2 \right] = 0 \qquad (19)$$

The capital adjustment cost, measured as a function of change in investment, introduces an investment dynamics that depend on both past and future investments. The effects of these shocks on the investment and the market value of the capital operate in the same fashion as the so-called net-worth shocks illustrated in Bernanke, Gertler and Gilchrist (1999). The effects of the financial-market-shock on investment and Tobin's Q differentiate that shock from the discount factor shock (preference shock), which only affects consumption through the Euler equation.

[15] Note that the Lagrange multiplier is the shadow price or shadow value of the constraint. Since the marginal rate of transformation from the previously installed capital (after it has depreciated by $1-\delta$) to the new capital is exactly unity, the price of the new and used capital must be the same.

The first order condition with respect to the capital utilization rate is given by:

$$R_{Kt} = J'(u_t) \tag{20}$$

Equation (20) establishes the equality between the cost of higher utilization rate and the rental price of capital services.

Equations (18), (19), and (20) represent the equilibrium decision rules of the capital production firm. The first observation is that the investment dynamics and the optimal choice with respect to the capital utilization rate are identical to those in Smets and Wouters (2003, 2007) closed economy models, where households are allowed to own capital and to make decisions on investment, capital stock, and capital utilization rate. Transferring capital good's ownership from the household to a distinctive component does not distort the dynamics of investment; these dynamics seem to depend primarily on the capital goods market structure rather than on the ownership of the capital stock. The dynamics of the shadow price of capital Q_t is also similar; an expected increase in the real rate of return to capital, *ceteris paribus*, boots the demand for capital goods, which in turn raises the market value of capital.

This setting assumes that capital producers use the capital service to produce physical capital goods. Christiano, Motto, and Rostogno (2007) adotpt a different perspective. In their model, capital producers purchase the installed capital goods, which they combine with the current period investment to produce the new capital stock ready for use in the next period.

3.2.2- Domestic retailer firms

Final goods firms in the domestic economy assemble $Y_{H,t}(i)$, under perfect competition to produce $Y_{H,t}$. More specifically, $Y_{H,t}$ is a continuum of intermediate goods $Y_{H,t}(i)$ bought on the market and packaged according to an aggregator function

F. The general form of F we assume here is that of a flexible aggregator as in Kimball's (1995) neo-monetarist model,

$$1 = \int_0^1 F\left(\frac{Y_{H,t}(i)}{Y_t}, \varepsilon_{p,t}\right) di \tag{21}$$

The index i identifies the intermediate good $Y_{H,t}(i)$ produced in the s sector; $\varepsilon_{p,t}$ is a stochastic process that channels exogenous shocks to the aggregator function, F. The general aggregator function F satisfies the condition $F(1) = 1$. In addition, F is an increasing function ($F'(x) > 0$) and strictly concave ($F''(x) < 0$).

Shocks to the general aggregator function change the elasticity of the demand for $Y_{H,t}(i)$ and the markup of the producer. The conventional interpretation of this shock is that of a "cost-push-shock" (Clarida, Gali and Getler, 1999; Smets and Wouters, 2003, 2007) to the inflation dynamics.

3.2.2.1- Domestic retailer Firm's problem

Final goods producers operating in a competitive goods market, aim to maximize their profit given by:

$$P_{H,t}Y_{H,t} - \int_0^1 P_{H,t}(i)Y_{H,t}(i)\, di \tag{22}$$

where the maximization is carried over ($Y_{H,t}, Y_{H,t}(i)$) and is subject to the constraint imposed by (21). $P_{H,t}$ is the final goods price, and $P_t(i)$ is the intermediate good i's price.

The solution of the final goods producer's problem is generally obtained by using the Lagrangian optimization method. Let λ_t be the Lagrange multiplier associated with the constraint (22). The Lagrangian for the final good firm maximizing its profit is given by:

$$L_t = P_{H,t}Y_{H,t} - \int_0^1 P_{H,t}(i)Y_{H,t}(i)\,di + \lambda_t\left[\int_0^1 F\left(\frac{Y_{H,t}(i)}{Y_{H,t}}, \varepsilon_{p,t}\right)di - 1\right]$$

The first order conditions with respect to Y_{st} and $Y_{sH,t}(i)$, respectively, are as follows:

$\frac{\partial L_t}{\partial Y_t} = P_{H,t} + \lambda_t \int_0^1 F'\left(\frac{Y_{H,t}(i)}{Y_t}, \varepsilon_{p,t}\right)\left(-\frac{Y_{H,t}(i)}{Y_{H,t}^2}\right)di = 0$, which can be written as

$$P_{H,t} = \frac{\lambda_t}{Y_{H,t}} \int_0^1 F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}}, \varepsilon_{p,t}\right)\left(\frac{Y_{H,t}(i)}{Y_{H,t}}\right)di \tag{23}$$

and

$$\frac{\partial L_t}{\partial Y_{H,t}} = -P_{H,t}(i) + \frac{\lambda_t}{Y_{H,t}} F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}}, \varepsilon_{p,t}\right),$$

which is equivalent to

$$P_{H,t}(i) = \frac{\lambda_t}{Y_{H,t}} F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}}, \varepsilon_{p,t}\right) \tag{24}$$

Dividing side by side (23) and (24), we obtain

$$\frac{P_{Ht}}{P_{H,t}} = \frac{\int_0^1 F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}}, \varepsilon_{p,t}\right)\left(\frac{Y_{H,t}(i)}{Y_{H,t}}\right)di}{F'\left(\frac{Y_{H,t}}{Y_{H,t}}, \varepsilon_{p,t}\right)}$$

This equation is equivalent to

$$F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}},\varepsilon_{p,t}\right)=\frac{P_{H,t}(i)}{P_{H,t}}.\int_0^1 F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}},\varepsilon_{p,t}\right)\left(\frac{Y_{H,t}(i)}{Y_{H,t}}\right)di.$$

The demand curve for the input Y_{it} is then given by:

$$Y_{H,t}(i)=Y_{H,t}F'^{-1}\left[\int_0^1 F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}},\varepsilon_{p,t}\right)\left(\frac{Y_{H,t}(i)}{Y_{H,t}}\right)di\right] \tag{25}$$

As mentioned above, the properties of the aggregator function ensure that the demand for the intermediate good $Y_{H,t}(i)$ is a decreasing function of the relative price[16] $\frac{P_{H,t}}{P_{H,t}(i)}$.

The competitive market structure for the final good firms imposes a zero profit condition to the expression (22); that condition helps to derive the aggregate price $P_{H,t}$, the expression of which is given by:

$$P_{H,t}=\int_0^1 P_{H,t}(i)F'^{-1}\left[\int_0^1 F'\left(\frac{Y_{H,t}(i)}{Y_{H,t}},\varepsilon_{p,t}\right)\left(\frac{Y_{H,t}(i)}{Y_{H,t}}\right)di\right]di \tag{26}$$

Several aggregator functions are used in the literature. The original functional forms, tracing back to Dixit Stiglitz (1977), put emphasis on a constant elasticity of substitution between varieties. Recent developments in the DSGE modelling literature tend to advocate a time varying elasticity of substitution through which exogenous shocks impinge into the aggregate function. For example, Christiano, Motto and Rostagno (2007); Smets and Wouters (2003, 2007); Del Negro, Shorfheid, Smets and Wouters (2007), and Adolfson, Laséen, Lindé and Villani (2007) propose the functional form $F(x)=(x)^{\frac{1}{1+\varepsilon_t^p}}$ and in this case the final good is given by the relation

[16] To prove that the demand for the intermediate good is a decreasing function on the relative price; first, recall that $F''(x)<0$ implies that F' is an invertible function, and that F'^{-1} denotes the inverse function. Second, for any positive value x, one can easily write $F'\left(F'^{-1}(x)\right)=x$. The derivative of this last equality yields $F''\left(F'^{-1}(x)\right)\left(F'^{-1}(x)\right)'=1$, which implies that $\left(F'^{-1}(x)\right)'=\frac{1}{F''\left(F'^{-1}(x)\right)}$. As $F''(x)<0$, we have $\left(F'^{-1}(x)\right)'<0$. In other words, the derivative of the function F'^{-1} has a negative sign. That property notably makes F'^{-1} being a decreasing function on its arguments, hence, a decreasing function on the relative price.

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}^{\frac{1}{1+\varepsilon_{p,t}}}(i)di\right]^{1+\varepsilon_{p,t}} \quad (27)$$

where $\varepsilon_{p,t}$ characterizes the stochastic process through which shocks affect the aggregator function F. It embodies the time varying elasticity of the demand curve that is faced by the supplier i and is assumed to follow an $ARMA(1,1)$ process given by

$$ln\varepsilon_{p,t} = (1-\ \rho_p)ln\varepsilon_p + \rho_p ln\varepsilon_{p,t-1} + \eta_{p,t-1} + \mu_p\eta_{p,t-1} \quad (28)$$

where the "cost-push-shock" $\eta_{p,t-1}$ is identically and independently distributed such that $\eta_{p,t-1}\sim N(0,\sigma_{sp})$. As in Smets and Wouters (2007), inclusion of the MA term in the $\varepsilon_{p,t-1}$ process is meant to capture frequency fluctuations of the domestic good inflation.

The demand curve for the intermediate good i, determined from Equation (25) of the final good producer's profit maximization problem is given by:

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{\frac{1+\varepsilon_{p,t}}{\varepsilon_{p,t}}} Y_{H,t}$$

The aggregate price index, as specified by (26), is given by

$$P_{Ht} = \left[\int_0^1 P_{Ht}^{-\frac{1}{\varepsilon_{p,t}}}(i)di\right]^{-\varepsilon_{p,t}}$$

3.2.3- Intermediate goods firms

We now suppose that in addition to labour ($L_t(j)$) and capital $K_t(j)$, a representative firm j, $j \in (0,1)$, uses, intermediate inputs ($M_t(j)$) imported from abroad. The representative firm combines these production factors in a CES way to produce $Y_{H,t}(i)$:

$$Y_{H,t}(i) = A_{H,t}\left[(\alpha_H)^{\frac{1}{\omega_H}}\left((K_t(i))^{\chi_H}(L_t(i))^{1-\chi_H}\right)^{\frac{\omega_H-1}{\omega_H}} + (1-\alpha_H)^{\frac{1}{\omega_H}}(M_t(i))^{\frac{\omega_H-1}{\omega_H}}\right]^{\frac{\omega_H}{\omega_H-1}}$$

where α_H denotes the weight of the composite of capital and labour in production and ω_H, the degree of substitution between imported inputs M_t and the other factors of production. $A_{H,t}$ is an exogenous level of the technology available to all firms following a first-order autoregressive process in log:

$$ln(A_t) = a_t = \rho_a a_{t-1} + \epsilon_{a,t}$$

with $0 < \rho_a < 1$ and $\epsilon_{at} \sim i.i.d(0,\sigma_{\epsilon a}^2)$

As in Senbeta (2011), we assume that firms face a foreign exchange constraint when purchasing intermediate inputs that they buy from abroad. This constraint is introduced as follow:

$$\frac{P_{F,t}M_t}{S_t} \leq \Omega_t \tag{29}$$

where $P_{F,t}$, M_t, and S_t are the average price level of imported inputs in terms of domestic currency, imported intermediate inputs, and the nominal exchange respectively. Ω_t denotes the quantity of foreign currency available at the beginning of period t and that firms need for importing intermediate inputs for their production during that period.

This stock of foreign exchange is kept by the central bank and is assumed, to evolve according to the following equation of motion:

$$\Omega_t =$$

$$\Omega_{t-1} + P_{X,t-1}X_{t-1} + F_{t-1} + A_{t-1} + REM_{t-1} - \left(1 + i^*_{t-2} + \zeta\left(\frac{F_{t-2}}{P_{t-2}K_{t-2}}\right)\right)F_{t-2} -$$

$$\frac{P_{F,t-1}}{e_{t-1}}\left(C_{F,t-1} + M_{t-1}\right)$$

(30)

where X_t and $P_{X,t}$ are exports and foreign currency price of exports, respectively, while F, A, and REM are foreign loan, foreign aid and remittances, respectively,. i^*_t is the foreign nominal interest rate. ζ captures the risk perception of foreigners about the domestic economy. K is the capital stock of the domestic economy. This equation indicates that the domestic economy faces higher cost of borrowing as the risk perception increases and/or the debt capital stock ratio increases (Eicher et al., 2008).

As mentioned earlier, equation (30) shows that the amount of intermediate inputs that firms can employ during a given period, expressed in the foreign currency, is determined by the amount of foreign currency available at the beginning of the period. The stock of foreign currency available, in turn, is the result of many endogenous and exogenous events that took place in the previous period and beyond, as expressed in (30). Factors that affect the availability of this foreign exchange positively include the previous periods inflow of foreign exchange from export revenue, $P_{X,t-1}X_{t-1}$, foreign loan, F_{t-1}, official development assistance or foreign aid, A_{t-1}, remittances, REM_{t-1}, and the stock of foreign exchange available at the beginning of the previous period which itself is the result of the interplay of the same factors in the past. On the other hand, repayment of the principal, interest and premium on foreign debt and import of consumption goods and intermediate inputs during the previous period negatively affect the quantity available for the current period. In general, poor performance of the external sector of the economy in the previous period, and periods before, affects the performance of the economy during the current period as well as in future periods. For simplicity, we assume here that in each period the central bank sells some proportion of foreign currency inflows to firms importing intermediate inputs, and that the foreign exchange constraint is binding. The relationship between import of intermediate inputs and export earnings can thus be approximated as:

$$\frac{P_{F,t}M_t}{\varepsilon_t} = \Omega_t = \vartheta P_{x,t}X_t = \vartheta P_t^* C_{H,t}^* \tag{31}$$

where ϑ, is some constant, P_t^*, the overall price index of the rest of the world, and $C_{H,t}^*$, the consumption by the rest of the world of domestically produced goods (exports). Following Senbeta (2011), this assumption simplifies the analysis and does not change the dynamics of the model significantly[17].

The objective of a representative firm is to minimize its cost of production given its technology

$$\underset{L_t(i),K_t(i)\,M_t(i)}{\text{Min}}\left(W_t(j)L_t(j) + R_{K,t}(i)K_t(i) + P_{F,t}M_t\right)$$

subject to :

$$Y_{H,t}(i) = A_{H,t}\left[(\alpha_H)^{\frac{1}{\omega_H}}\left((K_t(i))^{\chi_H}(L_t(i))^{1-\chi_H}\right)^{\frac{\omega_H-1}{\omega_H}} + (1-\alpha_H)^{\frac{1}{\omega_H}}(M_t(i))^{\frac{\omega_H-1}{\omega_H}}\right]^{\frac{\omega_H}{\omega_H-1}}$$

[17] It is important to admit that incorporating (30) instead of (31) will have additional benefits as it captures almost all sources of financial shock that low income countries face. In an event of financial crisis, like the recent meltdown, countries face lower inflow of official development assistance, remittances, and face difficulties accessing foreign loans which reinforces the impact of a crisis on their economic activity. The worsening economic activity, in turn, lowers the ability of the country to service its debt which leads to increasing interest rates and risk premia on new loans. Specifying the components of (29) captures all these effects and links them to production. However, as discussed in the text, relying on (29) directly requires obtaining the steady-state ratios of all the arguments to the stock of foreign exchange (Ω_t) in order to log-linearize the model. For the purpose of this paper, however, the simplification is appropriate.

Solving this problem for L_t K_t and M_t, gives the conditional demand functions for these inputs from which the real total cost as a function of input prices, output price, total factor productivity and output can be derived. From the total cost then, the marginal cost $MC_{H,t}(i)$ of producing variety i is given by

$$MC_{H,t} = \frac{W_t L_t(i) + R_{K,t} K_t(i) + P_{F,t} M_t(i)}{Y_{H,t}(i)}$$

Given the constant return to scale technology available to firms, and the fact that there are no adjustment costs for inputs which are rented from competitive markets, marginal cost is independent of the scale production.

In what follows, we restrict the analysis to the specific case where $M_t = O_{H,t}$, an immediate implication of which is $P_{F,t} = P_{O,t}$.

3.2.3.1- Intermediate goods firm's price setting problem

Monopolistic competition provides intermediate goods firms with market power (chapter 1 and the persistence of prices). Following Calvo (1983), a fraction $1 - \theta_H$ of intermediate goods firms are randomly selected to set their prices optimally in each period. This happens after these firms have received a "price signal" (Christiano, Eichenbaum and Evans, 2005; Smets and Wouters, 2003, 2007). The remaining θ_H fraction of intermediate goods firms who are unable to optimize prices, adjust their prices mechanically according to the rule of thumb described in Smets and Wouters (2007) or Del Negro, Shorfheide, Smets and Wouters (2007). The rule of thumb implies price increases to be equal to a weighted average of the last period domestically produced goods gross inflation rate ($\pi_{Ht-1} = P_{Ht-1}/P_{Ht-2}$) and the steady state gross inflation π_*. Under that rule of thumb, the θ_H firms adjust their price at time t as: $P_{H,t}(i) = \left(\frac{P_{Ht-1}}{P_{Ht-2}}\right)^{\theta_H} \pi_*^{1-\theta_H} P_{H,t-1}(i)$. The parameter $\theta_H \in (0,1)$ is the degree of indexation to the past inflation in the production sector.

An intermediate goods firm able to set prices optimally to $\tilde{P}_{Ht}(i)$ in period t and has not been able to set it optimally since then will have the following price:

$$P_{H,t+k}(i) = \left(\frac{P_{Ht}}{P_{Ht-1}} \frac{P_{Ht+1}}{P_{Ht}} \dots \frac{P_{Ht+k-1}}{P_{Ht+k-2}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{H,t}(i)$$

$$= \prod_{s=1}^{k} \left(\frac{P_{Ht+k-1}}{P_{Ht+k-2}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{Ht}(i) = \left(\prod_{s=1}^{k} \pi_{Ht+s-1}^{\theta_H} \pi_*^{1-\theta_H}\right) \tilde{P}_{Ht}(i) \text{ in period } t+s$$

This price expression is simplified as

$$P_{Ht+k}(i) = \left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{Ht}(i) \tag{32}$$

An intermediate goods firm which sets prices in period t, chooses $\tilde{P}_{sH,t}(i)$ to maximize the discounted present value of the firm's through the horizon over which the price $\tilde{P}_{sH,t}(i)$ is in effect. That is, it chooses $\tilde{P}_{sH,t}(i)$ that maximizes

$$E_t \sum_{k=0}^{\infty} \xi_n^k \Gamma_{t,k} \left[\left(\prod_{s=1}^{k} \pi_{Ht+s-1}^{\theta_H} \pi_*^{1-\theta_H}\right) \tilde{P}_{Ht}(i) Y_{H,t}(i) - P_{F,t} M_t - W_t L_t\right] \tag{33}$$

subject to the demand constraint

$$Y_{H,t+k}(i) = \left(\frac{\left(\prod_{s=1}^{k} \pi_{Ht+s-1}^{\theta_H} \pi_*^{1-\theta_H}\right) \tilde{P}_{it}}{P_{H,t+k}}\right)^{\frac{1+\varepsilon_{p,t}}{\varepsilon_{p,t}}} Y_{H,t+k}$$

where $\Gamma_{t,k}$ is the discount factor.

Since households ultimately own all intermediate goods firms, $\Gamma_{t,k} = \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}}$, which is the discount factor of shareholders-households.

Equation (33) shows that the intermediate goods firm's real total cost is equal to $MC_{t+k} Y_{H,t+k}(i)$ in each period $t+k$. Substituting the expressions of the discount factor, the total real cost, and the demand into expression (33), intermediate goods firms optimizing prices in period t chooses $\tilde{P}_{H,t}(i)$ that solves

$$\max_{\tilde{P}_{sH,t}(i)} E_t \sum_{k=0}^{\infty} \xi_n^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} \left[\left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{H,t}(i) \left(\frac{\left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{H,t}(i)}{P_{H,t+k}} \right)^{\frac{1+\varepsilon_{p,t}}{\varepsilon_{p,t}}} Y_{H,t+s} \right.$$
$$\left. - P_{sHt+k} MC_{sH,t+k} \left(\left(\frac{\left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{H,t}(i)}{P_{H,t+k}} \right)^{\frac{1+\varepsilon_{p,t}}{\varepsilon_{p,t}}} \right) \right]$$

The firm's price setting behaviour maximizes the difference between the discount streams of the firm's expected income and cost. The first order condition from this profit maximization is:

$$0 = E_t \textstyle\sum_{k=0}^{\infty} \xi_n^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} Y_{H,t}(i) \begin{bmatrix} \left(1 - \frac{1+\varepsilon_{p,t+k}}{\varepsilon_{p,t+k}}\right) \left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_H} \tilde{P}_{H,t}(i) \\ + \left(\frac{1+\varepsilon_{p,t+k}}{\varepsilon_{p,t+k}}\right) P_{Ht+k} MC_{H,t+k} \end{bmatrix},$$

or

$$0 = E_t \sum_{k=0}^{\infty} \xi_n^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} \frac{Y_{H,t}(i)}{\varepsilon_{p,t+k}} \begin{bmatrix} \left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_{sH}} \tilde{P}_{sH,t}(i) \\ + (1+\varepsilon_{p,t+k}) P_{Ht+k} MC_{H,t+k} \end{bmatrix}$$

The pricing rule that emerges is then given by

$$\tilde{P}_{H,t}(i) = \frac{E_t \sum_{k=0}^{\infty} (\beta\xi_n)^k \left(\frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}}\right) Y_{H,t+s}(i) \left(\frac{1+\varepsilon_{p,t+k}}{\varepsilon_{sp,t+k}}\right) P_{Ht+k} MC_{Ht+k}}{E_t \sum_{k=0}^{\infty} (\beta\xi_n)^k \left(\frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}}\right) \frac{Y_{Ht+k}}{\varepsilon^{P}_{t+k}} \left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_{sH}} \pi_*^{1-\theta_H}} \tag{34}$$

The fraction θ_H of intermediate goods firms unable to set prices optimally in period t had a price P_{Ht-1} at time $t-1$. The rule of thumb, applied by these firms, implies updating their period t price up to $\left(\frac{P_{Ht+k-1}}{P_{Ht-1}}\right)^{\theta_H} \pi_*^{1-\theta_H} P_{Ht-1}$. The price-setting rule of the final goods firm, in Equation (29) results in an aggregate domestic goods price that evolves according to the law of motion:

$$P_{Ht} = \left[\theta_H \left(\left(\frac{P_{Ht-1}}{P_{Ht-2}}\right)^{\theta_H} \pi_*^{1-\theta_H} P_{Ht-1}\right)^{-\frac{1}{\varepsilon_{p,t}}} + (1-\theta_H)\tilde{P}_{Ht}^{-\frac{1}{\varepsilon_{p,t}}}(i)\right]^{-\varepsilon_{p,t}} \tag{35}$$

Equation (34) which establishes the intermediate goods firm's pricing rule and equation (35) that gives the final goods firm's pricing rule are the two equations that determine the dynamic properties of the domestically produced goods prices inflation around the steady-state. If the degree of partial indexation is set to zero ($\theta_H = 0$), the inflation dynamics in the domestic goods production sector becomes similar to the traditional forward-looking Phillips curve. The degree of prices indexation hence determines the backward looking component of the domestically produced goods inflation process.

The speed of adjustment of the domestically produced goods prices to the desired markup depends on the degree of price stickiness (θ_H), the curvature of the Kimball's aggregator in the domestically produced goods market, and the steady-state markup which in the equilibrium is a function of the share of the fixed cost in production. If flexible prices are restored in the goods production sector, Equation (34) reduces to the monopolistically standard condition that goods prices are set as a markup of the real marginal cost. In addition, assuming that all prices are indexed to the lagged steady state rate leads to a vertical Phillips curve in the long run.

3.2.4- Imports goods retailer

For obvious reasons, the small open economy DSGE model we are considering should also account for the incomplete exchange rate pass-through by distinguishing between the world market price of imported goods and the price of these same goods in the domestic economy. To come over this challenge, we allow for imperfect competition and pricing to market in the domestic economy. We also assume that the law of one price does not hold in the imported goods sector and leave room for a difference between the imported goods price in the domestic market P_{Ft} and the price at the docksides $S_t P_t^*$.

The imported goods sector consists of two types of importing firms. One type of firms buys a homogenous good on the world market at a price P_t^*, and turns that good into multiple differentiated goods through a "differentiating technology" or brand naming. Another type of firms buys these differentiated imported goods, package them into a final imported good and sells the final imported good to households, entrepreneurs, capital goods producing firms and government in a domestically competitive goods market.

Differentiated goods importing firms follow Calvo's (1983) price-setting mechanism. These firms are able to reset their prices if they receive a price change signal. In general, intermediate imported goods firms face a probability $1 - \theta_F$ to set their price at each period t. With a probability θ_F, a firm does not reset its price and mechanically adjusts it according to a rule of thumb, identical to that of domestically produced goods firms. These θ_F firms adjust their prices to $P_{Ft}(i) = \left(\pi_{F,t}\right)^{\theta_F} (\pi_*)^{1-\theta_F} P_{Ft}(i)$, where $\pi_{Ft-1} = P_{Ft-1}/P_{Ft-2}$ is the previous period imported goods gross inflation and π_* is the steady-state gross inflation rate.

The profit maximization problem by price-setting imported goods firms is identical to that of the intermediate domestically producing goods firms. Nonetheless, we assume no shock to the intermediate goods firm's demand curve elasticity, and the period $t+k$ imported goods aggregator is defined as a constant elasticity of substitution (CES) bundle

$$Y_{Ft+k} = \left[\int_0^1 Y_{Ft+k}(i)^{\frac{\theta_F - 1}{\theta_F}}\right]^{\frac{\theta_F}{\theta_F - 1}}$$

where $\theta_F > 1$.

The demand for intermediate imported goods is given by

$$Y_{Ft+k} = \left(\frac{\left(\frac{P_{Ft+k-1}}{P_{Ft-1}}\right)^{\chi F} \pi_*^{1-\chi F}\, \tilde{P}_{Ft}(i)}{P_{Ft+k}}\right)^{-\chi F} Y_{Ft+k}$$

at each period $t+k$.

The intermediate imported good firm's nominal cost is $S_{t+k}P^*_{t+k}$. The real marginal cost $MC_{Ft+k} = \frac{S_{t+k}P^*_{t+k}}{P_{Ft+k}}$ is, up to log-linearization, the difference between the nominal marginal cost and the average price. The real marginal cost is independent of the firm's characteristics. This relation between the imported firm's marginal cost and the foreign price of imported goods shows that all exogenous shocks that might affect the latter, propagate to domestic inflation. Exchange rate shocks feed immediately to the imported goods firm's marginal cost, but sticky imported goods prices tend to slow the speed at which local imported prices adjust to the desired markup. As a result, exchange rate shocks feed to the domestic inflation at a lower speed or with delays. This feature characterizes an incomplete exchange rate pass-through. If all imported goods prices are flexible ($\theta_F = 0$), the standard condition that imported goods prices are a constant markup of the marginal cost holds, and there is full exchange rate pass-through.

Intermediate imported goods firms that can set prices in period t choose the price $\tilde{P}_{Ft}(i)$ that solves

$$\max_{\tilde{P}_{Ft}(i)} E_t \sum_{k=0}^{\infty} \xi_F^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} \left(\frac{\left(\frac{\left(\frac{P_{Ft+k-1}}{P_{Ft-1}}\right)^{\chi F} \pi_*^{1-\chi F} \tilde{P}_{Ft}(i)}{P_{Ft+k}} \right)^{-\chi F}}{P_{Ft+k}} \right)^{-\theta_F} Y_{Ft+k} \left[\left(\frac{P_{Ft+k-1}}{P_{Ft-1}}\right)^{\chi F} \pi_*^{1-\chi F} \tilde{P}_{Ft}(i) - P_{Ft+k} MC_{F,t+k} \right]$$

The first-order condition associated with this problem is given by:

$$0 = E_t \sum_{k=0}^{\infty} \xi_m^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} Y_{Ft+k}(i) \left[(1-\theta_F) \left(\frac{P_{Ft+k-1}}{P_{Ft-1}}\right)^{\chi F} \pi_*^{1-\chi F} \tilde{P}_{Ft}(i) - \theta_F P_{Ft+k} MC_{F,t+k} \right]$$

As a result, an intermediate imported goods firm that can set its price optimally in period t will choose $\tilde{P}_{Ft}(i)$ that fulfils the price-setting rule:

$$\tilde{P}_{Ft}(i) = \frac{\theta_F}{\theta_F - 1} \frac{E_t \sum_{k=0}^{\infty} \xi_F^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} Y_{Ft+k}(i) P_{Ft+k} MC_{t+k}}{E_t \sum_{k=0}^{\infty} \xi_F^k \frac{\beta^k \Lambda_{t+k} P_t}{\Lambda_t P_{t+k}} Y_{Ft+k}(i) \left(\frac{P_{Ft+k-1}}{P_{Ft-1}}\right)^{\chi F} \pi_*^{1-\chi F}} \tag{36}$$

where $\frac{\theta_F}{\theta_F - 1} > 1$ represents the gross markup the intermediate imported goods firm applies over the ratio of the discounted stream of total nominal cost, divided by the discounted stream of real output.

In each period, $1 - \theta_F$ intermediate imported goods firms that can set prices have the same markup and identical price $\tilde{P}_{Ft}(i)$. In addition, θ_F intermediate imported goods firms adjust their prices to last period import good price P_{Ft-1}. The aggregate imported goods price's law of motion is defined by:

$$P_{Ft}^{1-\theta_F} = \xi_F \left(\left(\frac{P_{Ft+k-1}}{P_{Ft-1}} \right)^{\chi_F} \pi_*^{1-\chi_F} \right)^{1-\theta_F} + (1-\xi_F) \tilde{P}_{Ft}^{1-\theta_F} \qquad (37)$$

Equations (36) and (37) give the pricing rules of the intermediate imported goods firms and the finals imported goods firms, respectively. They are the two equations that define the imported goods inflation dynamics.

3.2.5- Commodity sector

Following Medina and Soto (2007), we assume that a single firm produces a homogenous commodity good that is completely exported abroad. Production of such a good is assumed to evolve with the same stochastic trend as other aggregate variables and to require no input since they do not undergo any transformation.

$$Y_{S,t} = \left(\frac{T_t}{T_{t-1}} Y_{S,t-1} \right)^{\rho_{y_S}} \left(Y_{S,0} \right)^{1-\rho_{y_S}} exp\left(\varepsilon_{y_S,t} \right)$$

where $\varepsilon_{y_S,t} \sim N\left(0, \sigma_{y_S}^2\right)$ is a stochastic shock and where ρ_{y_S} captures the persistence of the shock to the production process. Needless to say how important is the modelling of such sector in an economy like Cameroon where it is likely to capture the developments of natural resources production for instance.

An increase in commodity production implies directly an increase in domestic GDP. Because there are no inputs, an increase in production comes as a windfall gain. It may also increase exports, if no counteracting effect on home goods exports dominates. We would expect that, as with any increase of technological frontier of tradable goods, a boom in this sector would induce an exchange rate appreciation.

The magnitude of the appreciation would depend on the structural parameters governing the degree of intra-temporal and inter-temporal substitution in aggregate demand and production.

3.3- Government

While the fiscal policy is the responsibility of the government, the monetary policy is conducted by the central bank[18]. On the budget of the government, the only asset owned by this latter is its share in the commodity exporting firm. Government liabilities are public bonds held by the private sector, and money.

3.3.1- Fiscal policy

Let $B^*_{G,t}$and $B_{G,t}$ be the net asset position of the government in foreign and domestic currencies, respectively. The evolution of the total net position of the government is given by:

$$\frac{S_t B^*_{G,t}}{(1+\, i^*_t)\Theta\left(\frac{S_t B^*_t}{P_{Y,t} Y_t}\right)} + \frac{B_{G,t}}{(1+\, i_t)} = S_t B^*_{G,t-1} + B_{G,t} + T_t - P_{G,t} G_t$$

where $(1+\, i^*_t)$ and $(1+\, i_t)$ are the relevant gross interest rates for public assets denominated in the foreign currency and in the domestic currency, respectively. G_t denotes government expenditures and T_t, total net fiscal nominal revenues (income tax revenues minus transfers to the private sector).

[18] Cameroon is a member of CAEMC (Economic Community of Central African States) and its monetary policy is conducted by the Monetary Policy Committee (MPC) of the Bank of Central African States (BEAC). The MPC's national responsibilities are exercised by the Monetary and Financial Committee. The BEAC's monetary policy has sought to stabilize prices and the real effective exchange rate and to prevent public spending from crowding out private investment.

Fiscal policy is defined by the four variables $B_{G,t}$, $B^*_{G,t}$, T_t, and G_t. Therefore, given the budget constraint of the government, it is necessary to define a behavioural rule for three of these four variables.

Portfolio considerations can give rise to a preferable composition for the public assets holdings either in foreign or domestic currency. When agents are Ricardian, defining a trajectory for the primary deficit is irrelevant for household decisions, as long as the budget constraint of the government is satisfied. In contrast, when a fraction of the agents are non-Ricardian, the trajectory of the public debt and the primary deficit are relevant. In addition, the path of public expenditures may be relevant on its own as long as its composition differs from the composition of private consumption.

Assuming that a relevant fraction of households are non-Ricardian ($\lambda > 0$) makes the timing of fiscal decisions (variables) relevant for the private sector. Suppose in addition that the public assets position is denominated in foreign currency ($B_{G,t} = 0$). Fiscal revenues come from two sources: income tax from the private sector, which is a function of GDP, $T_{P,t} = \tau_t P_{Y,t} Y_t$, and revenues from natural resources which are given by $P_{S,t} Y_{S,t}$, where $\chi Y_{S,t}$ are natural resources sales, the parameter χ defining the domestic share of ownership in total natural resource production. The variable τ_t corresponds to the average income tax.

Following Medina and Soto (2006a), we now adopt the structural balance fiscal rule, which implies that the share of government expenditures in GDP is given by:

$$\frac{P_{G,t}G_t}{P_{Y,t}Y_t} = \left\{\left(1 - \frac{1}{(1+ i^*_{t-1})\Theta_{t-1}}\right)\frac{S_t}{S_{t-1}}\frac{S_{t-1}B^*_{G,t-1}}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t} + \tau\left(\frac{\bar{Y}_t}{Y_t}\right) + S_t\bar{P}^*_{S,t}\chi\frac{Y_{S,t}}{P_{Y,t}Y_t} - \frac{B_{S,t}}{P_{Y,t}Y_t}\right\} exp(\xi_{G,t})$$

where $\bar{P}^*_{S,t}$ is the long-run (”reference”) price of natural resources, and $\xi_{G,t}$ is a shock that captures any deviation of government expenditures from this fiscal rule. This shock follows an AR(1) process with i.i.d. innovations. The purpose of this fiscal rule is to avoid excessive fluctuations in government expenditures, coming from transitory movements in fiscal revenues. For example, in the case of a transitory rise of fiscal revenues originated by commodity (wood) price increases, the rule implies that this additional fiscal income should in principle be saved. Notice that the level of public expenditures that is consistent with the rule includes interest payments. Therefore, if the net position of the government improves, current expenditures may increase.

3.3.2- Monetary policy

The central bank is here the monetary policy authority. It adjusts the short-run interest rate.

The monetary policy instrument follows an interest rate rule in the form of Ortiz and Sturzenegger (2007):

$$R_t = R_{t-1}^{\rho_R}\left[R^{ss}\pi_*\left(\frac{\pi_t}{\pi_*}\right)^{\psi_1}\left(\frac{Y_t}{Y_t^*}\right)^{\psi_2}\left(\frac{\frac{S_t}{S_{t-1}}}{\Delta S_{ss}}\right)^{\psi_2}\right]^{1-\rho_R} exp(\eta_{Rt})$$

Where $R_t = 1 + i_t$, and R^{ss} is the steady-state real interest rate. The parameter ρ_R captures the degree of interest rate smoothing, while the parameters ψ_1, ψ_2, and ψ_3 are Taylor's coefficients on inflation, output, and exchange rate fluctuations, respectively. The monetary policy shock η_{Rt} is assumed to be independently and identically normally distributed, $\eta_{Rt} \sim N(0, \sigma_R)$.

The monetary policy rule follows the generalized Taylor (1993) rule. The monetary authority responds to exogenous shocks to the domestic economy by a gradual adjustment of the policy-controlled interest rate, targeting three major goals. First, the monetary authority responds to the deviation of the inflation rate from its target π_*, which coincides with the steady-state (gross) inflation rate. Second, the monetary policy instrument adjusts the output gap, which is defined following Taylor (1993), as the difference between the actual output Y_t and the natural output $Y_t^* = Y_{ss}exp(\bar{g}t)$ where the quarterly trend growth rate to real GDP is $\bar{g} = 100(g-1)$. Third, the exchange rate fluctuations are an integral component of the monetary policy reaction function. Consistent with the DSGE literature, the steady-state exchange rate is set to one.

3.4- Foreign sector

The external sector of the domestic economy characterizes the exports dynamics, the incomplete exchange rate pass-through, and the aggregate balance of payment.

3.4.1- Exports dynamics

Final goods producers export domestically produced goods on foreign competitive markets at an exogenous price since the small open economy is a price taker. Domestically produced goods are purchased by foreign households. We assume that foreign households' aggregate consumption C_t^* is described by a CES function that combines home produced and import goods

$$C_t^* = \left[\gamma_1^{\frac{1}{\varphi_1}} X_t^{\frac{\varphi_1 - 1}{\varphi_1}} + (1-\gamma_1)^{\frac{1}{\varphi_1}} C_{Ht}^{*\frac{\varphi_1 - 1}{\varphi_1}}\right]^{\frac{\varphi_1}{\varphi_1 - 1}}$$

where γ_1 is the share of the economy's exports in the rest of the world's consumption C_t^*, and φ_1 is the elasticity of substitution between the home economy's exports and the foreign produced goods.

Likewise, foreign households determine their demands for goods by minimizing their consumption expenditures. We allow for trade credit in the foreign economy and assume that a fraction ϕ of the home economy's exports must be financed in advance through loans contracted by foreign households from foreign financial intermediaries. The cost minimization problem is identical to that of the domestic households, and the export demand is given by the relation:

$$X_t = \gamma_1 \left(\frac{P_{Xt}(1 + \phi i_{t-1}^*)}{P_t^*} \right)^{-\varphi_1} C_t^*$$

where P_{Xt} is the foreign currency price of exports. We assume that the law of one price holds in the export sector and that, $P_{Ht} = S_t P_{Xt}$, which allows to write the export demand as

$$X_t = \gamma_1 \left(\frac{P_{Ht}(1+ \phi i_{t-1}^*)}{S_t P_t^*} \right)^{-\varphi_1} C_t^*$$

The quantity $\frac{P_{Ht}}{S_t P_{Ht}^*}$, where P_{Ht}^* is the price of foreign produced goods, denotes the real exchange rate[19]. The rest of the world's aggregate consumption C_t^* is exogenous for the small open economy, and its path is assumed to evolve along a stochastic log-linear autoregressive process given by:

$$lnC_t^* = (1 - \rho_X)\, lnC_{ss}^* + \rho_X\, lnC_{t-1}^* + \eta_{Xt}$$

where $0 < \rho_X < 1$, and the structural export demand shock η_{Xt} is identically and independently distributed: $\eta_{Xt} \sim N(0, \sigma_X)$.

Movements of the export price P_{Xt} relative to the import price at the dockside $S_t P_t^*$ characterize the terms of trade fluctuations in this small open economy. Thus, the terms of trade are given by the relation $\varepsilon_{T,t} = \frac{P_{Ht}}{S_t P_t^*}$. Since the rest of the world consumption price index P_t^* is exogenous to the small open economy and is assumed

[19] Note that, this small open economy's real exchange rate could be approximated by $\frac{P_{Ht}}{S_t P_t^*}$ since its share in the world trade is too small.

to follow an exogenous stochastic process; the terms of trade $\varepsilon_{T,t}$ also follow a stochastic process that is assumed to be an $ARMA(1,1)$ given by

$$ln\varepsilon_{T,t} = (1 - \rho_T)ln\varepsilon_T + \rho_T ln\varepsilon_{T,t-1} + \eta_{T,t} + \mu_T\eta_{T,t-1} \qquad (38)$$

where $0 < \rho_T < 1$. The structural terms of trade shock $\eta_{T,t}$ is normally, identically, and independently distributed:$\eta_{T,t} \sim N(0,\sigma_T)$. The MA term in Equation (38) aims to capture the frequency fluctuations of the import and export prices, specifically, their component related to commodities prices.

3.5- Aggregate equilibrium of the model

Firms producing varieties must satisfy demand at the current price. Therefore, the market clearing condition for each variety implies that:

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t} + \left(\frac{P^*_{H,t}(i)}{P^*_{H,t}}\right)^{-\epsilon_H} Y^*_{H,t}$$

where , $Y_{H,t} = C_{H,t} + I_t + G_t$, and $Y^*_{H,t} = \varsigma^* \left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta^*} Y^*_t$. The equilibrium implies that total labour demand by intermediate varieties producers must be equal to labour supply:$\int_0^1 l_t(i)di = l_t$, where $l_t = \left[\int_0^1 (l_t(n))^{\frac{1}{1+\lambda_{w,t}}} dn\right]^{1+\lambda_{w,t}}$.

Since the economy is open and there is no reserve accumulation by the central bank, the current account is equal to the capital account. Using the equilibrium conditions in the goods and labour markets, and the budget constraint of households and the government, we obtain the following expression for the evolution of the net foreign asset position:

$$\frac{\varepsilon_t B_t^*/P_{Y,t}Y_t}{(1+\,i_t^*)\Theta\left(\frac{\varepsilon_t B_t^*}{P_{Y,t}Y_t}\right)\varepsilon_t^*} = \frac{\varepsilon_{t-1}B_{t-1}^*}{P_{Y,t}Y_t} - (1-\,\chi)\frac{P_{S,t}Y_{S,t}}{P_{Y,t}Y_t} + \frac{P_{X,t}X_t}{P_{Y,t}Y_t} - \frac{P_{M,t}M_t}{P_{Y,t}Y_t}$$

where B_t^* is the aggregate net (liquid) asset position of the economy vis-a-vis the rest of the world, χ, the share of the government revenue from the commodity sector, $(1-\,\chi)$, the share of foreigners and

$$P_{Y,t}Y_t = P_{C,t}C_t + \,P_{*H,t}G_t \,+\, P_{I,t}I_t \,+\, P_{X,t}X_t - \,P_{M,t}M_t$$

is the nominal GDP –measured from demand side. Nominal imports and exports are given by

$$P_{M,t}M_t = \,\varepsilon_t\left(P_{F,t}^*Y_{F,t} + \,P_{O,t}\left(C_{o,t} + \,O_{H,t}\right)\right), \quad \text{and,} \quad P_{X,t}X_t = \,\varepsilon_t\left(P_{H,t}^*Y_{H,t}^* + \,P_{S,t}^*Y_{S,t}\right),$$

respectively.

Conclusion

In this chapter, we have described the open economy of Cameroon in a New-Keynesian frame. The model set up is then based on a New-Keynesian framework characterized by nominal and real rigidities. This framework allows us to include microeconomic foundations of optimum behaviour of the economic agents into the system. Firms are assumed to adjust prices infrequently whereas wages are set in a staggered fashion. The model embeds financial frictions which hinder investment financing and amplify the effect of interest rate and exchange rate fluctuations on borrower's real net worth positions, the balance sheets, and the real macroeconomic equilibrium. The model also incorporates the exchange rate pass-through since the speed at which exchange rate shocks feed into the domestic price level seems to be higher in developing economies than it is in the industrial world. External shocks such as oil price shocks and commodity price shocks are integrated in the model since Cameroon depends heavily on the export of primary commodities which makes it so vulnerable to such types of shocks.

Unfortunately, as we mentioned earlier in chapter 1, there are another crucial characteristic of the Cameroonian economy we didn't account for and which we leave for future research. One such characteristic is “economic dualism”, which refers to the partition of a single economy into formal and informal sectors. In the literarture, Ahmad et al. (2012) develop a closed economy DSGE model for Pakistan economy, where they incorporate informality in labour and product markets. Gabriel *et. al.* (2010) constructs in a similar framework a closed economy NK-DSGE model for Indian economy. His model has more features of liquidity constrained consumers, financial accelerator and informal sector in product and labour markets. This study step-by-step adds features of financial frictions and informal sector to a canonical dynamic New Keynesian model. Zenou (2007) develops two-sector general equilibrium model to study labour mobility between formal and informal labour markets under different labour policies. In the model design, formal labor market has search and matching frictions and informal labour market exhibits perfect competition. Antunes and Cavalcanti (2007) study the impact of regulation costs and financial contract enforcement on size of informal economy and per capita GDP using a small open economy general equilibrium model. Koreshkova (2006) studies the consequences of tax-evading informal sector for budget financing that ultimately affects inflation. Conesa *et. al.* (2002) explains the negative relationship between participation rate and GDP fluctuation observed in cross country data through existence of informal sector. Using a dynamic general equilibrium model incorporating informal sector in labour and product markets, the study shows that agents switch between formal and informal sectors during productivity shocks.

In the next chapter, the non-linear optimality conditions of agents such as Households and firms are used to calibrate the DSGE model in such a way that it mimics the Cameroonian economy as closely as possible alongside its long run properties.

Appendix C2 presents the log-linearized version of the DSGE model developed in this chapter. This log-linearized version of the DSGE model is estimated in chapter 3.

Appendix C

Appendix C1: Household's demands for given goods X_{it} and X_{jt}

For any level of consumption X_t as described by equations (9) and (10), each household purchases a composite of X_{it} and X_{jt} goods. This appendix aims to describe the demand of X_{it} and X_{jt} given their respective prices P_{it} and P_{jt}.

Suppose that a household consumes X_t and X_t is a composite constant elasticity of substitution (CES) function of X_{it} and X_{jt} given by

$$X_t = \left[b^{\frac{1}{\alpha}} X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}} X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{\alpha}{\alpha-1}}, \quad b \in (0,1) \text{ and } \theta > 0. \tag{C1.1}$$

At the first stage of his optimization, he chooses the combination of these two types of goods that minimizes the cost of achieving any level of a composite index X_t defined by a CES function (C1.1).

To determine the division of his consumption between X_{it} and X_{jt}, the agent minimizes his expenditures $P_{it}X_{it} + P_{jt}X_{jt}$ subject to the constraint (C1.1). Note that P_{it} is the aggregate price level of good i, and P_{jt} is the aggregate price level of good j.

This corresponds to the minimization problem formulated by

$$\min_{X_{it}, X_{jt}} P_{it}X_{it} + P_{jt}X_{jt}$$

subject to

$$X_t = \left[b^{\frac{1}{\alpha}} X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}} X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{\alpha}{\alpha-1}}$$

Let now λ_{Xt} be the Lagrangian multiplier associated to the constraint (C1.1). The Lagrangian is given by

$$L_t = P_{it}X_{it} + P_{jt}X_{jt} + \lambda_{Xt}\left\{X_t - \left[b^{\frac{1}{\alpha}}X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{\alpha}{\alpha-1}}\right\}.$$

The first order necessary condition with respect to X_{it} is

$$P_{it} + \lambda_{Xt}\left(\frac{\alpha-1}{\alpha}\right)\left[b^{\frac{1}{\alpha}}X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{1}{\alpha-1}}\left(\frac{\alpha-1}{\alpha}\right)b^{\frac{1}{\alpha}}X_{it}^{\frac{-1}{\alpha}} = 0,$$

which is equivalent to

$$P_{it} = \lambda_{Xt}\left[b^{\frac{1}{\alpha}}X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{1}{\alpha-1}} b^{\frac{1}{\alpha}}X_{it}^{\frac{-1}{\alpha}}$$

(C1.2)

The first order condition with respect to X_{jt} is

$$P_{jt} = \lambda_{ct}\left[b^{\frac{1}{\alpha}}X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{1}{\alpha-1}}(1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{-1}{\alpha}} \qquad \text{(C1.3)}$$

Dividing (C1.2) and (C1.3) side by side, we obtain

$$\frac{P_{it}}{P_{jt}} = \frac{b^{\frac{1}{\alpha}}}{(1-b)^{\frac{1}{\alpha}}}\frac{X_{it}^{\frac{-1}{\alpha}}}{X_{jt}^{\frac{-1}{\alpha}}}$$

After some rearrangements, this yields the following relation between X_{it} and X_{jt}

$$X_{it} = \frac{b}{1-b}\left(\frac{P_{it}}{P_{jt}}\right)^{-\alpha} X_{jt} \qquad \text{(C1.4)}$$

Equation (C1.4) shows that α is the elasticity of substitution between good i and good j, and that the household's preferences are homothetic. This means the relative demand X_{it}/X_{jt} depends only on the relative price P_{it}/P_{jt}.

To determine the consumer's price index P_t, one needs to observe that the consumption based price index P_t measures the minimum expenditure such that the households consumption index X_t equals unit given P_{it} andP_{jt}. In term of the consumer's decision problem, P_t represents the marginal increase in the total consumption expenditure when the household raises its consumption by unit. This implies $P_t = \lambda_{Xt}$, which indicates a perfect equality between the aggregate consumer's price and the Lagrangian multiplier associated to the household constraint (C1.1).

To obtain the Lagrange multiplier λ_{Xt}, we introduce the expression (C1.4) into (C1.3) to eliminate X_{it} and to derive the expression of λ_{Xt}. This yields the following development

$$P_{jt} = \lambda_{Xt}\left[b^{\frac{1}{\alpha}}X_{it}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{1}{\alpha-1}}(1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{-1}{\alpha}}$$

$$= \lambda_{Xt}\left[b^{\frac{1}{\alpha}}\left(\frac{b}{1-b}\right)^{\frac{\alpha-1}{\alpha}}\left(\frac{P_{it}}{P_{jt}}\right)^{1-\alpha}X_{jt}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{1}{\alpha-1}}(1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{-1}{\alpha}}$$

$$= \lambda_{ct}\left[\frac{b^{\frac{1}{\alpha}}b^{\frac{\alpha-1}{\alpha}}P_{it}^{1-\alpha}X_{jt}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}(1-b)^{\frac{\alpha-1}{\alpha}}P_{jt}^{1-\alpha}X_{jt}^{\frac{\alpha-1}{\alpha}}}{(1-b)^{\frac{b-1}{b}}P_{jt}^{1-b}}\right]^{\frac{1}{\alpha-1}}(1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{-1}{\alpha}}$$

$$= \lambda_{Xt}\left[bP_{it}^{1-\alpha} + (1-b)P_{jt}^{1-\alpha}\right]^{\frac{1}{\alpha-1}}\frac{1}{P_{jt}^{-1}}$$

The final result is given by

$$1 = \lambda_{Xt}\left[bP_{it}^{1-\alpha} + (1-b)P_{jt}^{1-\alpha}\right]^{\frac{1}{\alpha-1}}$$

which we can rewrite as

$$P_t = \left[bP_{it}^{1-\alpha} + (1-b)P_{jt}^{1-\alpha}\right]^{\frac{1}{1-\alpha}} \qquad \text{(C1.5)}$$

Now, the demand for good j is found by substituting (C1.4) into expression of the composite consumption index (C1.1).

$$X_t = \left[b^{\frac{1}{\alpha}}\left(\frac{b}{1-b}\right)^{\frac{\alpha-1}{\alpha}}\left(\frac{P_{it}}{P_{jt}}\right)^{1-\alpha}X_{jt}^{\frac{\alpha-1}{\alpha}} + (1-b)^{\frac{1}{\alpha}}X_{jt}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{\alpha}{\alpha-1}}$$

$$= \left[\frac{b^{\frac{1}{\alpha}}b^{\frac{\alpha-1}{\alpha}}P_{it}^{1-\alpha} + (1-b)^{\frac{1}{\alpha}}(1-b)^{\frac{\alpha-1}{\alpha}}P_{jt}^{1-\alpha}}{(1-b)^{\frac{b-1}{b}}P_{jt}^{1-b}}\right]^{\frac{1}{\alpha-1}}X_{jt}$$

$$= \left[bP_{it}^{1-\alpha} + (1-b)P_{jt}^{1-\alpha}\right]^{\frac{\alpha}{\alpha-1}}\frac{1}{(1-b)P_{jt}^{-\alpha}}X_{jt}$$

When it is recognized that the expression in bracket is $P_t^{-\alpha}$, the solution of the demand of good j is given by

$$X_{jt} = (1-b)\left(\frac{P_{jt}}{P_t}\right)^{-\alpha} X_t$$

(C1.6)

A straightforward introduction of (C1.6) in (C1.4) rules out X_{jt} and provides the expression for the demand of good i as

$$X_{it} = b\left(\frac{P_{it}}{P_t}\right)^{-\alpha} X_t$$

(C1.7)

Equation (C1.7) (respectively (C1.6)) establishes the proportionality of the demand for good i (respectively good j) to the consumption index X_t. The coefficient of proportionality is equal to a fraction b (respectively $1-b$) of an isoelastic function that depends upon the ratio of price P_{it} (respectively P_{jt}) to the price of the consumption index P_t.

Appendix C 2: Linearized DSGE model

This linearized dynamic stochastic general equilibrium model describes the deviations from the steady-state of the endogenous variables as linear equations[20]. To obtain the linear approximation of the DSGE model, we apply the log-linearization methodology put forward by Campbell (1994) and which Uhlig (1999) extensively popularised. According to the basic principle of this methodology[21], a (detrended) variable $\bar{X}_t$ can be expressed around its steady-state X_{ss} as $\bar{X}_t = X_{ss}\exp(\hat{X}_t) = X_{ss}(1+\hat{X}_t)$. The quantity $\hat{X}_t = \log\left(\frac{\bar{X}_t}{X_{ss}}\right)$ denotes the percentage deviation of the (detrended) variable $\bar{X}_t$ around its steady-state value. By applying this to all economic agent'ss decision rules and equilibrium conditions, we obtain a system of linear equations. That linear system characterizes the dynamic of the economy in terms of small deviations around the steady-state (or equivalently the balance growth path). This appendix presents for each decision rule, the final equation of the log-linearization. We begin with the household sector

Households

Ten equations determine the households' equilibrium condition. Equation (6) defines the optimal choice of the Ricardian household consumption. Equation (7) provides the uncovered interest rate parity condition. Equation (8) establishes the non-Ricardian household's budget constraint. Equation (12), (13), (14), and (15) determine the demand for goods $X_{jt} \in \{C_{Z,t}, C_{O,t}, C_{H,t}, C_{F,t}\}$. Equations (10) and 16 give respectively the total consumer price index and the consumer price index for non-oil goods. Equation (*) and (**) give the wage dynamic.

[20] The coefficients associated with these linear equations involve structural parameters and steady-state ratios. Structural parameters are a collection of technological parameters, preference parameters, and auxiliary or nuisance parameters that include standard deviations of exogenous shocks and persistence of disturbances. Steady-state ratios are determined by functions of macroeconomic variables evaluated at the steady-state. These steady-state ratios appear on equilibrium conditions such as the balance of payments, or they are embodied in some linear decision rules such as the entrepreneur's net worth decision rule.

[21] Recall that the first order Taylor series of the exponential function is $exp(x_t) \approx 1 + x_t$, and that the logarithm function is $log(1 + x_t) \approx x_t$.

1- Consumption of Ricardian household

The Ricardian household's consumption equation with external habit formation is given by:

$$\hat{c}_t^R = -\frac{1-h}{1+h}E_t\left[\hat{\imath}_t - \hat{\pi}_{C,t+1}\right] + \frac{1}{1+h}E_t\left[\hat{c}_{t+1}^R\right] + \frac{h}{1+h}\hat{c}_{t-1}^R + \frac{1-h}{1+h}\left[\hat{\zeta}_{C,t} - E_t\left[\hat{\zeta}_{C,t+1}\right]\right] - \frac{1}{1+h}\left[h\hat{\zeta}_{T,t} - E_t\left[\hat{\zeta}_{T,t+1}\right]\right]$$

2- Consumption of non-Ricardian households

The non-Ricardian household's consumption is given by his budget constraint as:

$$\hat{c}_t^{NR} = \frac{W}{PC}\left(\widehat{wr}_t + \hat{l}_t\right) - \frac{\tau_p}{PC}\hat{\tau}_{p,t}$$

3- Aggregate consumption

The aggregate consumption is a weighted sum of Ricardian and non-Ricardian household’s consumption given as

$$\hat{c}_t = (1-\lambda)\hat{c}_t^R + \lambda\hat{c}_t^{NR}$$

4- Uncovered interest rate parity condition

The arbitrage condition for the Ricardian household's optimal choice of domestic currency denominated debt and foreign currency denominated debt yields the uncovered interest rate parity condition for household's debt:

$$\hat{\imath}_t = \hat{\imath}_t^* + \rho\widehat{b}_t^* + E_t\left[\Delta\hat{e}_{t+1}\right]$$

where $\widehat{b}_t^* = ln\left(\frac{S_tB_t^*}{P_{X,t}X_t}\Big/\frac{SB^*}{P_XX}\right)$. The foreign interest rate $\hat{\imath}_t^*$ captures not only the relevant interest rate in the international market but also any exogenous fluctuation in the risk premium not captured by $\rho\widehat{b}_t^*$.

The household's debt denominated on foreign currency depends positively on the expected real return differential on integrated financial markets. It also depends positively on the foreign currency expected rate of appreciation and negatively on the exogenous premium on the return bonds

5- Labour supply

The real wage rate is given by

$$[\kappa_L + (1+\beta)]\widehat{wr}_t = \kappa_L\left(\sigma_L \hat{l}_t + \frac{1}{1-h}\hat{c}_t - \frac{h}{1-h}\hat{c}_{t-1} + \hat{\zeta}_{L,t}\right) + \widehat{wr}_{t-1} + \beta E_t[\widehat{wr}_{t+1}] - (1+\beta\chi_L)\hat{\pi}_{C,t} + \chi_L\hat{\pi}_{C,t-1} + \beta E_t[\hat{\pi}_{C,t+1}]$$

where $\kappa_L = \frac{(1-\beta\phi_L)(1-\phi_L)}{\phi_L(1+\sigma_L\epsilon_L)}$

The real wage is a function of expected and past real wages and the expected, current, and past inflation rates, where the relative weights depend on the degree of wage indexation.

5- Consumption goods bundle

The demand of non-oil good is given as

$$\hat{c}_{Z,t} = \hat{c}_t - \omega_C\widehat{pr}_{Z,t}$$

The demand of oil consumption is as follows

$$\hat{c}_{O,t} = \hat{c}_t - \omega_C\widehat{pr}_{O,t}$$

$$0 = \alpha_C\widehat{pr}_{Z,t} + (1-\alpha_C)\widehat{pr}_{O,t}$$

The demand of domestic goods is as follows

$$\hat{c}_{H,t} = \hat{c}_{Z,t} - \eta_C\widehat{pr}_{H,t}$$

The demand of foreign goods is as follows

$$\hat{c}_{F,t} = \hat{c}_{Z,t} - (1-\eta_C)\widehat{pr}_{F,t}$$

The overall real price of non-oil goods is given as

$$\widehat{pr}_{Z,t} = \gamma_C\widehat{pr}_{H,t} + (1-\gamma_C)\widehat{pr}_{F,t}$$

Capital goods firms

The capital goods sector determines the Tobin's Q , the investment, the rental rate of capital, and the capital stock dynamics.

6- Capital accumulation

The evolution of stock capital is as follows

$$\hat{k}_{t+1} = \frac{1-\delta}{(1+n)(1+g_y)}\hat{k}_t + \left(1 - \frac{1-\delta}{(1+n)(1+g_y)}\right)(\widehat{inv}_t + \hat{\zeta}_{I,t})$$

7- Investment goods bundle

The Home investment evolves as follows

$$\widehat{inv}_{H,t} = \widehat{inv}_t - \theta_I(\widehat{pr}_{H,t} - \widehat{pr}_{I,t})$$

The Foreign investment evolves as follows

$$\widehat{inv}_{F,t} = \widehat{inv}_t - \theta_I(\widehat{pr}_{F,t} - \widehat{pr}_{I,t})$$

The overall real investment price is as follows

$$\widehat{pr}_{I,t} = \gamma_I \widehat{pr}_{H,t} + (1-\gamma_I)\widehat{pr}_{F,t}$$

8- Demand and supply of investment goods

$$\widehat{pr}_{I,t} = \frac{Qr}{Pr_I}(\widehat{qr}_t + \hat{\varepsilon}_{I,t}) - \frac{Qr}{Pr_I}\left(1 + \frac{1}{1+r}\right)\mu_s(1+g_y)^2\widehat{inv}_t + \frac{Qr}{Pr_I}\mu_s(1+g_y)^2\widehat{inv}_{t-1} + \frac{Qr}{Pr_I}\mu_s(1+g_y)^2\frac{1}{1+r}E_t[\widehat{inv}_{t+1}]$$

Goods production firms

The dynamic of the goods production firms is characterized by the demand for domestically produced goods, the production function, the marginal cost, and inflation.

9- First order conditions for cost minimization and marginal cost

A constant return to scale intermediate firm's technology of production requires that the deviations of the firm's real marginal cost around the steady-state equilibrium be a linear function of deviations of factor prices around their steady-state values, minus the total factor productivity. The contribution of the deviation of each factor price is proportional to the share of output allocated to that factor. The relations are the following

$$(\hat{k}_t - \hat{\zeta}_{T,t} - \hat{l}_t) = \widehat{wr}_t - \widehat{zr}_t$$

$$\frac{1}{\omega_H}\hat{o}_{H,t} - \left(\left(\frac{1}{\omega_H} + \frac{1}{\theta_H}\right)\eta_H - \frac{1}{\theta_H}\right)\hat{l}_t - \left(\frac{1}{\omega_H} + \frac{1}{\theta_H}\right)(1 - \eta_H)\left(\hat{k}_{t-1} - \hat{\zeta}_{T,t}\right) + \widehat{pr}_{O,t} - \widehat{wr}_t = 0$$

10- The Phillips curve for the domestic goods consumed at home

In a monopolistic competitive good market, domestic good prices stickiness as in Calvo (1983) and partial indexation to lagged inflation of prices that cannot be reset optimally impose a sluggish adjustment to the desired markup. It follows that, the domestic good inflation rate dynamic is characterized by a New-Keynesian Phillips curve given by

$$\hat{\pi}_{H,t} = \frac{\beta}{1+\beta\chi_H}E_t[\hat{\pi}_{H,t+1}] + \frac{\chi_H}{1+\beta x_H}\hat{\pi}_{H,t-1} + \frac{\kappa_H}{1+\beta\chi_H}\left[\widehat{mcr}_{H,t} - \widehat{pr}_{H,t}\right]$$

Domestically produced good inflation (GDP deflator inflation rate) depends positively on the past inflation, the expected inflation, and the firm's real marginal cost.

11- Inflation of the exported goods in this sector

Prices stickeness as in Calvo (1983) and partial indexation to lagged inflation for exported goods prices that cannot be re-optimized imply that import prices adjust sluggishly to the desired markup. The dynamic of the imported goods inflation rate is given by

$$\hat{\pi}_{HF,t} = \frac{\beta}{1+\beta\chi_{HF}}E_t[\hat{\pi}_{HF,t+1}] + \frac{\chi_{HF}}{1+\beta x_{HF}}\hat{\pi}_{HF,t-1} + \frac{\kappa_{HF}}{1+\beta\chi_{HF}}\left[\widehat{mcr}_{HF,t} - \widehat{rer}_t - \widehat{pr}_{HF,t}\right]$$

Exported goods inflation depends positively on past inflation, the expected inflation, and the firm's real marginal cost.

12- Phillips curve for the imported goods

Prices stickeness as in Calvo (1983) and partial indexation to lagged inflation as in Smets and Wouters (2007) for imported goods prices that cannot be re-optimize imply that import prices adjust sluggishly to the desired markup. The dynamic of the imported goods inflation rate is given by

$$\hat{\pi}_{F,t} = \frac{\beta}{1+\beta\chi_F} E_t[\hat{\pi}_{F,t+1}] + \frac{\chi_F}{1+\beta\chi_F}\hat{\pi}_{F,t-1} + \frac{\kappa_F}{1+\beta\chi_F}[\widehat{rer}_t - \hat{\zeta}^*_{F,t} - \widehat{pr}_{F,t}]$$

where $\kappa_H = \frac{(1-\beta\phi_H)(1-\phi_H)}{\phi_H}$; $\kappa_{HF} = \frac{(1-\beta\phi_{HF})(1-\phi_{HF})}{\phi_{HF}}$; $\kappa_F = \frac{(1-\beta\phi_F)(1-\phi_F)}{\phi_F}$

The imported goods firm's marginal cost depends negatively on the domestic prices of imported goods, but positively on the exchange rate and the foreign prices of imported goods.

13- Structural balance rule for government consumption

$$\frac{P_G G}{P_Y Y}\hat{g}_t = \frac{\tau_P}{P_Y Y}(\hat{\tau}_{P,t} - \hat{y}_t) + \chi\frac{P_s Y_s}{P_Y Y}(\widehat{\overline{pr}}_{S,t} + \hat{y}_{S,t} - \widehat{pr}_{y,t} - \hat{y}_t)$$
$$+ \left(1 - \frac{1}{\Theta(1+i^*)}\right)\frac{B_G}{P_Y Y}\frac{1}{(1+\pi^*)(1+g_y)(1+n)}(\Delta\hat{e}_t - \hat{\pi}_{C,t} + \hat{b}_{G,t-1}$$
$$- \Delta\widehat{pr}_{Y,t} - \Delta\hat{y}_t - \hat{\zeta}_{T,t})$$
$$+ \frac{1}{\Theta(1+i^*)}\frac{B_G}{P_Y Y}\frac{1}{(1+\pi^*)(1+g_y)(1+n)}\hat{i}^*_{d,t-1}$$
$$+ \frac{P_G G}{P_Y Y}(\hat{\zeta}_{G,t} + \widehat{pr}_{H,t} - \widehat{pr}_{Y,t} - \hat{y}_t)$$

Fiscal authority

14- Choice of fiscal policy

$$\hat{g}_t - \widehat{pr}_{H,t} + \widehat{pr}_{Y,t} + \hat{y}_t = 0$$

15- Evolution of the fiscal net asset position

The following equation describes the evolution of the government debt.

$$\frac{\varepsilon B^*_G}{P_Y Y}\frac{1}{\Theta(1+i^*)}\hat{b}_{G,t}$$
$$= \frac{1}{(1+\pi^*)(1+g_y)(1+n)}\frac{\varepsilon B^*_G}{P_Y Y}(\Delta\hat{e}_t - \hat{\pi}_{C,t} + \hat{b}_{G,t-1} - \Delta\widehat{pr}_{Y,t} - \Delta\hat{y}_t$$
$$- \hat{\zeta}_{T,t}) + \frac{\tau_P}{P_Y Y}\hat{\tau}_{P,t} + \chi\frac{P_s Y_s}{P_Y Y}(\widehat{pr}_{S,t} + \hat{y}_{S,t} - \widehat{pr}_{Y,t} - \hat{y}_t) - \frac{P_G G}{P_Y Y}\hat{g}_t$$
$$+ \frac{B_G}{P_Y Y}\frac{1}{\Theta(1+i^*)}i^*_{d,t-1}$$

where $i^*_{d,t} = i^*_t + \rho b^*_t$

This equation shows that, the contemporaneous debt depends positively on the past debt and negatively on the government consumption, and depends positively on the external debt.

Monetary authority

16-Monetary policy

The monetary policy reaction function around the steady-state equilibrium is described by the equation

$$\hat{r}_t = \psi_r \hat{r}_{t-1} + (1-\psi_r)(\psi_\pi - 1)\hat{\pi}_{Z,t} + (1-\psi_r)\psi_y \Delta\hat{y}_t + (1-\psi_r)\psi_{rer}\widehat{rer}_t + \hat{\zeta}_{m,t}$$

17- The foreign demand for domestically produced goods

$$\hat{y}^*_{H,t} = \hat{y}^*_t - \eta^* \widehat{pr}_{HF,t}$$

18- The law of one price for commodity goods

$$\widehat{pr}_{S,t} = \widehat{rer}_t + \widehat{pr}^*_{S,t}$$

The real price of oil evolves according to the following expression

$$\widehat{pr}_{O,t} = \widehat{rer}_t + \widehat{pr}^*_{O,t}$$

Relative prices

In what follows, a "real" price denoted by $\widehat{pr}_{j,t}$, is the corresponding nominal price of good j relative to the price of the consumption bundle $\widehat{pr}_{j,t} = \hat{p}_{j,t} - \hat{p}_t$.

19- The law of motion for relative prices

The real price of non-oil goods evolves as follows

$$\hat{\pi}_{Z,t} = \widehat{pr}_{Z,t} - \widehat{pr}_{Z,t-1} + \hat{\pi}_{C,t}$$

The real price of domestically produced goods evolves as follows

$$\hat{\pi}_{H,t} = \widehat{pr}_{H,t} - \widehat{pr}_{H,t-1} + \hat{\pi}_{Z,t}$$

The real price of domestically produced goods sold abroad evolves as follows

$$\hat{\pi}_{HF,t} = \widehat{pr}_{HF,t} - \widehat{pr}_{HF,t-1} + \hat{\pi}^*_t$$

The real price of imported goods evolves as follows

$\hat{\pi}_{F,t} = \widehat{pr}_{F,t} - \widehat{pr}_{F,t-1} + \hat{\pi}_{Z,t}$

Let $\hat{\pi}_t^* = \hat{p}_{F,t}^* - \hat{p}_{F,t-1}^*$ be the foreign inflation expressed in foreign currency. From the definition of the real exchange rate, we obtain the following expression for the evolution of this variable:

$\Delta\hat{e}_t = \widehat{rer}_t - \widehat{rer}_{t-1} + \hat{\pi}_{C,t} - \pi_t^*$

20- Real interest rate (*ex-post*)

$\hat{r}_t = \hat{\imath}_t - \hat{\pi}_t$

Aggregate equilibrium

21- The total demand for domestically produced goods

The market clear condition for the Home goods sector is expressed as

$$\frac{P_H Y_H}{P_Y Y}\hat{y}_{H,t} = \gamma_C \frac{P_C C}{P_Y Y}\hat{c}_{H,t} + \frac{P_G G}{P_Y Y}\left(\hat{g}_t - \widehat{pr}_{H,t} + \widehat{pr}_{Y,t} + \hat{y}_t\right) + \gamma_I \frac{P_I I}{P_Y Y}\widehat{inv}_{H,t} + \frac{P_H Y_H^*}{P_Y Y}\hat{y}_{H,t}^*$$

The ratio $\frac{Y_H}{Y}$, corresponds to the steady-state fraction of Home goods to the total GDP, $\frac{G}{Y}$, the steady-state fraction of public consumption to the total GDP, $\frac{I}{Y}$, the steady-state fraction of total investment to the total GDP, and $\frac{Y_H^*}{Y}$, the steady-state fraction of foreign output to the total GDP.

22- The total supply of domestically produced goods

From the production function, we obtained the following log-linearized version output in the Home goods sector

$$\hat{y}_{H,t} = \hat{a}_{H,t} + \gamma_H^{1/\omega_H}\left(A_H \frac{O_H}{Y_H}\right)^{\frac{\omega_H - 1}{\omega_H}} \hat{o}_{H,t} + (1-\gamma_H)^{1/\omega_H}\left(A_H \frac{V_H}{Y_H}\right)^{(\omega_H - 1)/\omega_H} \eta_H \hat{l}_t$$
$$+ (1-\gamma_H)^{1/\omega_H}\left(A_H \frac{V_H}{Y_H}\right)^{(\omega_H - 1)/\omega_H} (1-\eta_H)\left(\hat{k}_{t-1} - \hat{\zeta}_{T,t}\right)$$

23- Real GDP

From the definition of total GDP, we got the following expression for the log-linearized total output

$$\hat{y}_t = \frac{P_C C}{P_Y Y}\hat{c}_t + \frac{P_G G}{P_Y Y}\left(\hat{g}_t - \widehat{pr}_{H,t} + \widehat{pr}_{Y,t} + \hat{y}_t\right) + \frac{P_I I}{P_Y Y}\widehat{inv}_t + \frac{P_X X}{P_Y Y}\hat{x}_t - \frac{P_M M}{P_Y Y}\widehat{m}_t$$

Where $\frac{C}{Y}$ is the consumption ratio to GDP in steady-state, $\frac{X}{Y}$ is total exports to GDP ratio and $\frac{M}{Y}$ is total import to GDP ratio.

24- Balance of payment

The foreign asset position of the domestic economy evolves according to the following expression

$$\begin{aligned}\frac{(1-\rho)B^*}{(1+i^*)\Theta(B^*)}\hat{b}_t^* &= \frac{B^*}{(1+i^*)\Theta(B^*)}\hat{i}_t^* \\ &+ \frac{B^*}{(1+\pi^*)(1+n)(1+g_y)}\left(\Delta\hat{e}_t - \hat{\pi}_{C,t} - \Delta\widehat{pr}_{Y,t} - \Delta\hat{y}_t + \hat{b}_{t-1}^* - \hat{\zeta}_{T,t}\right) \\ &- (1-\chi)\frac{\varepsilon P_S^* Y_S}{P_Y Y}\left(\widehat{pr}_{S,t} + \hat{y}_{S,t} - \widehat{pr}_{Y,t} - \hat{y}_t\right) \\ &+ \frac{P_X X}{P_Y Y}\left(\widehat{pr}_{X,t} + \hat{x}_t - \widehat{pr}_{Y,t} - \hat{y}_t\right) - \frac{P_M M}{P_Y Y}\left(\widehat{pr}_{M,t} + \widehat{m}_t - \widehat{pr}_{Y,t} - \hat{y}_t\right)\end{aligned}$$

where $B^* = \varepsilon B^*/P_Y Y$

25- Real export, import and the corresponding price deflators

The detrended and log-linearized expression for exports can be expressed as

$$\hat{x}_t = \frac{\varepsilon P_S^* Y_S}{P_X X}\hat{y}_{S,t} + \left(1 - \frac{\varepsilon P_S^* Y_S}{P_X X}\right)\hat{c}_{H,t}^*$$

where $\frac{Y_S}{X}$ is an export commodity ratio to total exports

The real price index of exports (exports deflator relative to the consumer price index) is given by

$$\widehat{pr}_{X,t} = \frac{\varepsilon P_S^* Y_S}{P_X X}\widehat{pr}_{S,t} + \left(1 - \frac{\varepsilon P_S^* Y_S}{P_X X}\right)\left(\widehat{pr}_{HF,t} + \widehat{rer}_t\right)$$

The detrended and log-linearized expression for imports can be expressed as

$$\widehat{m}_t = (1-\gamma_C)\frac{P_C C}{P_M M}\hat{c}_{F,t} + (1-\gamma_I)\frac{P_I I}{P_M M}\widehat{inv}_t M + \frac{P_O(C_O + O_H)}{P_M M}\left(\frac{C_O}{C_O + O_H}\hat{c}_{O,t} + \frac{O_H}{C_O + O_H}\hat{o}_{H,t}\right)$$

The real price index of imports (imports deflator relative to the consumer price index) is given by

$$\widehat{pr}_{M,t} = \widehat{rer}_t + \left(1 - \frac{P_O(C_O + O_H)}{P_M M}\right)\hat{\zeta}_{F,t} + \frac{P_O(C_O + O_H)}{P_M M}\widehat{pr}^*_{O,t}$$

26- Exogenous shocks

$\hat{u}_t = \rho_u \hat{u}_{t-1} + \eta_t$

where $\eta_t \sim N\left(0, \sigma_\eta^2\right)$ and $u_t = a_{H,t}, \zeta_{T,t}, y_{S,t}, \zeta_{m,t}, \zeta_{L,t}, \zeta_{C,t}, p^*_{S,t}, p^*_{O,t}, \zeta^*_{F,t}, i^*_t, \pi^*_t, y^*_t$

The linearized system formed with all the 54 equations are used to estimate the structural parameters.

CHAPTER 3: EMPIRICAL SETUP: CALIBRATION, ESTIMATION AND EVALUATION

Abstract

In this chapter, we estimate and evaluate a NK-DSGE model for Cameroon. The estimation and evaluation procedures require that optimality and equilibrium conditions in the model be detrended and that a linear approximation of the model be available. We solve for linear approximate decision rules and map from this solution into a state space model to generate Kalman filter projections. The likelihood of the linear approximate NKDSGE model is based on these projections. The projections and the likelihood are useful inputs into the Metropolis-Hastings Markov chain Monte Carlo simulator that we employ to produce Bayesian estimates of the NKDSGE model. We discuss an algorithm that implements this simulator. This algorithm involves choosing priors of the NKDSGE model parameters and fixing initial conditions to start the simulator. Given the posterior distributions, the NKDSGE model is evaluated under a DSGE-VAR approach.

Keywords: DSGE model, Bayesian, Metropolis-Hasting, Markov Chain Monte Carlo, Kalman filter, Likelihood, Cameroon

Introduction

In this chapter, we determine the values of the structural parameters that consistently describe the Cameroonian economy (chapter 2) along its long-run and short-run dimensions. This is achieved through two major steps. The model parameters are divided into two groups: (1) parameters that govern the steady-state solution of the model, which are calibrated so that the steady state is consistent with presumed long-run great ratios (shares in GDP), input weights in production or (imbalanced) growth rates for example; (2) parameters that govern only the dynamics of the system, which are in general estimated.

Thus, we focus in first on calibrating structural parameters such as depreciation rate of capital or parameters that are functions of steady-state ratios such as the labor and capital share in gross production of Home good which is function of the steady-state ratio of home capital to home labor. These parameters are weakly identified by variables expressed as deviations from the steady state and therefore cannot be pinned down consistently by estimating the linearized DSGE model with detrended data. The calibration aims at accurately depicting the structure of the Cameroonian economy, along its long-run properties. This implies determining a set of parameter values consistent with the steady state of the economy. To achieve this goal, we solve for the structural parameters using the non-linear decision rules evaluated at the steady state, and sample long-run averages are subsequently used to compute the values of these parameters.

Second, we infer the values of the remaining non-structural parameters (non-calibrated parameters) by estimating the linearized DSGE model using Cameroonian macroeconomic data. Those non-structural parameters are inferred under assumption of distributions with mean-zero and covariance matrix which require stationary variables. Those variables are expressed as percentage deviations from the steady state. Proceeding in this way ensures that variables measured from observed data are made compatible with their theoretical counterparts in the specified model.

In the literature, efforts to estimate and evaluate DSGE yielded on the classical optimization methods such as: maximum likelihood (ML) method, generalized method of moments (GMM), and indirect inference (II) method to estimate DSGE models. These estimators rely on classical optimization either of a log likelihood function or of a GMM criterion. Early authors of frequentist ML estimation of DSGE models are Altug (1989) and Bencivenga (1992). These authors apply classical optimization routines to the log likelihood of the restricted finite-order vector autoregressive-moving average (VARMA) implied by the linear approximate solutions of their real business cycle (RBC) models. The restrictions arise because the VARMA lag polynomials are non-linear functions of the DSGE model parameters. A restricted VARMA engages an ML estimator that differs from the approach of Sargent (1989). Sargent (1989) maps the linear solution of permanent income (PI) models with a serially correlated endowment shock into likelihoods that are built on Kalman filter innovations of the observed data and the associated covariance matrix. Sargent assumes that the data are ridden with measurement errors, which evolve as independent first-order autoregressions, AR(1)s[22]. This helps in identification because serially correlated measurement errors add restrictions to the VARMA implied by the PI model solution. An extension of Sargent's approach is Ireland (2001). Ireland (2001) replaces the independent AR(1) measurement errors with an unrestricted VAR(1); see Curdia and Reis (2011) for a Bayesian version of this method. Besides measurement errors, this VAR(1) inherits the sample data dynamics left unexplained by the RBC model that Ireland studied.

The tools of classical optimization are also useful for GMM estimation of DSGE models. Christiano and Eichenbaum (1992) construct GMM estimates of a subset of the parameters of their RBC model using its steady state conditions and the relevant shock processes as moments. Since the moment conditions are outnumbered by RBC model parameters, only a subset of these parameters are identified by GMM.

In their studies, these different authors looked for identification and misspecification problems in DSGE models. Identification matters for ML estimation of DSGE models. For example, Altug (1989), Bencivenga (1992), and Ireland (2001) only identify a subset of RBC model parameters after pre-setting or calibrating several other parameters. Analysis by Hall (1996) suggests a reason for this practice. Hall (1996) shows that whether ML or GMM is being used, these estimators are relying on the same sample and theoretical information about first moments to identify DSGE model parameters. Although ML is a full information estimator, which engages all the moment conditions expressed by the DSGE model, GMM and ML rely on the same first moment information for identification. This suggest that problems of identification in DSGE models are similar whether ML or GMM is the chosen estimator (see Fernández-Villaverde et al., 2009) for more discussion of these issues.

[22] Assuming sample data suffers from classical measurement error helps Altug identify the Kydland and Prescott

(1982) RBC model. Bencivenga achieves the same objective with AR(1) taste shocks in an RBC model.

Looking for the misspecification problem, the frequentist assumption of a true model binds the identification problem to the issue of DSGE model misspecification. The question is whether any parameters of a DSGE model can be identified when the model is misspecified. For example, frequentist ML loses its appeal when models are known to be misspecified[23]. Thus, it seems that no amount of data or computing power will solve problems related to the identification and misspecification of DSGE models. A frequentist response to these problems yields on the use of the II method. The first application of II to DSGE models is Smith (1993). Smith (1993) and Gourieroux, Monfort, and Renault (1993) note that II yields an estimator and specification tests whose asymptotic properties are standard even though the true likelihood of the DSGE model is not known[24]. The II estimator minimizes a GMM like criterion in the distance between a vector of theoretical and sample moments. These moments are readily observed in the actual data and predicted by the DSGE model. Estimating DSGE model parameters is “indirect” because the objective of the GMM like criterion is to match moments not related directly to the structure of the DSGE model[25]. Theoretical moments are produced by simulating synthetic data from the solution of the DSGE model. A classical optimizer moves the theoretical moments closer to the sample moments by updating the DSGE model parameters holding the structural shock innovations fixed[26].

In this thesis, we estimate the linearized DSGE model (see Appendix C2 of chapter 2) using Bayesian techniques. The motivation underlying the Bayesian approach to estimate the structural parameters of DSGE models are manifold. First, the Bayesian approach allows one to avoid the problem of specification of the model assuming that there exists a true or correctly specified DSGE model because of the likelihood

[23] White (1982) develops quasi-ML for misspecified models, but its consistency needs a strong set of assumptions.

[24] Gregory and Smith (1990, 1991) anticipate the II approach to DSGE model estimation and evaluation.

[25] Also, II can estimate DSGE model parameters by minimizing the distance between the likelihoods of an auxiliary model generated using actual and simulated samples. Simulated quasi-ML yields an asymptotically less efficient estimator because the likelihood of the auxiliary model differs from that of the DSGE model; see Smith (1993).

[26]Christiano et al (2005) estimate an NKDSGE model by matching its predicted impulse responses to those of an SVAR. This approach to moment matching is in the class of II estimators. See Canova and Sala (2009) for a discussion of the identification problem facing this estimator and Hall, et al (2012) for an optimal impulse response matching estimator of DSGE models.

principle (LP)[27]. Since the data's probabilistic assessment of a DSGE model is summarized by its likelihood, availability of a series of likelihoods, corresponding to different DSGE models allows one to judge which "best" fit the data. Thus, Bayesian likelihood-based evaluation is consistent with the view that there is no true DSGE model because. This is important at least because DSGE models are known to be afflicted with incurable misspecification (Guerrón-Quintana and Nason, 2012). Second, Bayesian methods offer researchers the chance to estimate and evaluate a wide variety of macro models that frequentist econometrics often find challenging. Third, advances in Bayesian theory are providing an expanding array of tools that researchers can exploit to estimate and evaluate DSGE models. Fourth, popularity of the Bayesian approach is also explained by the increasing computational power, available to estimate and evaluate small to large-scale DSGE models, using Markov chain Monte Carlo (MCMC) simulators.

Once consistent values of the parameters have been obtained, evaluation of the DSGE model is implemented. The purpose of this step is the assessment of the DSGE parameters to be able to capture the empirical dynamic and stochastic of the considered economy. We therefore adopt the DSGE-VAR approach under which a posterior predictive analysis is conducted and where the artificial data generated by the calibrated-estimated DSGE model are compared to actual data.

The rest of the chapter is organized as follows. Section 2 addresses the calibration issue. Estimation of non-calibrated parameters is performed in section 3. Model evaluation is conducted in section 4. In section 5, we infer forecasts of key macroeconomic variables from the estimated model. Section 6 concludes.

2- Model Calibration

In this section we calibrate the DSGE model's parameters associated with the long-run values of the endogenous variables. Following the traditional approach to calibration,

[27] The LP being the foundation of Bayesian statistics, it says that all evidence about a DSGE model is contained in its likelihood conditional on the data (see Berger and Wolpert, 1988).

outwards the steady-state parameters which are calculated, we borrow the other parameters' values from the literature on economies showing a similar structure. Practitioners of DSGE models recognise such a strategy as being the easiest way towards making the theoretical model mimic and reproduce stylized facts about the economy under investigation (DeJong and Dave, 2007). The calibrated model then serves as a reference when assessing the dynamics of key macroeconomic variables that arise after the economy is hit by some random shock. In this study, we borrow most of the parameters' values from other studies. More specifically, in the absence of similar studies on the economy of Cameroon, we borrow most of the parameter values from Sangare (2013) who provides a DSGE model for the Economic Community of West African States (ECOWAS)[28]. Only for those parameters not available in Sangare (2013), do we borrow our calibration values from other studies investigating the economies of of developing countries. Examples of studies we rely on are those of Haider et al.(2013) for Pakistan or Medina and Soto (2007) for Chile, etc.. Parameters for which the available literature on developing countries is not helpful are assigned values from the world. Examples of these are the studies by Smets and Wouters (2007) and Lubik and Shorfheide (2005). The complete list of calibrated parameters is reported in table 1 below.

2.1- Calibrated structural parameters

The first category of structural parameters is related to household preferences. The parameter value of the discount factor (β) is taken as 0.99. This value is consistent with the annual estimates of discount factor β as in Sangare (2013). This value is set in order to obtain historical mean of the real interest rate in the steady state. As argued in Ahmed, *et al.*(2012), the long-run real interest rate is low in most developing countries. Therefore, the selected parameter value of the intertemporal discount factor is quite useful for our model calibration as our prime concern is to

[28] ECOWAS encompasses 15 members, namely Benin, Burkina Faso, Cape-Verde, Cote-d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria and Sierra Leone, Senegal and Togo.

replicate business cycle fluctuations of a developing economy like Cameroon. The parameter value of the wage elasticity of labour supply (σ_L) is taken as 1.5. This value is consistent with the estimates reported in Sangare (2013), Ahmed et al. (2012), and Fagan and Messina (2009). The share of core goods in the consumption basket of households (γ_C) is taken as 0.75. This value is used by Batini (2010b) for India and Haider et al. (2013) for Pakistan. It is consistent with the observation that the subsistence level of consumption is high in most developing economies and that people spend approximately 75% of their budget on core-consumption related goods. The rest is allocated to oil and energy related items. The elasticity of intertemporal substitution between core and oil goods consumption bundle is fixed at 0.35. This value is consistent with posterior estimates given in An and Kang (2009) for Korea and in Medina and Soto (2007) for Chile economies. We also set the share of oil in the consumption basket at 1.5% ($\alpha_C = 0.985$) as in Medina and Soto (2007). The relative size of non-Ricardian households is set to ($\lambda = 0.6$). This corresponds to the percentage (60%) of households that cannot smooth consumption in the time.

The second category of parameters relates to aggregate investment and production. The share of home investment in aggregate private investment (γ_I) is fixed at 0.65. The corresponding elasticity of substitution between home and foreign private investment (η_I) is taken as 1.20. These parameter values are consistent with Medina and Soto (2007). The capital depreciation rate (δ) is taken as 0.03 following Sangare (2013). It implies that capital annually depreciates at a rate around 12%. Bukhari and Khan (2008), Haider and Khan (2008) and Ahmad et al.(2012) studies used a similar estimate for the depreciation rate for Pakistan.

2.2- Other calibrated parameters

Because we do not have information on prices and wages markups, we use the values suggested by Medina and Soto (2007) and Haider et al. (2013) and set $\epsilon_L = \epsilon_{HD} = \epsilon_{HF} = \epsilon_F = 11$[29].

In the production function of domestic producers, we assume that the labor share is about two thirds ($\eta_H = 68\%$) of the value added following Ahmed et al. (2012). Oil as an intermediate input represents $1\ \%$ of the gross value of the home good production ($\alpha_H = 0.99$) following Medina and Soto (2007) for Chile and Beidas-Strom and Poghosyan (2011) for Jordan.

OLS estimates of the whole sample period for the underlying parameters governing the AR(1) process of the international wood and oil prices. The point estimates then are: $\rho_{P_S^*} = 0.86$ and $\rho_{P_O^*} = 0.91$ with standard errors equal to 19% and 22.7% respectively[30].

Once the structural parameters are calibrated, the steady-state ratios can be set or computed. Thus, the share of the commodity export sector in total GDP is set to 19 %, the net export to GDP ratio, $\frac{X-M}{Y}$, in the steady state is set to 3.5%, which is consistent with its average value in the sample period analysis. The remaining steady-state ratios are presented in table 1 below.

Table 3.1: Calibrated parameters

Parameters or	Sample Long-run	Descriptions

[29] ϵ_L, wage markup; ϵ_{HD}, home domestic price markup; ϵ_{HF}, home foreign price markup; ϵ_F, foreign price markup.

[30] $\rho_{P_S^*}$ and $\rho_{P_O^*}$ are respectively the persistence coefficient of price commodity and international oil price.

Ratios	averages	
g_y	4.5%	Steady-state GDP growth
$\bar{\pi}$	5.5%	Steady-state inflation target
β	0.99	Discount factor
α_C	98.5%	Share of core consumption
γ_C	65%	Share of home goods in core consumption
γ_I	50%	Share of home goods in investment
χ	40%	Government share in commodity production
δ	5.8%	Depreciation rate of capital
α	99%	Labor and capital share in gross prod. of Home good
η_H	68%	Labor share in value added prod. of home goods
ρ_{ϵ_L}	0.75	AR(1) coef. of the elast. of sub among lab. var.
ρ_{ϵ_H}	0.56	AR(1) coef. of the elast. of sub among H. goods
ρ_{ϵ_F}	0.81	AR(1) coef. of the elast. of sub among H. goods
$\rho_{p_S^*}$	0.86	AR(1) coefficient of the int. commod price
$\rho_{p_O^*}$	0.91	AR(1) coefficient of the international oil price
$\sigma_{p_S^*}$	19%	Std. deviation of the international commod
$\sigma_{p_O^*}$	22.7%	Std. deviation of the international oil price
Ah	0.5738	Steady technology

BG/Y	0.01	Steady state ratio of public debt to output
$\frac{CA}{Y}$	-0.5486	Current Account/GDP ratio
C/Y	0.5625	Steady state ratio of household consumption to output
Gh/Kh	0.1884	Steady state ratio of domestic government expenditure to home cap.
Gh/Lh	3.9183	Steady-state ratio of domestic government expenditure to home labor
Gh/Y	0.2	Steady-state ratio of domestic government expenditure to output
I/Y	0.2275	Steady-state ratio of whole investment to output
Id/Kh	0.0241	Steady-state ratio of domestic investment to domestic capital
Kh/Lh	20.7966	Steady-state ratio of home capital to home labor
M/Y	0.3401	Steady-state ratio of import to output
Mo/M	0.6159	Steady-state ratio of imported oil to import
NX/Y	0.03499	Steady-state ratio of net export to out
Oh/Lh	0.3501	Steady-state ratio of oil input to labor
X/Y	2.2034	Steady-state ratio of export to GDP
Yh/Y	1.1195	Steady-state ratio of domestic production to GDP
Ys/Y	0.19	Steady-state ratio of commodity to output
S/I	4.8962	Steady-state ratio of saving to investment

3- Model Estimation

The estimation requires using the Kalman filter algorithm to form the maximum likelihood function of the observed data and maximizing the posterior distribution through numerical methods. Non-existence of clear analytical solutions to the maximization of the posterior distribution motivates the use of numerical methods. Once the posterior mode and the hessian condition number have been computed, we resort to a Monte-Carlo Markov-Chain technique to construct draws from the posterior distribution and get its complete picture. We do this using the Metropolis-Hastings algorithm. To test the stability of the sample and monitor the convergence of the posterior distribution to its target distribution, we calculate convergence diagnostics as described in Brooks and Gelman (1998) and compare between and within moments of multiple chains.

Likelihood maximization is achieved through the following steps. We first solve for a reduced-form state-space representation of the model, expressed in its general form as follows

$$E_t[f(y_t, y_{t+1}, y_{t-1}, u_t, \theta)] = 0 \qquad (1)$$

$$E(u_t) = 0 \qquad (2)$$

$$E(u_t u_t') = \Sigma_u \qquad (3)$$

where (1) is a system of difference equations, $E_t[f(.)]$ denoting conditional expectation. y_t is a vector of endogenous variables, u_t is a vector of exogenous stochastic shocks, θ a vector of parameters and Σ_u is the covariance matrix of the exogenous shocks. The parameters and the covariance matrix are estimated here and not calibrated. In general, the solution is in the form

$$y_t = g_y(\theta) y_{t-1} + g_u(\theta) u_t, \qquad (4)$$

where $E(u_t u_t') = \Sigma_u$

and it usually serves to determine the policy function. Several techniques can be applied to solve (1)[31].

In the second step, the linearized model is casted into a state space specification. This involves to increase the state equation in the predetermined variables with an observation equation that links observable macroeconomic variables to predetermined variables. Usually, this observation equation, also known as the measurement equation, takes the form:

$$y_t^{obs} = A(\theta)x_t + B(\theta)\bar{y} \qquad \text{or} \qquad y_t^{obs} = A(\theta)x_t + B(\theta)\bar{y} + e_t \tag{5}$$

A subset of the endogenous variables consists of empirically observable variables y_t^{obs}, and they are linked to the whole set of endogenous variables in the model through the measurement function $f^{obs}(.)$. These measurement functions link the observable variables to the other endogenous variables with the inclusion of steady state values.

The third step entails the use of the Kalman filter (see Appendix D 1 for the theoretical running of Kalman filter) to form the likelihood function of the observed data (see for example Guerrón-Quintana and Nason, 2012; Wolters, 2012)[32]. The final step involves estimation of non-calibrated parameters by maximizing the likelihood function.

[31] The Blanchard and Kahn (1980) method, the anderson and Moore (1985) algorithm, the Sims (2002) method, the Klein (2000) method, and the Uhlig (1999) method are the most commonly used in the applied macroeconomics literature.

[32] The Kalman filter is useful for evaluating the likelihood of a linearized NKDSGE model because the forecasts are optimal within the class of all linear models. When shock innovations and the initial state of the NKDSGE model are assumed to be Gaussian (*i.e.*, normally distributed), the Kalman filter renders forecasts that are optimal against all data-generating processes of the states and observables.

Equations (4) an (5) may be summarized in the following form $y_{t+1} = \mathcal{G}(y_t, u_{t+1}, \Theta)$, and the likelihood of the data sample $y^T = \{y_1, \dots, y_T\}$ conditional on our model $\mathcal{G}$ with parameters $\Omega = \{\Theta, \Sigma_u\}$ is given by

$$L(y^T/\mathcal{G}, \Omega) = \prod_{t=1}^{T} p\left(y_t^{obs}/y^{T-1};\ \mathcal{G}, \Omega\right)$$

$$= \prod_{t=1}^{T} \int p\left(y_t^{obs}/y_t;\ y^{T-1};\ \mathcal{G}, \Omega\right).p(y_t/y^{T-1};\ \mathcal{G}, \Omega)dy_t$$

where p denotes a probability density.

The Bayesian approach is used to estimate the DSGE model. The goal of Bayesian estimation is the construction of the posterior distributions, $p(\theta/y_T)$, of DSGE model parameters conditional on sample data y_T of length T. Bayesian estimation exploits the fact that the posterior distributions equal the DSGE model likelihood, $L(y_T/\theta)$, multiplied by the econometrician's priors on the DSGE model parameters, $p(\theta)$, up to a factor of proportionality

$$p(\theta/y_T) \propto L(y_T/\theta)p(\theta) \qquad (6)$$

From (6), Bayesian estimation of DSGE models is confronted with the posterior distribution being too complicated to evaluate analytically. The complication arises because the mapping from a DSGE model to its likelihood function, $L(y_T/\theta)$, is nonlinear in θ, which suggests using simulation to approximate $p(\theta/y_T)$.

As it is argued in DeJong and Dave (2011), the motivation to incorporate $p(\theta)$ into the analysis is found behind the definition of the conditional probability which holds that the joint probability of (y, θ) may be calculated as

$$p(y_T,\theta) = L(y_T/\theta)p(\theta) \tag{7}$$

or, reversing the roles of θ and y,

$$p(y_T,\theta) = p(\theta/y_T).p(y_T) \tag{8}$$

In (6), the likelihood function is used to perform the conditional probability calculation, and conditioning is made with respect to θ; $p(\theta)$ in turn assigns probabilities to specific values of θ. In (7), $p(\theta/y_T)$ is used to perform the conditional probability calculation, and conditioning is made with respect to y, $p(y_T)$ in turn assigns probabilities to specific values of y. Eliminating $p(y_T,\theta)$ by equating (6) and (7) and solving for $p(\theta/y_T)$ yields the Bayes' rule as

$$p(\theta/y_T) = \frac{L(y/\theta)\mu(\theta)}{p(y_T)}$$

$$\propto L(y_T/\theta)p(\theta) \tag{9}$$

Where $p(y_T)$ is a constant from the point of view of the distribution for θ.

$p(\theta/y_T)$ in (8) is the posterior distribution of θ given y_T. Conditional on y_T and the prior $p(\theta)$, it assigns probabilities to alternative values of θ; this distribution is the central focus of Bayesian analysis.

Among the earliest examples of Bayesian likelihood-based estimation of a DSGE model is DeJong, Ingram, and Whiteman (2000a, 2000b). They resort to the notion of importance sampling to compute posterior distributions of functions of θ, $\mathcal{G}(\theta)$. Importance sampling relies on a finite number N of IID random draws from an arbitrary density $\mathcal{D}(\theta)$ to approximate $\mathcal{G}(\theta)$. The approximation is computed with weights that smooth $\mathcal{G}(\theta)$. The weights, $\mathcal{W}(\theta_i)$, $i = 1, \dots, N$ smooth the approximation by giving less (greater) mass to posterior draws of $\mathcal{G}(\theta_i)$, that occur frequently (infrequently)[33]. One drawback of importance sampling is that it is often unreliable when θ has a large dimension. Another drawback is that there is little guidance about updating $p(\theta/y_T)$, and therefore, $\mathcal{G}(\theta)$, from one draw of $\mathcal{D}(\theta)$ to the next, given $p(\theta)$.

Otrok (2001) reports estimates of a DSGE model grounded on the Metropolis-Hasting (MH) algorithm. This is, perhaps, the first instance of MH-MCMC simulation applied to DSGE model estimation according to Guerrón-Quintana and Nason (2012). The MH algorithm proposes to update θ using a multivariate random walk. It, however, requires that an initial draw of θ from, $p(\theta)$ be first available. The initial θ is updated by adding to its draws from a distribution of "shock innovations." The decision to keep the initial θ or to move to the updated θ depends on whether or not the latter increases $L(y_T/\theta)$. This process is repeated by sampling from the multivariate random walk to update θ.

In the literature, the MH-MCMC simulator is often preferred to the importance sampling methods to estimate DSGE models. One reason is that the MH algorithm places less structure on the MCMC simulator. Thus, a wide class of time series models can be estimated by MH-MCMC simulation. Also MH-MCMC simulators generate serial correlation in the posterior distribution, which induces good asymptotic properties, especially as compared to importance samplers. These properties reduce the computational burden of updating the prior. Another useful feature of MH-MCMC simulation is that its flexibility lessens the demands imposed by high dimensional θ. Thus, Bayesian estimation of NKDSGE models leans heavily on MH-MCMC simulation. Smets and Wouter (2003, 2007), Del Negro and Schorfheide (2004), and Del Negro, Schorfheide, Smets and Wouter (2007) estimate NKDSGE models that are similar in nature to the one we estimate in this thesis. Open

[33] Given N draws from $\mathcal{D}(\theta)$, $E\{\mathcal{G}(\theta)\}$ is approximate as $\bar{\mathcal{G}}_N = \sum_{i=1}^{N} \mathcal{W}(\theta_i)\,\mathcal{G}(\theta_i)/\sum_{i=1}^{N} \mathcal{W}(\theta_i)$, where the weights, $\mathcal{W}(\theta_i)$, equals $p(\theta_i/Y_t)/\mathcal{D}(\theta_i)$

economy NKDSGE models are estimated using MH-MCMC simulators by Adolfson, Laséen, Lindé, and Villani (2007), Lubik and Schorfheide (2007), Kano (2009), Justiniano and Preston (2010), Rabanal and Tuesta (2010), and Guerrón-Quintana (2010b) among others. Other studies relying on MH-MCMC algorithm include Sala, Söderström, and Trigari (2008) who estimate a DSGE model with job search, Leeper, Plante, and Traum (2010) who focus on fiscal and monetary policy interactions and Aruoba and Schorfheide (2011) who compare sticky price monetary transmission to monetary search frictions.

Our study is based on annual Cameroonian data covering the 1960-2012 period. Our observable variables are household consumption, C_t, investment, inv_t, real GDP, Y_t, commodity production, $Y_{s,t}$, short-run interest rate, R_t, a measure of core-inflation computed by the Central Bank as a proxy for core-inflation, the real exchange rate, RER_t, current account/GDP ratio, $\frac{CA_t}{P_{Y,t}Y_t}$. We also include the international price of wood and oil (in dollars, deflated by a proxy of the foreign price index) as a proxy for the real price of the commodity good exported and imported, $P^*_{S,t}$ and $P^*_{O,t}$, respectively. International inflation and international growth are the foreign observed data. In total, we have twelve observable variables. Inflation rate is expressed as the deviation from its target level, $\hat{\pi}_{z,t}$. In the case of real output we use the first difference of the corresponding logarithm and we express it as the deviation from its long-run growth rate. The short-run interest rate corresponds to the monetary policy rate. Thus the set of our observable variables is the following:

$$y_t^{obs} = \left\{\Delta lnY_t, \hat{R}_t, \hat{\pi}_{Z,t}, \widehat{rer}_t, \widehat{pr}_{O,t}, \widehat{pr}^*_{S,t}, \frac{CA_t}{P_{Y,t}Y_t}, \Delta lnY^*_t, \hat{R}^*_t, \widehat{inv}_t, \hat{c}_t, \hat{y}_{S,t}\right\}$$

where $\hat{R}_t = \hat{\imath}_t - \hat{\pi}_{C,t}$ denotes the real ex-post interest rate.

Now, to obtain the linearized version of the DSGE model, we have defined a detrended endogenous variable y_t as $y_t = \bar{y}(\exp)^{\hat{y}_t}$ where $\bar{y}$ is the (detrended) endogenous variable steady state (and defined the balanced growth path when combine with the trend growth rate) and $\hat{y}_t$ is its deviation from the steady state (or from the balance growth path). To establish the correspondence between what is explained by the model and what the data actually measure, the observable variable is defined as $y_t^{obs} = \bar{y}_t^{obs}(exp)^{\hat{y}_t}$, where $\bar{y}_t^{obs}$ denotes the trend component (balance growth path) and $\hat{y}_t$the deviation from that trend (cyclical component). The trend component is characterized by $\bar{y}_t^{obs} = \bar{y}^{obs}(exp)^{\bar{g}t}$ where $\bar{g}$ is the annual growth rate. Thus the observable variable y_t^{obs} is defined by $y_t^{obs} = \bar{y}^{obs}(exp)^{\bar{g}t}(exp)^{\hat{y}_t}$. As in theory endogenous real variables are supposed to have a common trend component, the balance growth path, symmetrically, it is dictated to remove it from all observable real variables which are: GDP, consumption, investment, etc..

Taking the logarithm on both sides of the observable variable's definition, we obtain $log(y_t^{obs}) = log(y^{obs}) + \bar{g}t + \hat{y}_t$. Trend removal is achieved through differencing, and the first difference of the endogenous observable variable y_t is given by:

$$dlog(y_t^{obs}) = log(y_t^{obs}) - log(y_{t-1}^{obs}) = (1-L)log(y_t^{obs})$$
$$= log(y^{obs}) + \bar{g}t + \hat{y}_t - log(y^{obs}) - \bar{g}(t-1) - \hat{y}_{t-1}$$
$$= \hat{y}_t - \hat{y}_{t-1} + \bar{g}$$

where L is the conventional lag operator. We apply this differencing technique to obtain the measurement equation associated to the log difference of real GDP, real consumption, and real investment.

To estimate the linearized DSGE model in Dynare version 4.2.2, we first maximize the log posterior distribution function, which combines the prior distribution on the parameters with the likelihood function of the data obtained through the Kalman filter. Once the mode and the Hessian at the mode have been computed, we use the Metropolis-Hasting algorithm with 2.000.000 draws (in two parallel chains) to obtain a complete picture of the posterior distribution and evaluate the marginal likelihood of the model. We tune to 0.2 the scale for the jumping distribution in the Metropolis-Hasting such that the acceptance rates are close to 30% (37.65% in the first chain and 34.85% in the second chain). The first half of the draws is disregarded. To test the stability of the sample and monitor the convergence of the posterior distribution, we perform the convergence diagnostics in the spirit of Brook and Gelman (1998) and compare between and within moments of multiple chains as it is shown in the appendix at the end of this chapter. Before presenting the estimation results, we give an overview of our assumptions regarding the prior distributions.

3.1- Prior distributions of the estimated parameters

Priors' distributions (means and standard deviations) are gleaned from personal belief about parameter values and economic theory (Schorfheide, 2000). In practice, priors are chosen on the basis of theoretical restrictions on the parameter values (non-negativity or confidence interval) given in the existing literature. Thus, the Beta distribution is chosen for parameters with values constrained in interval [0, 1], while the gamma and normal distributions pertain to parameters the values of which are non-negative. The inverse gamma distribution is used for the distribution of standard deviations of shocks.

We also assume that all the standard errors of the structural shocks contained in the model follow an inverse-gamma distribution with three degrees of freedom. Our assumption is motivated by the inverse-gamma distribution ensuring that the variances of the shocks are positive and are estimated over a large support as in Smets and Wouters (2004, 2007). The precise mean for these prior distributions are based on estimation using the training sample. The persistent coefficients of each AR(1) describing an exogenous process is Beta-distributed with mean 0.75 and standard error 0.2. Since the standard error covers the 0-1 range, the autoregressive parameter of each exogenous process falls between 0 and 1, which ensures stationarity of the estimated DSGE model (see also Medina and Soto, 2007).

Priors distributions on technology and utility parameters are set following Medina and Soto (2007), Haider et al. (2013) and Smets and Wouters (2007). Thus, the coefficient of the relative risk aversion is Gamma distributed with mean 1 and a standard error of 0.75. Similarly, the inverse of the elasticity of work effort with respect to real wage is assumed to follow a Gamma distribution with a mean equal to 1 and a standard deviation equal to 0.85. The habit formation parameter is Beta-distributed with mean 0.57 and standard deviation 0.1. The elasticity of substitution of oil in the consumption basket and the elasticity of substitution of oil in production are inverse-gamma-distributed with 5 degrees of freedom and mean 0.3. Intratemporal elasticity of consumption and intratemporal elasticity of investment also follow an inverse-gamma distribution with 5 degrees of freedom and mean 1. The same distribution is assumed for the investment inertia coefficient with 3 degrees of freedom and a mean of 2.

The Calvo parameter in the domestically produced goods and the import goods sectors are assumed to be Beta-distributed with mean 0.75, suggesting an average length of price contract around four months, and a standard deviation of 0.1 so that the domain covers a reasonable range of parameters values. The training sample suggests a much higher mean to the Calvo probability for wage indexation. Thus, this parameter follows a Beta distribution with mean 0.75 and a standard deviation of 0.05. The price indexation parameters in the domestically produced goods sector and in the import goods sectors are assumed to fluctuate around 0.5 as the wage indexation parameter. The standard deviation of their Beta distribution is 0.25.

We now set the prior information describing the monetary policy rule as in Smets and Wouters (2007). The long run reaction to inflation, output gap, and currency depreciation are assumed to be described by a Gamma distribution with means 1.5, 0.5, and 0.2, respectively. The standard deviation associated with these Gamma distributions are 0.15, 0.15, and 0.1, respectively. The smoothing coefficient of the interest rate is assumed to be Beta-distributed with mean 0.75 and standard error 0.15.

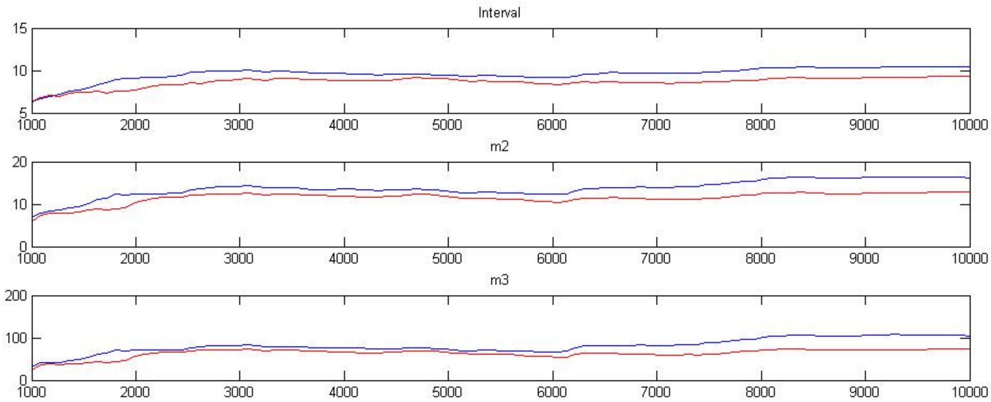
Eventually, the intratemporal elasticity in foreign demand and the elasticity of endogenous external premia are assumed to follow inverse-gamma distributions with

4 degrees of freedom and means 1 and 0.01, respectively, as in Smet and Wouters (2007).

3.2- Posterior estimates of parameters

In the estimation process, the mean, along with the 5th and 95th percentile of the posterior distribution of the parameters, are obtained through the Metropolis-Hasting algorithm (see appendix D2 for the running of Metropolis-Hasting algorithm). This algorithm is based on 200.000 iterations. The convergence diagnostic test performed is done using the "multivariate diagnostic", as is depicted in Figure 1 below. In this figure and for a set of estimated parameters, "interval" is constructed from an 80% confidence interval around the mean, "m2" is a measure of the variance, and "m3" is based on the third moments. The red and blue lines on the charts represent those specific measures both within and between chains. In general, results within iterations of Metropolis-Hastings simulations are similar, and the results between the two chains are very close. Convergence and relative stability are obtained in all measures of the parameters moments with, 200.000 draws of the Metropolis-Hastings albeit slight differences exhibited by some measures, related to marginal share monitoring - cost parameters. The convergence diagnostic test performed using the “multivariate diagnostic”, depicted in figure 1, shows that the convergence is reached (see also univariate diagnostics in appendix D 3).

Figure 3.1: Multivariate convergence diagnostic



The following table shows results regarding the parameter estimates. In this table, the posterior mode is obtained by numerical optimization on the log posterior density with respect to the parameters, and the approximated standard errors based on the corresponding Hessian. In this Table, prior's shape, mean and standard deviation, and statistics for the posterior distribution are reported. The mode was retrieved by standard optimization algorithms and the standard deviation is approximated by the inverse of the Hessian matrix. The mean, as well as the 5th and 95th percentiles of the posterior distribution were calculated by generating 4 chains of 2.000.000 draws (half of which were burnt out) from the posterior distribution using the Metropolis-Hasting algorithm. The scaling factor of the algorithm was calibrated so as to obtain an acceptance rate of approximately 0.3. The convergence of the chains was monitored using the Brooks and Gelman (1998) algorithm.

According to this table, the mode of the Frish labor elasticity, σ_L^{-1} is estimated to be around 1. The habit formation parameter has a posterior mode which is equal to 0.85. This coefficient reflects the important degree of consumption inertia in Cameroon and is in line with estimates for developing countries such as Jordan by Beidas-Strom and Poghosyan (2011), Medina and Soto (2007) for Chile, Aider et al. (2013) for Pakistan. The intra-temporal elasticity of substitution between home and foreign goods in different bundles is estimated to have a mode close to one. We find that the data are not informative regarding the degree of substitution of oil in the consumption basket and in the production technology: in fact, the posterior mode of the corresponding parameters resembles quite closely our prior. The parameters of the monetary policy reaction function have a posterior mode between 1.4 and 1.6. The policy response to output growth is lower than the response to interest rate with a range from 0.5 to 0.7. Turning now to the productivity shock, the estimated persistence of the transitory shock turns out to be quite large: its mode is 0.93. Also, preference shocks and labor supply shocks seem to be persistent: Their modes are close to 0.9, well above the mode of our prior distributions. In contrast, investment shocks reveal to be less persistent than our prior. They, however, seem to be more volatile as shown by their standard deviations.

Table 3.2: Priors and Posterior estimations

Parameters	Mean	Stdv	Conf. Interval	Shap	Pst.mode	Stdv
σ_L: Inv. of the elast. of lab. supply	1.00	1.00	0.8417 0.9435	G	0.84	0.20
h: Habit formation	0.50	0.25	0.7167 0.8961	B	0.85	0.23
ϕL: Calvo probb in nominal wages	0.75	0.10	0.0060 0.2276	B	0.82	0.15
χL: Indexation of nominal wages	0.50	0.25	0.1224 0.5169	B	0.44	0.57
ηC: Intratemporal elasticity in consump	1.00	5.00	0.1158 0.5942	IG	1.12	0.14
ηI: Intratemporal elasticity in invest	1.00	5.00	0.8584 0.9111	IG	1.04	0.08
ϕHD: Calvo probb in dom price of home g.	2.00	3.00	0.0901 0.6154	IG	1.48	0.20
χHD: Indexation of dom price of home g.	0.75	0.10	0.4463 0.9571	B	0.74	0.16
ϕHF: Calvo probb in foreign price of h. g.	0.50	0.25	0.0017 0.2299	B	0.34	0.16
χHF: Indexation of foreign price of h. g.	0.75	0.10	0.7357 0.9687	B	0.59	0.18
ϕF: Calvo probb in price of imported g.	0.50	0.25	0.0272 0.9024	B	0.31	0.17
χF: Indexation price of imported goods	0.75	0.10	0.0694 0.4667	B	0.66	0.67
ωC: Elasticity of subst of oil in the cons b.	0.50	5.00	0.8682 1.2391	B	0.28	0.08
ωH: Elasticity of subst of oil in the product	0.75	5.00	0.6277	B	0.30	0.09

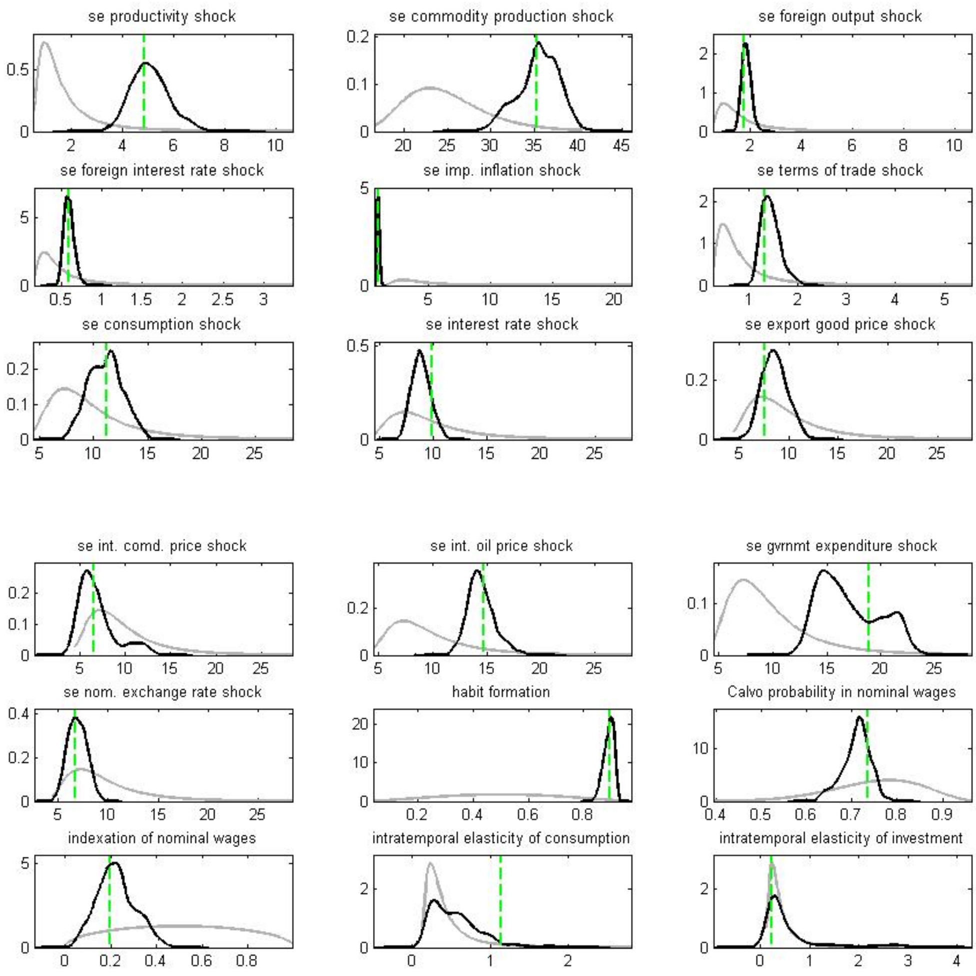
			0.7883			
ψi: Smoothing coef	1.50	0.15	1.1922 1.5032	IG	0.30	0.09
ψrer: Reaction to RER deviation	0.2	0.15	0.7922 1.2386	G	0.73	0.09
$\psi\pi$: Reaction to inflation deviation	0.50	0.10	0.2422 1.7840	G	1.61	0.13
ψy: Reaction to GDP growth deviation	0.30	0.15	0.0021 0.1070	G	0.28	0.16
$\eta *$: Intratemp. elast. in foreign demand	1.00	4.00	0.6488 0.9819	IG	0.79	0.14
ρ: Elast. of endogenous external premium	0.01	4.00	0.6227 0.7843	IG	0.01	0.13
ρaH: Persistence of productivity shock	0.70	0.20	0.5272 0.9024	B	0.93	0.50
ρys: Persistence comm production shock	0.70	0.20	0.5462 0.9334	B	0.77	0.48
$\rho y *$: Persistence foreign demand shock	0.70	0.20	0.8698 0.9668	B	0.67	0.53
$\rho i *$: Persistce foreign interest rate shock	0.70	0.20	0.7888 0.8964	B	0.87	0.24
$\rho\pi *$: Persistence foreign inflation shock	0.70	0.20	0.4678 0.7462	B	0.80	0.07
$\rho\varsigma L$: Persistence labor supply shock	0.70	0.20	0.2492 0.6570	B	0.89	0.27
$\rho\varsigma C$: Persistence preference shock	0.70	0.20	0.4032 0.8432	B	0.87	0.39
$\rho\varsigma G$: Persistce gov't expenditure shock	0.70	0.20	0.7961 0.9897	B	0.65	0.27
$\rho\varsigma I$: Persistence investment adj cost shock	0.70	0.20	0.6053 0.9398	B	0.34	0.44
$\rho\varsigma * F$: Persistce of for. imp. price shock	0.70	0.20	0.1047 0.3147	B	0.90	0.09

$\rho\varsigma T$: Persistence permanent prod shock	0.70	0.20	0.6067 0.9995	B	0.73	0.08
σaH: St dev transitory prod. shock innov.	1.00	3.00	0.7563 0.9943	G	1.43	0.10
σys: St dev comm prod. shock innov.	1.00	3.00	24.366 47.2364	G	4.51	0.16
$\sigma y*$: St dev foreign demand shock innov.	1.00	3.00	3.6162 9.3233	G	3.57	0.22
$\sigma i*$: St dev for interest rate shock innov	0.50	3.00	1.5459 2.1388	G	0.37	0.08
$\sigma\pi*$: St dev foreign inflation shock innov	0.25	3.00	0.4905 0.7108	G	0.28	0.01
σm: St dev monetary policy shock innov	0.20	3.00	0.7924 1.0650	G	0.39	0.23
$\sigma\varsigma L$: St dev labor supply shock innovation	1.00	3.00	1.0909 2.1124	G	1.01	0.01
$\sigma\varsigma C$: St dev preference shock innovation	1.00	3.00	6.0811 17.0956	G	5.99	0.24
$\sigma\varsigma G$: St dev gov't expendit shock innov	1.00	3.00	6.7077 11.3787	G	4.16	0.09
$\sigma\varsigma I$: St dev invest adj cost shock innov.	1.00	3.00	4.7996 11.3946	G	0.40	0.39
$\sigma\varsigma*F$: St dev of for imp price shock innov	1.00	3.00	4.0760 10.8157	G	0.56	0.17
σT: St dev permanent product shock innov	1.00	3.00	7.7336 31.9446	G	0.78	0.28

B: beta distribution; G: gamma distribution; IG: inverse gamma distribution; and stdv: standard deviation; Pst mode: posterior mode

Figure 2 below summarizes the estimation results visually as it consists of plots of the prior distribution (dashed lines), the posterior distribution (thick lines), and the mode from maximization into a vertical broken line. The data appear to be less informative on the structural parameters as well as the data that defined the stochastic process for the exogenous disturbances. Note cases in which the posterior distribution is similar in location and dispersion to the prior are an indication that the data is poorly informative with regards to the respective parameter (i.e. the likelihood function is fairly flat with respect to this parameter in the region searched).

Figure 3.2: Estimated parameters' prior and posterior distributions



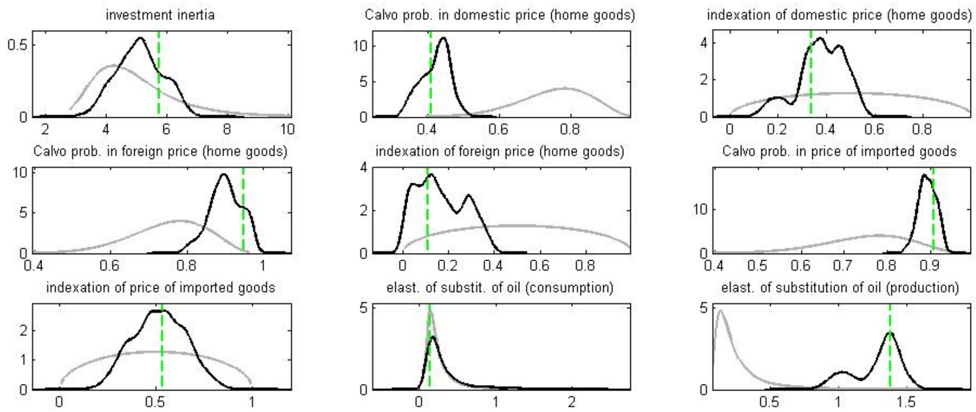
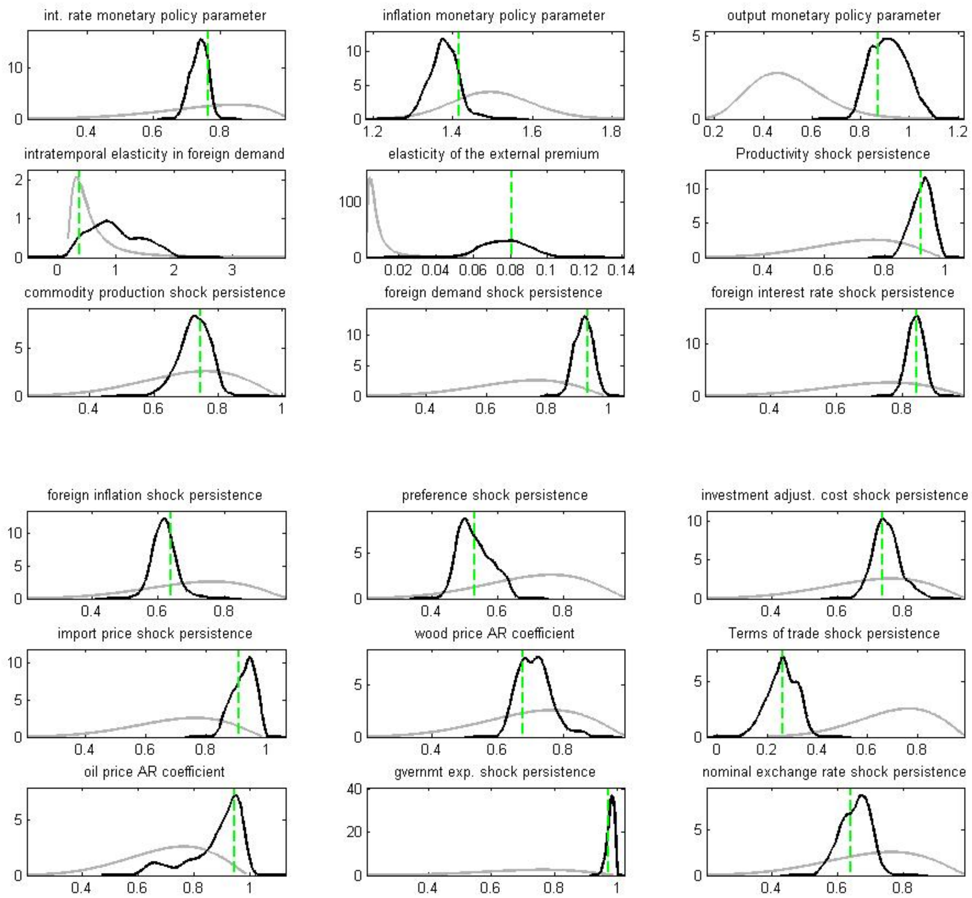


Figure 3.3: Estimated parameters' prior and posterior distributions



4- Model Evaluation: DSGE-VAR representation

The finite approximate VAR representation of the solved DSGE model is written as the following VAR in which the number of shocks is equal to the number of observable variables Y_t:

$$Y_t = \Lambda_0(\theta) + \Lambda_1(\theta)Y_{t-1} + \ldots + \Lambda_p(\theta)Y_{t-p} + U_t$$

$$U_t \sim N\left(0, \Sigma_p(\theta)\right)$$

$$Y = X\Lambda(\theta) + U$$

$$U_{Txn} = \left[U_{1,Tx1}, \ldots, U_{n,Txn}\right]$$

$$Y_{Txn} = \left[Y_{1,Tx1}, \ldots, Y_{n,Txn}\right]$$

$$X_{Tx(np+1)} = \begin{bmatrix} X_1' \\ . \\ . \\ . \\ X_T' \end{bmatrix}$$

$$X'_{T,1x(np+1)} = \left[1, Y'_{t-1,1xn}, \ldots, Y'_{t-p,1xn}\right]$$

$$\Lambda(\theta) = \left[\Lambda_{0,nx1}(\theta), \Lambda_{1,nxn}(\theta), \ldots, \Lambda_{p'nxn}(\theta)\right]$$

where all the coefficients are convolutions of the structural parameters that are included in the vector θ. Of course, the theoretical model imposes some restrictions on the VAR that can be tested through comparison with the unrestricted VAR. In a series of papers, Del Negro and Schorfheide (2004 and 2006) and Del Negro, Schorfheide, Smets and Wouters (2007a) propose a Bayesian framework for model evaluation. This method tilts coefficient estimates of an unrestricted VAR toward the restriction implied by a DSGE model. The weight placed on the DSGE-VAR model is controlled by a hyperparameter which is denoted λ. This parameter takes values ranging from 0 (no-weight on the DSGE model) to ∞ (no weight on the unrestricted

VAR). Therefore, the posterior distribution of λ provides an overall assessment of the validity of the DSGE model restrictions.

The DSGE restrictions are imposed on the VAR by defining:

$$\Gamma_{xx}(\theta) = E_\theta^D(X_t X_t')$$

$$\Gamma_{xy}(\theta) = E_\theta^D(X_t X_t')$$

where $E_\theta^D(.)$ denotes the expectation operator with respect to the distribution generated by the DSGE model, that of course have to be well defined.

Let Γ_{xx}; Γ_{xy}; Γ_{yx} and Γ_{yy} be the theoretical second-order moments of the variables in Y and X implied by the DSGE model, we set:

$$\Phi(\theta) = \Gamma_{xx}^{-1}(\theta)\Gamma_{xy}(\theta)$$

$$\Sigma(\theta) = \Gamma_{yy}(\theta) - \Gamma_{yx}(\theta)\Gamma_{xx}^{-1}(\theta)\Gamma_{xy}(\theta)$$

The moments are the dummy observation priors used in the mixture model. These vectors can be interpreted as the probability limits of the coefficients in a VAR estimated on the artifficial observations generated by the DSGE model.

Conditional on the vector of structural parameters in the DSGE model θ, the prior distributions for the VAR parameters $p(\Phi, \Sigma_u/\theta)$ are the Inverted-Wishart (IW) and Normal distributions:

$$\Sigma_u/\theta \sim IW(\lambda T \Sigma_u(\theta), \lambda T - k, n) \tag{10}$$

$$\Lambda/\Sigma_u, \theta \sim N\left(\Lambda(\theta), \frac{1}{\lambda T}\left(\Sigma_u^{-1} \otimes \Gamma_{xx}(\theta)\right)^{-1}\right)$$

where the parameter λ controls the degree of model misspecification with respect to the VAR: for small values of λ, the discrepancy between the VAR and the DSGE-VAR is large and a sizeable distance is generated between unrestricted VAR and DSGE estimators whereas large values of λ indicate small model misspecification. In the extreme case where $\lambda = \infty$, beliefs about DSGE misspecification degenerate to a point mass at zero. Bayesian estimation could be interpreted as estimation based on a sample where data are augmented by a hypothetical sample the observations of which are generated by the DSGE model, the so-called dummy prior observations. Within this framework, λ determines the length of the hypothetical sample.

Note that the posterior distribution of the VAR parameters is also of the Inverted-Wishart and Normal form. Given the prior distribution, posterior distributions are derived following the Bayes theorem:

$$\Sigma_u/\theta, Y \sim IW\left((\lambda+1)T\hat{\Sigma}_{u,b}(\theta), (\lambda+1)T - k, n\right) \tag{11}$$

$$\Phi/\Sigma_u, \theta, Y \sim N\left(\hat{\Phi}_b(\theta), \Sigma_u \otimes \left(\lambda T \Gamma_{XX}(\theta)\right)^{-1}\right) \tag{12}$$

$$\hat{\Phi}_b(\theta) = \left(\lambda T \Gamma_{XX}(\theta)\right)^{-1}(\lambda T \Gamma_{XY}(\theta) + X'Y)$$

$$\hat{\Sigma}_{u,b}(\theta) = \frac{1}{(\lambda+1)T}\left[(\lambda T \Gamma_{YY}(\theta) + Y'Y) - (\lambda T \Gamma_{XY}(\theta) + X'Y)\hat{\Phi}_b(\theta)\right]$$

where the matrices $\hat{\Phi}_b(\theta)$ and $\hat{\Sigma}_{b,u}(\theta)$ have the interpretation of maximum likelihood estimates of the VAR parameters based on the combined sample of actual observations and artificial observations generated by the DSGE model. Equations (11) and (12) show that the smaller λ is, the closer the estimates are to the OLS estimates of an unrestricted VAR. Likewise, the higher λ the closer the VAR estimates will be tilted towards the parameters in the VAR approximation of the

DSGE model $\widetilde{\Phi}_b(\theta)$ and $\hat{\Sigma}_{u,b}(\theta)$. In order to have proper prior distribution (10), λ has to be greater than λ_{min}:

$$\lambda_{min} \geq \frac{n+k}{T}; \; k = 1 + pn$$

p = number of lags

n = number of endogenous variables

This lambda is considered as the minimum lambda, and the optimal lambda must be greater or equal than the minimum lambda $\hat{\lambda} \geq \lambda_{min}$ to get a non-degenerate prior density and this is a necessary condition for computing meaningful marginal likelihoods.

Adolfson, Laséen, Lindé and Villani (2008) show that λ_{min} depends on the model and sample size. Therefore, the marginal likelihoods must be reported as functions of the ratio of the number of post-training artificial observations to the number of actual observations, $\hat{\lambda} - \lambda_{min}$.

The ratio $\frac{\hat{\lambda} - \lambda_{min}}{\lambda_{min}}$ could be seen as an indicator of how accurate is the DSGE model in approximating the DSGE-VAR one. If the ratio is high, the distance between $\hat{\lambda}$ and λ_{min} is high, hence implying that the DSGE model does accurately explain the data. Consequently, this ratio can also be seen as an indicator of how well does the DSGE model explain the actual data, in comparison to the statistical representation (the VAR) in the hybrid DSGE-VAR.

The posterior simulator used by Del Negro and Schorfheide (2004) is based on the Markov Chain Monte Carlo Method and the algorithm used is based on the Metropolis-Hastings acceptance method. This procedure generates a Markov Chain from the posterior distribution of θ; Monte Carlo experiments are realized.

The optimal λ is given by maximizing the marginal data density:

$$\hat{\lambda} = \text{argmax}_{\lambda \geq 0} L(Y, \lambda)$$

The optimal $\hat{\lambda}$ corresponds to the optimal mixture DSGE-VAR model that is chosen. This hybrid model is called a DSGE-VAR and $\hat{\lambda}$ is the weight of the priors, also indicating how well do the restrictions of the theoretical model fit the actual data. The table below reports the results from the DSGE-VAR estimation.

Table 3.3: Estimation results: DSGE-VAR

Names: description	Conf. Interval	Post. mode (DSGE-VAR)	Shap	Post. mode (DSGE)
σ_L: Inv. of the elast. of lab. supply	0.6417 0.9435	0.64	G	0.84
h: Habit formation	0.4167 0.8961	0.53	B	0.85
ϕL: Calvo probb in nominal wages	0.0060 0.2276	0.91	B	0.82
χL: Indexation of nominal wages	0.1224 0.5169	0.35	B	0.44
ηC: Intratemporal elasticity in consump	0.1158 0.5942	0.12	IG	1.12
ηI: Intratemporal elasticity in invest	0.8584 0.9111	0.04	IG	1.04
ϕHD: Calvo probb in dom price of home g.	0.0901 1.6154	0.48	IG	1.48
χHD: Indexation of dom price of home g.	0.4463 0.9571	0.74	B	0.74
ϕHF: Calvo probb in foreign price of h. g.	0.0017 0.2299	0.14	B	0.34
χHF: Indexation of foreign price of h. g.	0.7357 0.9687	0.59	B	0.59
ϕF: Calvo probb in price of imported g.	0.0272 0.9024	0.31	B	0.31
χF: Indexation price of imported goods	0.0694 0.4667	0.66	B	0.66
ωC: Elasticity of subst of oil in the cons b.	0.8682 1.2391	0.28	B	0.28

ωH: Elasticity of subst of oil in the product	0.6277 0.7883	0.30	B	0.30
ψi: Smoothing coefficient	1.1922 1.5032	1.30	IG	0.30
ψrer: Reaction to RER deviation	0.7922 1.2386	0.73	G	0.73
$\psi\pi$: Reaction to inflation deviation	0.2422 1.7840	1.61	G	1.61
ψy: Reaction to GDP growth deviation	0.0021 0.1070	0.28	G	0.28
$\eta *$: Intratemp. elast. in foreign demand	0.6488 0.9819	0.79	IG	0.79
ρ: Elast. of endogenous external premium	0.6227 0.7843	0.06	IG	0.01
ρaH: Persistence of productivity shock	0.5272 0.9024	0.73	B	0.93
ρys: Persistence comm production shock	0.5462 0.9334	0.77	B	0.77
$\rho y *$: Persistence foreign demand shock	0.5698 0.9668	0.77	B	0.67
$\rho i *$: Persistce foreign interest rate shock	0.7888 0.8964	0.87	B	0.87
$\rho\pi *$: Persistence foreign inflation shock	0.4678 0.9462	0.80	B	0.80
$\rho\varsigma L$: Persistence labor supply shock	0.2492 0.6570	0.89	B	0.89
$\rho\varsigma C$: Persistence preference shock	0.4032 0.8432	0.67	B	0.87
$\rho\varsigma G$: Persistce gov't expenditure shock	0.5961 0.9897	0.65	B	0.65
$\rho\varsigma I$: Persistence investment adj cost shock	0.6053 0.9398	0.84	B	0.34
$\rho\varsigma * F$: Persistce of for. imp. price shock	0.1047 2.3147	0.90	B	0.90
$\rho\varsigma T$: Persistence permanent prod shock	0.6067 0.9995	0.73	B	0.73
σaH: St dev transitory prod. shock innov.	1.7563 2.9943	1.43	G	1.43
σys: St dev comm prod. shock innov.	4.366 17.2364	10.51	G	4.51
$\sigma y *$: St dev foreign demand shock innov.	3.6162 9.3233	3.57	G	3.57
$\sigma i *$: St dev for interest rate shock innov	0.5459 2.1388	0.37	G	0.37
$\sigma\pi *$: St dev foreign inflation shock innov	0.4905 0.7108	0.98	G	0.28
σm: St dev monetary policy shock innov	0.7924 1.0650	1.09	G	0.39
$\sigma\varsigma L$: St dev labor supply shock innovation	1.0909 2.1124	1.01	G	1.01
$\sigma\varsigma C$: St dev preference shock innovation	4.0811 17.0956	5.99	G	5.99
$\sigma\varsigma G$: St dev gov't expendit shock innov	2.7077 8.3787	4.16	G	4.16
$\sigma\varsigma I$: St dev invest adj cost shock innov.	0.7996 3.3946	0.80	G	0.40
$\sigma\varsigma * F$: St dev of for imp price shock innov	0.0760 1.8157	1.56	G	0.56
σT: St dev permanent product shock innov	4.7336 31.9446	11.78	G	0.78

λ	0.5372 1.9124	0.664	U(0, 5)	

The posterior mode of the relative weight of our DSGE model in the DSGE-VAR mixture is estimated to be $\hat{\lambda} = 0.664$. This estimate indicates that the data put a larger weight on the VAR than on the DSGE model. It is comparable to that obtained by Del Negro and Schorfheide (2004) for the US economy and Del Negro et al., (2007) for the Euro area who found respectively 0.671 and 0.669, but is smaller than those obtained for small open economies like Australia and New Zealand by Hodge et al. (2008) who found 0.864 and Lees et al., (2011) who found 0.791 respectively. As argued by Watanabe (2009), a value of λ below 1 does by no means imply the DSGE model should be abandoned. First, the DSGE model contains structural information that remains highly useful for economic investigation. Second, prior setting relies on personal beliefs (Schorfheide, 2000), which may be responsible of the value of λ being lower than 1 and therefore, do not call into question the specification or the use of the model. Last but not least, there are many other factors, including measurement errors in the data or stochastic singularity of shocks (see, Tovar, 2009) that may influence the λ parameter.

Conclusion

Thanks to the empirical strategy that we developed in this chapter, the DSGE model that we designed in chapter 2 is ready for use for an analysis of the dynamics of the Cameroonian economy as well as for policy evaluation purposes. Two main steps have been necessary. First, weakly identified parameters that are functions of steady state ratios have been calibrated. Only then have the remaining structural parameters been inferred by estimating the linearized DSGE model using macroeconomic data from Cameroon and covering the period from 1960 to 2012. Estimation relied on

Bayesian methods, a choice we motivate through a discussion of the usefulness of such methods in a DSGE framework.

The chapter also outlined the mechanisms that underly the transmission of exogenous shocks into endogenous business cycle fluctuations. Studying the sources and causes of these propagation mechanisms required a number of preliminary steps, including the detrending of optimality and equilibrium conditions, construction of a linear approximation of the model, solving for its linear approximate decision rules and the mapping from this solution into a state space model that can produce Kalman filter projections and the likelihood of the linear approximate DSGE model. We resorted to a simulator to generate posterior distributions of our DSGE model. These posterior distributions yield summary statistics of the Bayesian estimates of the DSGE model parameters that are compared to results reported in the literature.

Our analysis resulted in a number of findings which we believe are new. For instance, the persistence of the different shocks introduced in our model suggests that the Cameroonian economy is confronted with exogenous shocks that are of larger magnitudes than those that are generally estimated for advanced economies. Likewise, our model explicitly considers the role of expectations in the form of model-consistent expectations. This is important as the lack of a forward-looking element significantly reduces the ability of the model to provide a credible description of the economy which is valuable to policymakers. Yet, our data suggest that inflation expectations in Cameroon are backward- rather than forward-looking inflation expectations. This implies that economic agents in Cameroon tend to be rather backward- than forward-looking in forming their expectations about inflation. The high persistence of inflation in Cameroon means that the current rate of inflation is strongly influenced by the previous period's inflation rate and not so much by the expected inflation rate.

Perhaps worth mentioning here is a shortcoming of Bayesian DSGE models that relates to the use of priors. Since priors setting relies on personal beliefs, the resulting estimates raise the question of whether the data are truly informative about the model under investigation or if posterior distributions of the model parameters are dominated by priors. Unfortunately, little is known about model misspecification in this context and its impact on the relationship between data, priors, and posterior distributions of DSGE models.

As mentioned earlier in chapter 1 of this thesis, the use of annual data in this study is another shortcoming one should keep aware of. In fact, the use of annual data in this study may not permit the model to accurately describe the dynamic effect of policy variables since the interactions between the variables that may occur within a year are not captured in annual data. In addition, low frequency data means smaller samples, which may weaken the efficiency of estimations.

Fortunately, there remains the possibility of assessing the reliablility of a given model through a comparison of its forecast performance to that of rival models. This is one of the analyses we focus on in the next chapter. But we also conduct an impulse response analysis to study the dynamics of the Cameroonian economy by investigating its responses to exogenous shocks. In addition, forecast error variance decomposition allows identification of the driving forces of observable macroeconomic aggregates. Eventually, so-called historical decompositions are also resorted to as a means of measuring the contribution of every shock to the fluctuations of the main aggregates.

Appendix D

Appendix D 1: The Kalman filter and the Likelihood Running

A key step in bayesian MH-MCMC estimation of a linearized DSGE model is the evaluation of its likelihood. A convenient tool to evaluate the likelihood of linear models is the Kalman filter. The Kalman filter generates projections or forecasts of the linear approximate solution of the DSGE model, given an information set including observed macro time series. Forecasts of these observables are also produced by the Kalman filter. The Kalman filter is then useful for evaluating the likelihood of a linearized DSGE model because the forecasts are optimal within the class of all linear models. When shocks innovations and the initial state of the DSGE model are assumed to be Gaussian (i.e., normally distributed), the Kalman filter renders forecasts that are optimal against all data-generating processes of the states and observables. Another implication is that, at date t the observables are normally distributed with mean and variance that are functions of forecasts of the state of the linearized DSGE model and lagged observables. Thus, the Kalman filter provides the building blocks of the likelihood of a linear approximate DSGE model.
We now describe the link between the solution of the linearized DSGE model and the Kalman filter.

Consider a DSGE model written as follows

$$E_t[F(N_{t+1}, N_t, X_{t+1}, X_t)] \qquad \text{(D 1.1)}$$

where X_t and N_t are vectors of predetermined (states) and non-predetermined (controls) variables respectively.

The solution of (D 2.1) takes the form

$$X_t = \Pi X_{t-1} + \Phi \varepsilon_t \qquad \text{(D 1.2)}$$

$$N_t = \Lambda X_t \qquad \text{(D1.3)}$$

where the first system of equations (D 1.1) is the linear approximate equilibrium decision rules of the state variables. The second set maps from the state variables to the control variables, Π, Φ, and Λ are matrices that are non linear functions of the structural parameters of the DSGE model, and ε_t, is the vector of the structural innovations.

Define the expanded vector of states as $S_t = [X_t, N_t]$. Using this definition, the state space representation of the DSGE model consists of the system of state equations

$$S_t = FS_{t-1} + Qu_t, \quad u_t \sim NID\,(0, I_m) \qquad \text{(D 1.4)}$$

and the system of observable equations

$$Y_t = M + HS_t + e_t\,, \quad e_t \sim NID\,(0, \Sigma_e) \qquad \text{(D 1.5)}$$

where Y_t corresponds to the vector of observables at time t; F and Q are functions of the matrices Π, Φ, and Λ; the matrix H, which contains zeros and ones, relates the model's definitions with data; M is a vector required to match the means of of the observed data; and e_t is a vector of measurement errors. assume the vector of observables and the vector of a states have dimensions m and n, respectively. Also define $S_{t/t-1}$ as the conditional forecast or expectation of S_t given $\{S_1, \ldots, S_{t-1}\}$, or $S_{t/t-1} \equiv E_t[S_t/S_{t-1}, \ldots, S_1]$. Its mean square error covariance matrix is $P_{t/t-1} \equiv E_t[(S_t - S_{t-1})(S_t - S_{t-1})']$.

The likelihood of the linearized DSGE model is built up by generating forecasts from the state-space system (D 1.4) and (D 1.5) period-by-period.

$$L(Y^T/\Theta) = \prod_{t=1}^{T} L(Y_t/Y_{t-1},\Theta)$$

Where $L(Y_t/Y_{t-1},\Theta)$ is the likelihood conditional on the information available up to date $t-1$ and to be clear, $Y_{t-1} \equiv \{y_0, \dots, y_{t-1}\}$. The Kalman filter computes this likelihood using the following steps:

1- Set $S_{1/0} = 0$ and $P_{1/0} = FP_{0/0}F + \Omega'$, with $\Omega' = QQ'$

2- Compute $Y_{1/0} = H'S_{1/0}$, $\Omega_{1/0} = E_t\left[(Y_1 - Y_{1/0})(Y_1 - Y_{1/0})'\right] = H'P_{1/0}H + \Sigma_e$

3- The prediction made in step 1 and 2 produce the likelihood

$$L(Y_1/\Theta) = (2\pi)^{-\frac{m}{2}}\left|\Omega_{1/0}^{-1}\right|^{1/2} exp\left[-\frac{1}{2}(Y_1'\Omega_{1/0}^{-1}Y_1)\right]$$

4- Next, update the date 1 forecasts

$$S_{1/1} = S_{1/0} + P_{1/0}H\Omega_{1/0}^{-1}(Y_1 - Y_{1/0})$$

$$P_{1/1} = P_{1/0} + P_{1/0}H\Omega_{1/0}^{-1}H'P_{1/0}$$

5- Repeat step 2, 3 and 4 to generate Kalman filter predictions of S_t and Y_t

$$S_{t/t-1} = FS_{t-1}P_{t/t-1}$$

$$P_{t/t-1} = FP_{t-1/t-1}F' + Q'$$

$$Y_{t/t-1} = H'S_{t/t-1}$$

$$\Omega_{t/t-1} = E_t\left[(Y_t - Y_{t/t-1})(Y_t - Y_{t/t-1})'\right] = H'P_{t/t-1}H + \Sigma_e$$

The likelihood is obtained as

$$L(Y_t/Y_{t-1},\Theta) = (2\pi)^{-\frac{m}{2}}\left|\Omega_{t/t-1}^{-1}\right|^{1/2} exp\left[-\frac{1}{2}\left((Y_t - Y_{t/t-1})'\Omega_{1/0}^{-1}(Y_t - Y_{t/t-1})\right)\right]$$

and the update of the state vector and its mean square error matrix

$$S_{t/t} = S_{t/t-1} + P_{t/t-1}H\Omega_{t/t-1}^{-1}(Y_t - Y_{t/t-1})$$

$$P_{t/t} = P_{t/t-1} + P_{t/t-1}H\Omega_{t/t-1}^{-1}H'P_{t/t-1}$$

for $t = 2, \dots, T$

Appendix D 2: The MH-MCMC Simulator

The posterior distribution of the DSGE model parameters in Θ is characterized using the MH-MCMC algorithm. The MH-MCMC algorithm is started up with an initial Θ^0. This parameter vector is passed to the Kalman filter routines in order to obtain an estimate of $L(Y_T/\Theta)$. Next, the initial Θ^0 is updated according to the MH random walk law motion. Inputing the proposed update of Θ^0 into the Kalman filter produces a second estimate of the likelihood of the linear approximate DSGE model. The MH decision rule determines whether the initial or proposed updated of Θ^0 and the associated likelihood is carried forward to the next step of the MH algorithm. Given this choice, the next step of the MH algorithm is to obtain a new proposed update of Θ^0 using the random walk law of motion and to generate an estimate of the likelihood at these estimates. This likelihood is compared to the likelihood carried over from the previous MH step using the MH decision rule to select the likelihood and Θ for the next MH step. this process is repeated $\mathcal{H}$ times to generate the posterior of the linear approximate DSGE model $p(\Theta/Y_T)$. This description of the MH-MCMC algorithm is summarized as follows:

1- Label the vector of DSGE model parameters chosen to initialize the MH algorithm $\hat{\Theta}_0$.

2- Pass $\hat{\Theta}_0$ to the Kalman filter routines to generate an initial estimate of the likelihood of the linear approximate DSGE model , $L\left(Y_T/\hat{\Theta}_0\right)$.

3- A proposed update of $\hat{\Theta}_0$ is Θ_1, which is generated using the MH random walk law of motion, $\Theta_1 = \hat{\Theta}_0 + \bar{\omega}\vartheta\varepsilon_1$ with $\varepsilon_1 \sim NID\ (0_d, I_d)$, where $\bar{\omega}$ is a scalar that controls the size of the "jump" of the proposed MH random walk update, ϑ, is the Cholesky decomposition of the covariance matrix of Θ_1, and d is the dimension of Θ. obtain $L(Y_T/\Theta_1)$ by running the Kalman filter using Θ_1 as input.

4- The MH algorithm employs a two-stage procedure to decide whether to keep the initial $\tilde{\Theta}_0$ or more to the update proposal Θ_1. First, calculate

$$\omega_1 = min\left\{\frac{L(Y_T/\Theta_1)p(\Theta_1)}{L\left(Y_T/\tilde{\Theta}_0\right)p\left(\tilde{\Theta}_0\right)}, 1\right\}$$

where, for example, $p(\Theta_1)$ is the prior at Θ_1. The second stage begins by drawing a uniform random variable $\varphi_1 \sim U(0,1)$ to set $\tilde{\Theta}_1 = \Theta_1$and the counter $p = 1$ if $\varphi_1 \leq \omega_1$ otherwise, $\tilde{\Theta}_1 = \tilde{\Theta}_0$ and $p = 0$.

5- Repeat steps 3 and 4 for $l = 2, 3, \dots, \mathcal{H}$ using the MH random walk law of motion.

$$\Theta_l = \tilde{\Theta}_{l-1} + \varpi\vartheta\varepsilon_l\,, \quad \varepsilon_l \sim NID\left(0_{dx1}, I_d\right)$$

and drawing the uniform random variable
$\varphi_1 \sim U(0,1)$ to test against

$$\omega_l = min\left\{\frac{L(Y_T/\Theta_l)p(\Theta_l)}{L\left(Y_T/\tilde{\Theta}_{l-1}\right)p\left(\tilde{\Theta}_{l-1}\right)}, 1\right\}$$

for equaling $\tilde{\Theta}_l$ to either Θ_l or $\tilde{\Theta}_{l-1}$. The latter implies that the counter is updated according to $p = p + 0$, while the former has $p = p + 1$.

Step 1-5 of the MH-MCMC algorithm produce the posterior $p\left(\tilde{\Theta}/Y_T\right)$, of the linear approximate DSGE model by drawing from $\left\{\tilde{\Theta}_l\right\}_{l=1}^{\mathcal{H}}$. Note that in step 4 and 5, the decision to accept the update proposal, $\varphi_l \leq \omega_l$, is asking to moving to a higher point on the likelihood surface.

Following Guerrón-Quintana and Nason (2012), there are several more issues that have to be resolved by running the MH-MCMC algorithm to create $p\left(\tilde{\Theta}/Y_T\right)$. Among these, are obtaining an $\tilde{\Theta}_0$ to initialize the MH-MCMC, computing ϑ, determining $\mathcal{H}$, fixing ϖ to achieve the optimal acceptance rate for the proposal Θ_l of $p/\mathcal{H}$, and checking that the MH-MCMC simulator has converged[34].

[34]Gelman et al (2004, pp 305–307) discuss rules for the MH-MCMC simulator that improve the efficiency of the
law of motion to give acceptance rates that are optimal.

Step 1 of the MH-MCMC algorithm leaves open the procedure for stting $\hat{\Theta}_0$. Employing classical optimization methods and an MH-MCMC "burn-in" stage helps to obtain $\hat{\Theta}_0$. First, a classical optimizer is applied repeatedly to the likelihood of the linear approximate DSGE model with initial conditions found by sampling $\mathcal{H}_1$ times from $p(\Theta)$. These estimates yield the mode of the posterior distribution of Θ that is identified as initial conditions for a "burn-in" stage of the MH-MCMC algorithm. The point of this "burn-in" of the MH-MCMC algorithm is to remove dependence of $p(\hat{\Theta}/Y_T)$ on the initial condition $\hat{\Theta}_0$. Drawing $\hat{\Theta}_0$ from a distribution that resembles $p(\hat{\Theta}/Y_T)$ eliminates this dependence. Next, $\mathcal{H}_2$ MH steps are run with $\bar{\varpi} = 1$ and $\vartheta = I_d$ to complete the "burn-in" stage. The final MH step of the "burn-in" gives $\hat{\Theta}_0$ to initialize the $\mathcal{H}$ steps of the final stage of the MH-MCMC algorithm. The $\mathcal{H}_3$ estimates of Θ generated during the MH "burn-in" steps are are used to construct an empirical estimate of the covariance matrix $\vartheta\vartheta'$. The Cholesky decomposition of this covariance matrix is the source of ϑ needed for the MH law of motion.

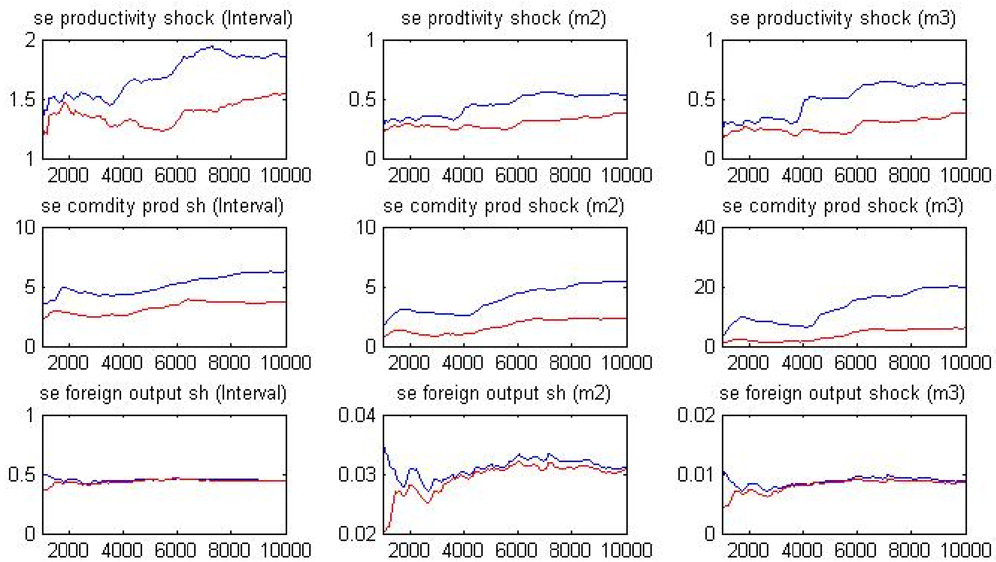
The scale of the "jump" from Θ_l to $\hat{\Theta}_{l-1}$ determines the speed at which the proposal Θ_l converge to $p(\hat{\Theta}/Y_T)$ with the MH-MCMC simulator. The speed of convergence is sensitive to $\bar{\varpi}$ as well as to $\mathcal{H}$. The number of steps of the final stage of the MH-MCMC simulator has to be sufficient to allow for convergence. $\mathcal{H}$ draws are obtained from the posterior $p(\hat{\Theta}/Y_T)$, but for larger and richer DSGE models, the total number of draws is often many times larger. Nonetheless, the choice of the scalar $\bar{\varpi}$ is key for controlling the speed of convergence of the MH-MCMC. Geltman et al. (2004) recommend that greatest efficiency of the MH law of motion is found with $\bar{\varpi} = 2.4/\sqrt{d}$.

In usual practice, the researcher checks the convergence of the MH-MCMC simulator. Information about convergence of the MH-MCMC simulator is provided by the $\hat{R}$ statistic of Geltman et al. (2004, pp. 269-297). This statistic compares the variances of the elements within the sequence of $\{\hat{\Theta}_l\}_{l=1}^{\mathcal{M}}$ to the variance across several sequences produced by the MH-MCMC simulator under different initial conditions. This process is often repeated three to five times. Geltman et al. (2004) suggest that $\hat{R} < 1.1$ for each element of $\hat{\Theta}$. If not, across the posteriors of the MH-MCMC chains, there is excessive variation relative to the variance within the sequences. When $\hat{R}$ is large, Geltman et al. (2004) propose increasing $\mathcal{H}$ until convergence is achieved as witnessed by $\hat{R} < 1.1$.

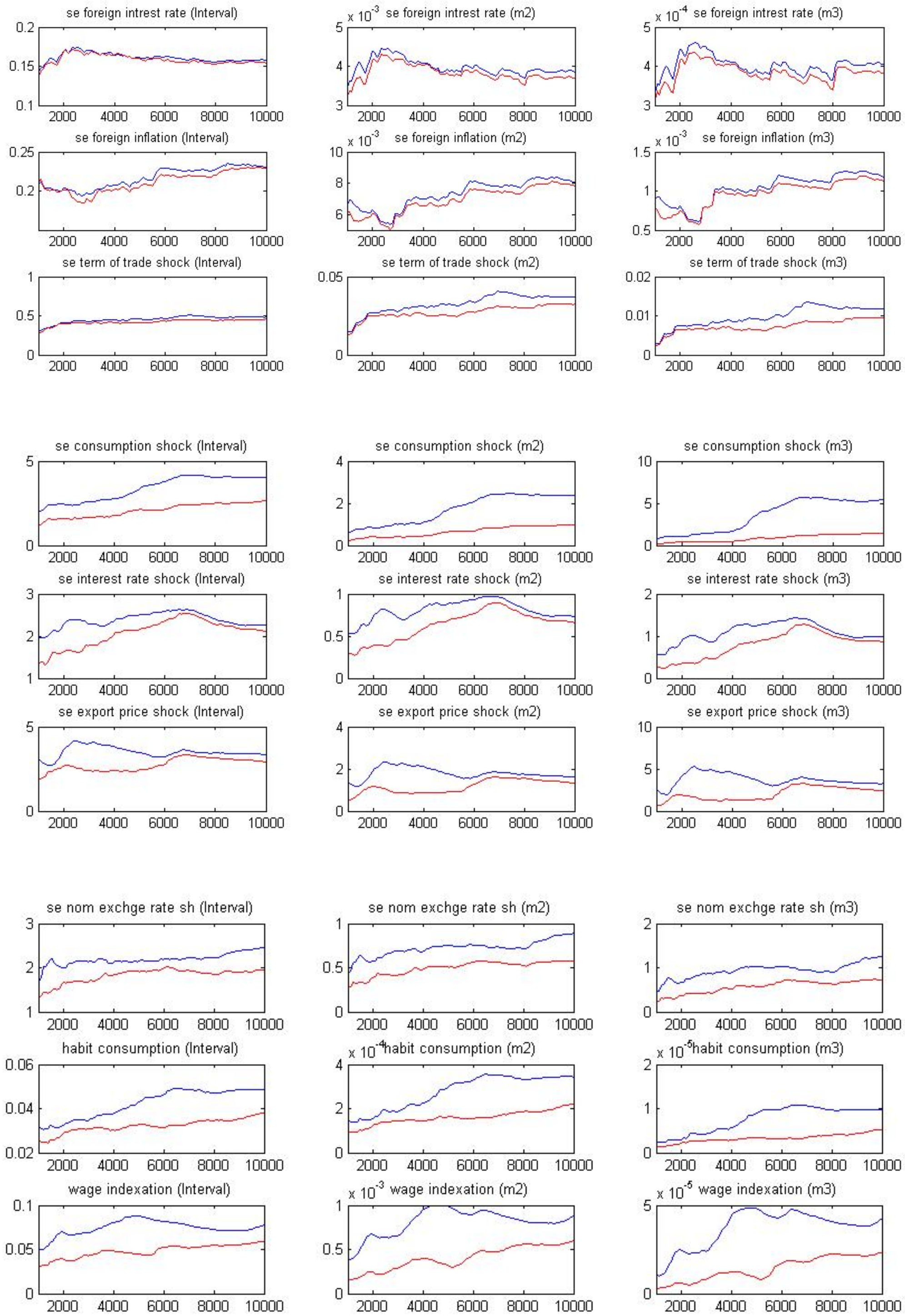
Appendix D3: Convergence of the posterior distribution and parameters stability

Convergence diagnostics are computed as described in Brook and Gelman (1998) in order to assess the stability of parameters and to monitor the convergence of the posterior distribution to its target distribution. The results from those diagnostics are depicted on figures below. Three measures are reported for each estimated parameter. "interval" is constructed from and 80% confidence interval around the mean, "m2" is measure of the variance, and "m3" is based on the third moments. The red and blue lines on the charts represent those specific measures both within and between chains. In general, results within iterations of Metropolis-Hastings simulations are similar, and the results between the two chains are very close. Convergence and relative stability are obtained in all measures of the parameters moments with, 200.000 draws of the Metropolis-Hastings albeit slight differences that might be exhibited by some measures, related to "marginal share monitoring -cost parameters.

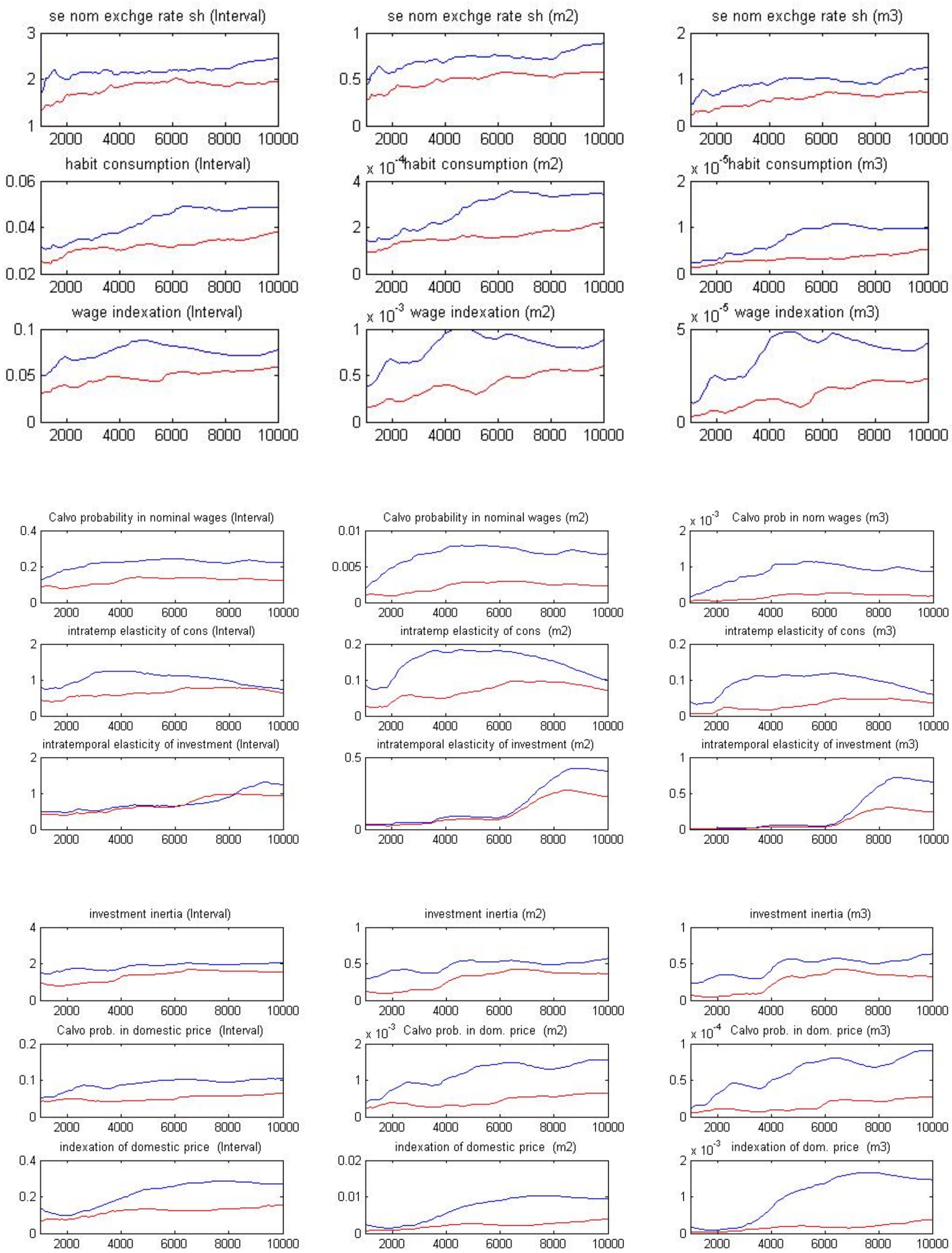
Figures D1: Monte Carlo Marko Chain univariate diagnostics (Brook and Gelman, 1998)



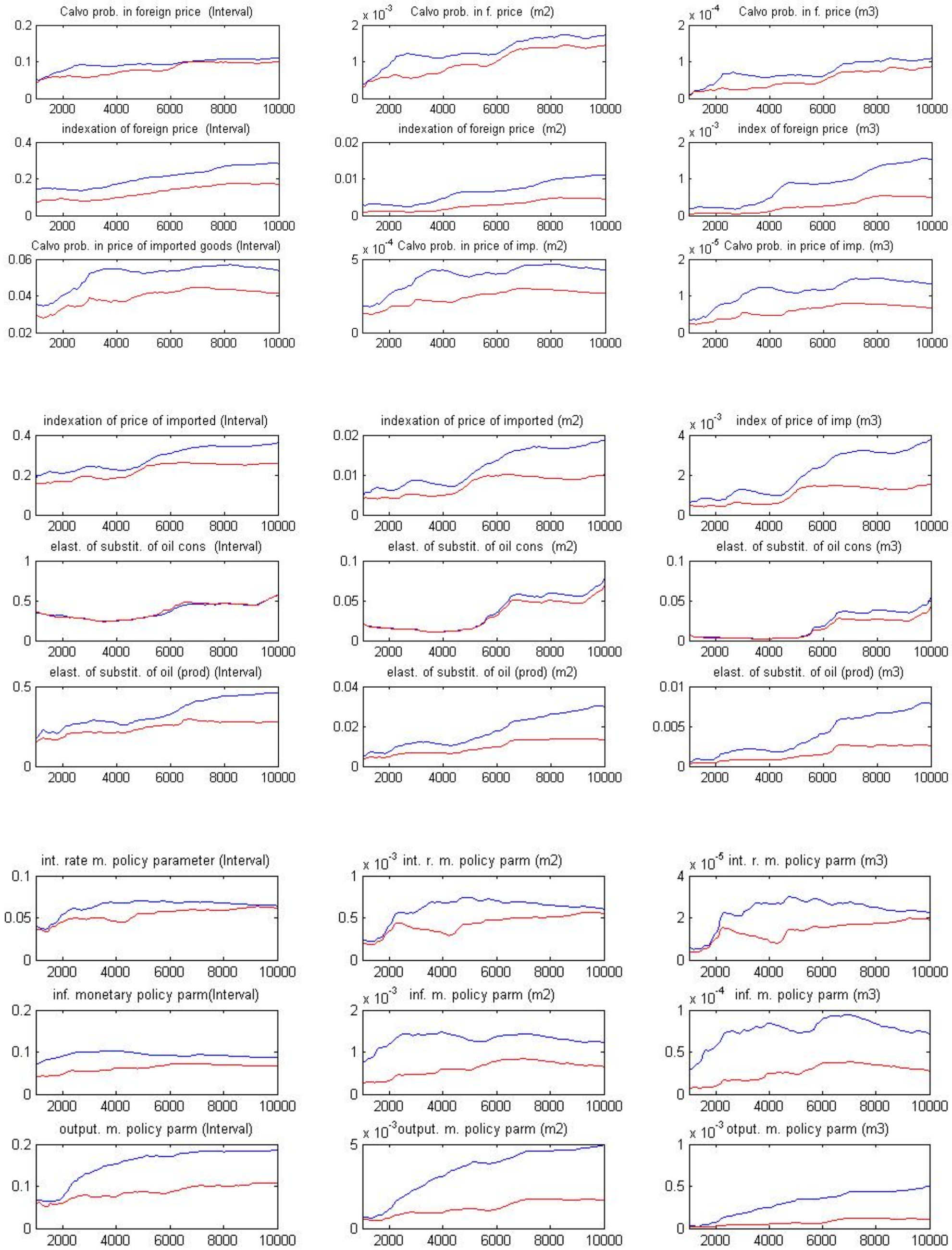
Figures D2: Monte Carlo Marko Chain univariate diagnostics (Brook and Gelman, 1998)



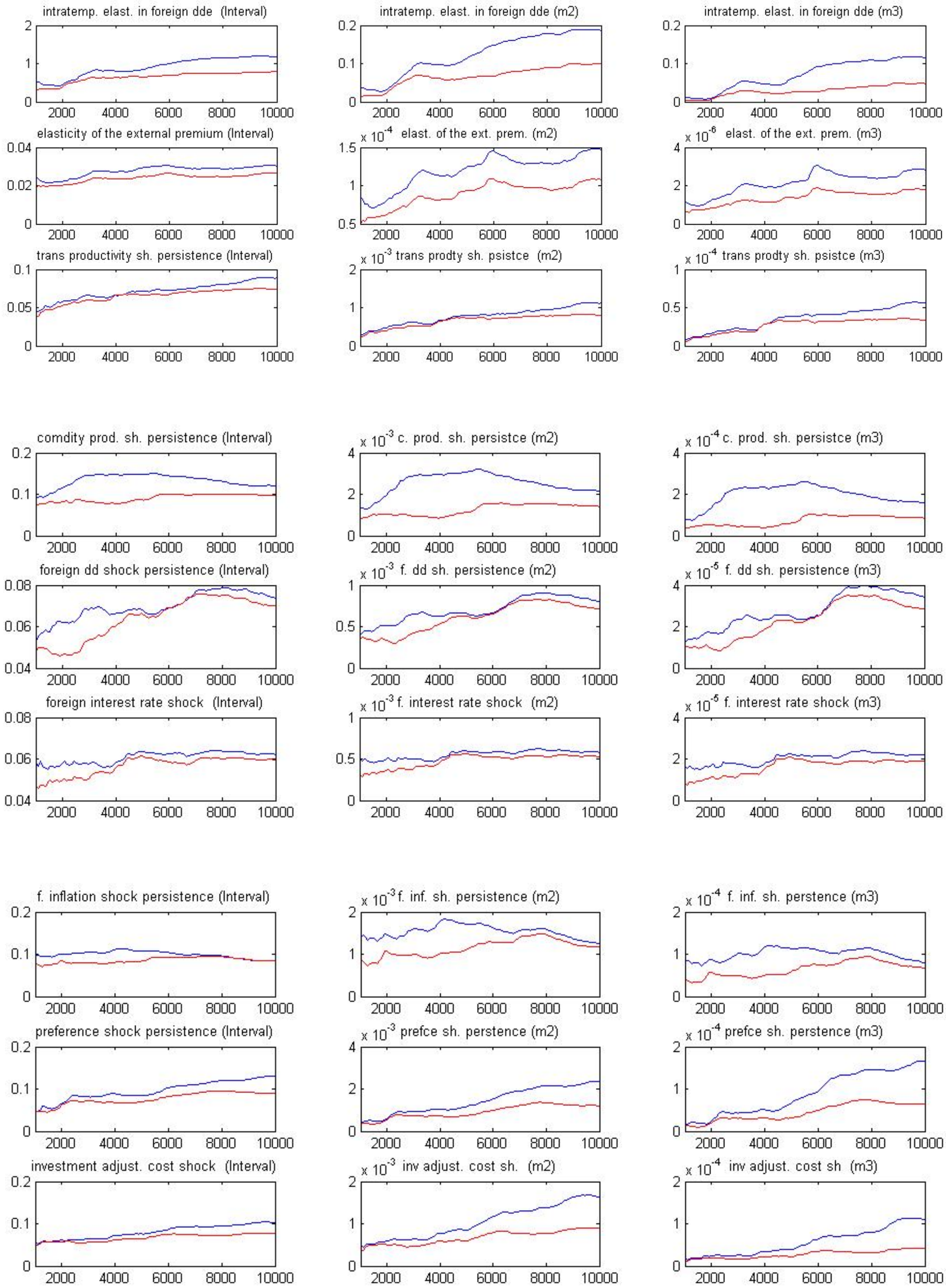
Figures D3: Monte Carlo Marko Chain univariate diagnostics (Brook and Gelman, 1998)



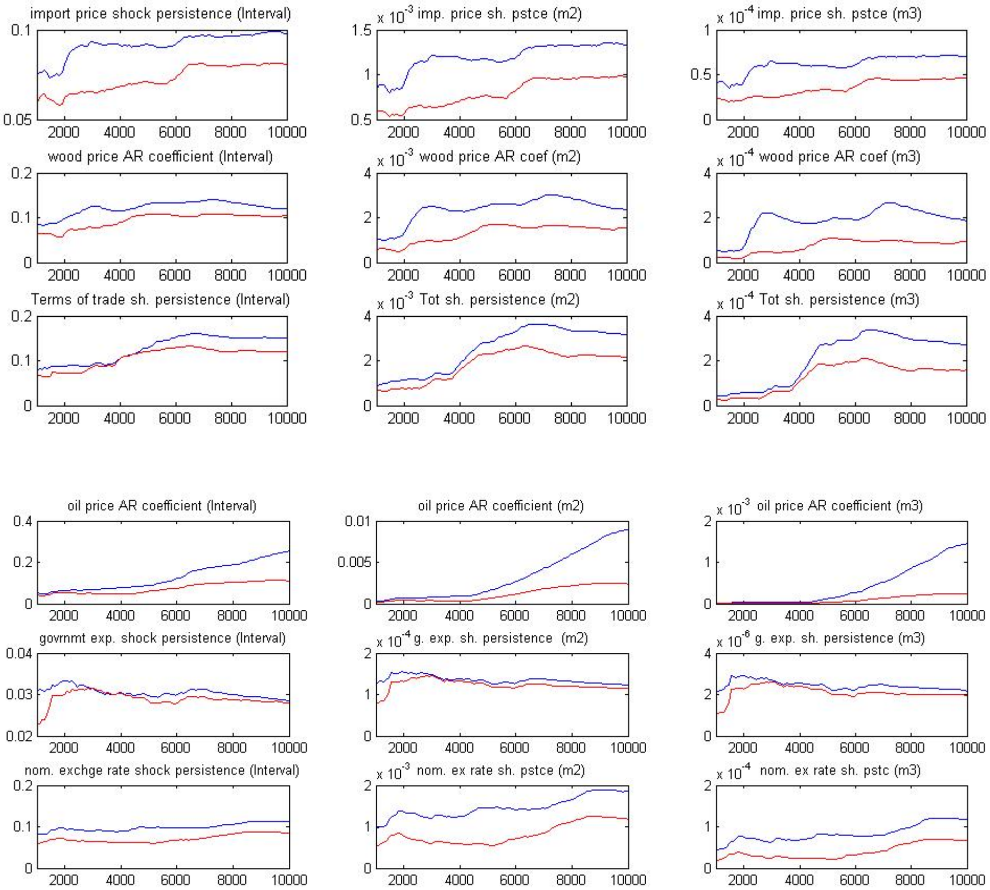
Figures D4: Monte Carlo Marko Chain univariate diagnostics (Brook and Gelman, 1998)



Figures D5: Monte Carlo Marko Chain univariate diagnostics (Brook and Gelman, 1998)



Figures D6: Monte Carlo Marko Chain univariate diagnostics (Brook and Gelman, 1998)



Measures that show slight differences might indicate signs of weak convergence. While these convergence issues may be explained by some structural breaks in the data, it is common in the literature to fix the values of parameters that may exhibit convergence problems. Alternatively, one could also reduce the size of the model and eliminate the features for which related parameters might show sign of weak convergence.

CHAPTER 4: FORECASTING MACROECONOMIC FLUCTUATIONS IN CAMEROON

Abstract

In this chapter, the open-economy DSGE model we have designed in chapter 2 and estimated in chapter 3 is used as a means of analysing the macroeconomic dynamics of Cameroon as well as of illustrating its usefulness in the conduct of economic policy in that country. We first assess the macroeconomic fluctuations through impulse response functions which trace out the responses of current and future values of each of the observed variables to a unit increase in the current value of one of the error terms in the model. We then seek to identify the main driving forces of key macroeconomic variables using forecast error variance decompositions. In addition, historical decomposition techniques provide information about the relative importance of each shock in affecting the endogenous variables in the DSGE model. However, prior to proceding with these analyses, we first assess the reliability of our estimated DSGE model by comparing its forecast performances to three alternative specifications. These are the Bayesian VAR model, the classical VAR model and the random-walk process.

Keywords: forecasting, DSGE model, macroeconomic fluctuations, Cameroon

Introduction

Now that a DSGE model describing the dynamics of the Cameroonian economy, we are able to assess the way key macroeconomic variables react to exogenous shocks hitting the economy. The Cameroonian economy is thus described as a dynamic system with a stationary equilibrium or steady-state. Any exogenous shock that hits such a system makes it deviate from the stationary equilibrium, hence generating fluctuations of macroeconomic variables. Exogenous shocks thus cause business cycle fluctuations.

Forecasting performance of DSGE models has of course been widely analysed in the literature, the most influential works being those of Smets and Wouters (2004), Del Negro and Schorfheide (2004), Dib, Gammoudi and Moran (2005), Kilponen and Ripatti (2006), and Edge et al. (2010). In a natural extension of their contribution to DSGE modelling, especially as applied to the Euro Area, Smets and Wouters (2004) showed that a new Keynesian DSGE (NKDSGE, henceforth) model with some rigidities can be used to forecast macroeconomic variables. They showed that their estimated DSGE model has good out-of-sample performances, better than those of the unstructural VARs and even those of the Bayesian VARs (BVAR, henceforth). Del Negro and Schorfheide (2004) extended the work of Smets and Wouters (2004). They used the foundations given by BVAR models in order to introduce priors derived from the estimated DSGE models. They showed that, even for a simple NKDSGE model, using priors derived from a DSGE model led to excellent performances relative to both unstructured VARs and BVARs. Dib, Gammoudi and Moran (2005) used a NKDSGE model for a closed economy characterized by rigid prices, and applied the model to the Canadian economy. They showed that using this model for forecasting the main macroeconomic variables allowed for good results as compared to unstructured VARs, especially as the forecast horizon increased. A good example of a practical and regular use of the NKDSGE approach in forecasting exercises is that of the Bank of Finland (BOF). BOF introduced the regular use of a DSGE model, called AINO, in the official forecast of the central bank. The model proved to offer good results, as it was capable of reproducing the tendencies of the Finnish economy both in the short and in the medium run (the forecasts are performed for an eight to ten quarters horizon), see Kilponen and Ripatti (2006). Edge et al. (2010) showed that the out-of-sample forecasting performance of the Federal Reserve Board's new DSGE model for the U.S economy (EDO) is in many cases better than their large-scale macro-econometric model (FRB/US) and their own published Greenbook forecasts. DSGE model's forecasting properties have therefore been evaluated against a wide range of less theoretically oriented forecasting tools such as VARs, Bayesian VARs (BVARs), and naïve forecasts based on univariate random walks. Several authors have noted the theoretical connection between Bayesian model posterior probabilities and out-of-sample forecasting performance, e.g. Geweke (1999) and Del Negro, Schorfheide, Smets and Wouters (2004). Using South-African data, Liu and

Gupta (2007) examined a calibrated version of Hansen's (1985) closed economy model and found that a simple BVAR outperforms the DSGE model. Liu et al. (2010) used a similar DSGE model with the error terms specified as a VAR (Ireland, 2004) and showed that this model can outperform a classical VAR, but not a BVAR. After extending this model to allow for sticky prices, Liu et al. (2009) found that a three variables DSGE model performs better than a BVAR forecast of inflation, but it is not able to do likewise for output growth or nominal short-term interest rates. Steinbach et al. (2009b) showed that a DSGE model can outperform the Reuters consensus forecasts for GDP growth over 1 to 7 quarters, and for inflation over 4 to 7 quarters. In this chapter, we follow the literature and compare the performance of our DSGE model relative to BVAR, classical VAR, and the random-walk (RW) process. Such comparisons are based on two criteria: root-mean squared error (RMSE) and mean forecast error.

However, the main aim of this chapter remains that of identifying shocks that drive key macroeconomic variables as well as that of assessing the contribution of each shock to the volatility of observable macroeconomic variables. This way, we are able to identify for any observable macroeconomic variable, the specific shocks that can be seen as having a significant driving influence on it. Since structural shocks are orthogonal (uncorrelated) it becomes possible to unambiguously decompose the forecast error variance of each macroeconomic variable into components that exclusively reflect the variability attributed to a specific shock. The relative contribution of an exogenous shock to the forecast error variance of a specific macroeconomic variable determines the virtual importance of that shock in explaining the fluctuations of that variable of interest. Exogenous shocks with the highest contributions to the forecast error variance of a macroeconomic variable of interest are its main driving forces or, equivalently, its main sources of fluctuations. This approach, also known as the forecast error variance decomposition, allows one to characterize business cycle features through a collection of statistics. Following Cooley (1995), such statistics are measured through the use of artificial data generated by simulating the theoretical DSGE model under consideration. We distinguish between four shock categories: domestic supply shocks, domestic demand-side shocks, monetary policy shocks and shocks that are associated with external factors. Finally, looking for the relative importance of each shock in affecting the endogenous variables in the DSGE model of Cameroon, this is done using the backward substitution and the Wald decomposition and by writing the model variables at each point of time as a function of initial values and structural shocks.

The rest of the chapter is organized as follows. Section 2 briefly discusses the empirical setup of our forecasting strategy. Section 3 presents impulse response analysis. Forecast error decomposition and historical decomposition are presented in section 4 and section 5, respectively. Section 6 concludes.

2- Forecasting with DSGE and competing Models

The DSGE model contains useful information about the dynamics of Cameroonian business cycles. It could therefore be seen as a policy evaluation tool. The content of this information is gauged by running forecast experiments among competing models. In particular, we consider the forecasts of the observable variables from the DSGE model, and compare them to those generated from BVAR, VAR, and random-walk models. In what follows, we first briefly describe the alternative VAR and BVAR models we consider in our forecast performance exercises.

2.1- Forecasting computation

Having estimated the model, forecasts for the year-horizons $h \in (0,1,2,3,4,5,6,7,8)$ are derived. We first compute density forecasts from which point forecasts are inferred as the means of the respective density forecasts. For each parameter, a large number of values are drawn from the parameter's posterior distribution. For a random draw s a projection of the observable variables is derived by iterating over the solution matrix $g_y(\hat{\theta}^{(s)})$. At each iteration i a vector of shocks $u_i^{(s)}$ i is also drawn from a mean zero normal distribution the variance of which being itself a random draw from the posterior distribution:

$$y_{t+h}^{s,obs} = A(\hat{\theta})\hat{\bar{y}}^{(s)} + A(\hat{\theta})g_y(\hat{\theta}^{(s)})^{h+1}y_{t-1} + A(\hat{\theta})\sum_{i=0}^{h} g_y(\hat{\theta}^{(s)})^{(h+1-i)}u_i^s$$

$$u_i^s \sim N\left(0, \hat{\Sigma}_u^{(s)}\right)$$

where a hat on the structural parameters $\theta^{(s)}$, on the covariance matrix Σ_u^s and on the steady state values of observable variables $\bar{y}^s$ means that the corresponding quantities are estimated. The reduced form solution matrices g_y and g_u are functions of the estimated parameters and change over time as the models are re-estimated. The procedure is repeated N times ($s = 1, \ldots, N$). The forecast density is given by the ordered set of forecast draws $y_{t+h}^{s,obs}$. The point forecast is given by the mean of the forecast density.

2.2- Forecast Evaluation

Given a variable, y, and its h-period ahead forecast (made h-periods in the past) based on a method m, $\hat{y}_m^h$, one can compute the root mean square error of the real time forecast:

$$RMSEy_m^h = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(y_t - \hat{y}_m^h\right)^2} \qquad (*)$$

Comparing the root mean square errors across different forecast methods, a policy maker can choose the method yielding the smallest RMSE. Using the RMSE as formulated above allows estimation of

$$y_t = \alpha_m^h + \beta_m^h \hat{y}_{m,t}^h + \varepsilon_{m,t}^h \qquad (**)$$

A "good" forecast should have an intercept of zero, a slope coefficient of one and a high R^2. A non-zero intercept would indicate that the forecast is on average biased. A non-unit slope would indicate that the forecast consistently under- or over-predicts the deviations from the mean. A small R^2 would indicate that only a small part of the variation of the variable to be forecast is captured by the forecast. It is also worth noting that whenever the point estimates of α_m^h and β_m^h are different from zero and one, respectively, the R^2 is a more charitable measure of the success of the forecast than the RMSE calculated in (*). This is due to the errors in (**) being the residuals obtained from the best fitting line. That is, a policy maker would make errors of size $\varepsilon_{m,t}^h$ only if s/he knew the values of α_m^h and β_m^h and adjusted $\hat{y}_{m,t}^h$ with those values. The R^2 that is comparable to the RMSE measures calculated in (*) would be that implied by equation (**) with α_m^h and β_m^h constrained to 0 and 1, respectively.

2.3- The Basics of the Alternative Forecasting models: The VAR and BVAR models

We use the same dataset containing observable series described in chapter 3 for the VAR and BVAR models. For the classical VAR model, we only consider one-lag and two-lag specifications, as higher order VARs, quickly exhaust the degrees of freedom available in our short dataset[35]. For the Bayesian VAR, we consider specifications with one through four lags, although the BVAR (1) specification provides the best in-sample fit to the data on each recursive estimation based on the log-marginal densities[36].

For the priors distributions of the BVARs, we utilize a Normal-Inverse Wishart (NIW) prior as in Kadiyala and Karlsson (1997) and Banbura et al. (2010). This extends the original Minnesota prior developed in Litterman (1986) and Doan et al.

[35] The Akaike and Schwartz lag-selection criteria suggest a one-lag specification in most of the recursive estimations, but not systematically.

[36] Interestingly, the BVAR (1) specification also provides a slightly higher log-normal density than the DSGE model estimated with Bayesian priors. Nevertheless, the performance of the DSGE model forecasts seems to be competitive with BVAR (1), if not better, especially for short horizons.

(1984) to allow for a non-diagonal variance-covariance matrix for the residuals[37]. The prior for the covariance matrix is Inverse-Wishart distributed and is based on the sample of standard deviations of each of the respective variables in the VAR[38]. Conditional on this covariance prior, the prior for the coefficient estimates is normally distributed. The standard NIW prior (as the original Minnesota prior on which it is based) places a prior mean equal to 1 on the coefficient of the first own-lag, and prior means of 0's on the higher own-lag terms and all cross-lag terms to reflect a unit-root prior. This is more appropriate when the variables in the VAR are non-stationary or exhibit a high degree of persistence. Since some of our data series are log-differenced already and are hence considered stationary, such a choice would be inappropriate. Therefore, we follow Banbura et al. (2010) and impose a white-noise prior by also setting the prior mean for the coefficient of the first own-lag equal to 0[39].

2.4- Results

In order to assess the predictive performance of the models, we begin by calculating the forecast errors, $\hat{e}_{t+h} = y_{t+h} - \hat{y}_{t+h/t}$, at different horizons h for each variables, y_t, and for each competing model. The mean forecast error is given by:

$$MFE = \frac{\sum_{t=1}^{T} e_{t+h}}{T}.$$

[37] This comes at the expense of having to specify the same tightness parameter for the priors on the own-lag and the cross-lag terms in the VAR.

[38] This is in contrast to Sims and Zha (1998) who use a random-walk prior on the coefficient estimates, and as such, use the standard deviation of the of the residual from an AR(1) model to generate the values for the covariance matrix. Here, we use a white noise prior on the coefficients and hence, the standard deviations of the series themselves for the covariance prior.

[39] We estimate the recursive BVAR models in Dynare which utilizes Sims' BVAR codes for Matlab based on the dummy observation method of imposing Bayesian priors. We modify the code slightly for our specific context as described in the text. For the hyperparameters, we set the tightness parameter to 3 and the decay parameter to 0.5. Only one replica of the dummy observations for the covariance matrix is used $(i.e. \omega = 1)$. The own-persistence parameter are set to $(\zeta = \mu = 0)$. The dummy-observations prior is augmented by the Jeffrey's improper prior following standard practice. To satisfy the degree-of-freedom condition, the initial data point is treated as a training sample prior.

In Table 1 (Appendix E3), we report the mean forecast errors (MFE) computed on key variables such as output growth, inflation, imported inflation, nominal interest rate, and nominal exchange rate. Obviously, the ideal value of MFE is zero : A $MFE > 0$ suggests that the model tends to under-forecast the variable being considered whereas a $MFE < 0$ suggests the latter is over-forecast.

Given the mean forecast errors, Tables 2a, 2b and 2c (appendix E3) report results of forecast efficiency tests for competing models. For each competing model, each variable, and at each horizon, the p-values of the Mincer and Zarnowitz (1969) forecast efficiency test (i.e. the joint test that $\alpha = 0$ and $\beta = 1$ in equation (**), labelled "MZ p-value") are reported. $\hat{\alpha}$ in equation (**) together with the p-value of the test, tells us whether or not the intercept equals zero, $\hat{\beta}$ in the same regression together with the p-value of the test, indicates whether or not the slope β equals one.

The results reported in Tables 2a, 2b and 2c show in general that the forecasts are not efficient at the 5% significance level, hence, exhibiting some bias in the regression. There are exceptions, however; the test does not reject joint forecast efficiency for output growth and CPI inflation at some horizons and for some of the models. In contrast, the joint forecast efficiency is rejected for imported inflation, nominal interest rate, and nominal exchange rate. These results show that not only the DSGE model, but also the majority of reduced-form models had difficulties to forecast the selected variables over the sample that we consider. In the literature, the intermediate horizon forecasts of the Smets and Wouters (2007) model are consistently efficient over time, although the p-values of the forecast efficiency test are very small at the end of the sample, raising concerns of lack of efficiency in the late 2000s. Efficiency is uniformly rejected over time for the random walk at all horizons and for the BVAR forecasts at most horizons.

Considering now the tests of relative forecasting performance the Root mean squared errors (RMSE) are reported in Table 3 (Appendix E3) for each variable, each competing model, and for different horizons. These results show a general pattern: the DSGE model tends to have a smaller RMSE over short horizons, with the exception of exchange rate and import inflation, where the BVAR and the VAR are more accurate. We do find it interesting that the DSGE model performs best among all models at short-horizons for the variables that are most relevant for policy making, namely output growth, CPI inflation, and interest rate. At longer horizons however, the accuracy of the DSGE forecasts deteriorates faster than the one of its rivals. We test whether or not the predictions produced by competing models are significantly different: $H_0 : E(d_{t+h}) = 0$, with d_{t+h}, a loss function based on the predictive error. For models i and j, we compute $d_{ij,t+h} = \hat{e}^2_{t+h,i} - \hat{e}^2_{t+h,j}$. We use the Diebold and Mariano (1995) test statistic (DM test statistic). Under the null hypothesis , the DM test statistic is given by $DM_{ij} = \frac{\bar{d}_{ij}}{\hat{\sigma}_{\bar{d}_{ij}}} \sim N(0,1)$ where $\bar{d}_{ij} = \frac{1}{T}\sum_{t=1}^{T} d_{ij,t}$, the sample mean loss differential and $\hat{\sigma}_{\bar{d}_{ij}}$, a consistent estimate of the standard deviation of $\bar{d}_{ij}$. Results of Diebold and Mariano (1995) statistics are reported in table 4 (Appendix E3). A negative Diebold-Mariano (DM) statistic signals a smaller loss value from the DSGE forecasts relative to the alternative[40]. These results show that the differences in the RMSEs from the DSGE and rival models tend to be statistically significant particularly for 1-year forecast horizons for output growth and CPI inflation.

Since the distortion of structural parameter estimates is not the primary concern of policy makers as it is argued in Wiriyawit (2014), we focus in the next sections on impulse responses analysis, variance decomposition, and historical decomposition.

[40] The DM-statistic has an asymptotic normal distribution; hence numbers above 2 signify significantly different loss function at the 5% significant level.

3- Impulse response function (IRF) analysis

We now investigate the responses of key macroeconomic variables of the Cameroonian economy to various exogenous shocks for the period covered from 1960 through 2012. This impulse response analysis helps to examine the dynamic properties of the model, to check its stability, and to identify the variables that display complex and interesting dynamics (e.g. by undershooting or overshooting their steady-state values). Simulations generate the Bayesian impulse responses of the observable macroeconomic variables following a one-off temporary change into each exogenous shock. The magnitude of each shock is set as a standard deviation of this shock. Variables such as real GDP, consumption, and investment are represented as the percentage deviations of their respective growth rates from the balanced growth path. The current account to GDP ratio, the inflation, and the domestic interest rate are represented in terms of percentage deviations from the steady-state level. Eventually, the current appreciation rate depicts the exchange rate. Figures in appendix E1 represent the impulse responses of the endogenous variables to different shocks hitting the Cameroonian economy: productivity shocks, commodity production shocks, investment adjustment cost shocks, labour supply shocks, preference shocks, government expenditure shocks, monetary policy shocks, wood price shocks, oil price shocks, foreign demand shocks, foreign interest rate shocks, foreign inflation shocks, and import price shocks.

Figure E1.1 shows the responses of endogenous variables to a productivity shock in the Cameroonian economy. According to this figure, productivity shock has a positive impact on output. This implies an immediate fall in inflation, as it reduces marginal costs of firm's production. However, employment initially falls because the increase of aggregate demand associated with the monetary expansion is not strong enough to raise labour demand. Productivity shocks also increase labour productivity, allowing firms to keep their production levels with less employment. Another implication of these shocks is that they raise investment over time, and increase the marginal productivity of labour. This last effect eventually leads to an increase in labour demand, with a consequent rise in wages and a subsequent rise in inflation. Productivity shocks also tend to depreciate the real exchange rate as they induce the fall in domestic prices on one side and lead to a real appreciation of the currency on the other. This is explained by the monetary policy tightening that follows periods after the shock to curb inflation. Eventually, in response to these shocks, the current account -as a fraction of GDP deteriorates.

Looking at Figure E1.7 (the impulse response to an investment shock) and E1.9 (the impulse response to a consumption shock), both figures show that, consumption and investment shocks temporarily raise output growth and inflation. The investment shock leads to a depreciation of the real exchange rate, as investment goods are relatively more import-intensive than other final goods. The consumption shock on the contrary results in a real appreciation of the currency. The policy response to both shocks leads to an interest rate increase. The commodity-price shock (E1.3) generates an output expansion, an increase in employment and a fall in inflation. This last effect is explained by the currency appreciation, which reduces import-good inflation and makes capital goods cheaper -which counteracts the pressure on marginal cost derived from the dynamics of employment and the increase in real wages. The oil price shock (E1.12) has a direct impact on marginal cost which increases and provokes an increase in inflation whereas both output and employment fall. Note that if that shock generates a real appreciation of the currency, this may also be due to the fact that oil is an input in production; an increase in oil price is equivalent to a negative technology shock in the non-commodity sector. Furthermore, an oil price shock motivates the monetary authority to raise interest rate in order to mitigate the effect of inflation. This leads to an appreciation of the CFA franc arising from capital inflow and decline in output. However, all variables return to their equilibrium values when oil price shock disappears. The main important effect of the oil price shock is an appreciation of the real exchange rate, which tends to push down the inflation rate. The commodity export sector becomes relatively more competitive, leading to a real currency appreciation.

According to figure E1.5, a foreign interest rate negatively affects investment decisions; it contracts consumption and leads to a fall in output and in employment. This shock also generates both a nominal and a real depreciation of the currency. In spite of the recession induced by this shock, the exchange rate depreciation leads to an increase in inflation. The shock that is most difficult to interpret is that relative to the price of import goods (figure E1.11). This shock corresponds to an increase in the price of the goods imported by the domestic economy, while keeping the price of other goods consumed by foreign agents constant. It is therefore equivalent to a relative fall in the productivity of the trade sector abroad. Consistently with the Balassa-Samuelson hypothesis, this shock leads to an increase in the price of the imported goods relative to goods that foreign agents consume. An increase of the price of imported goods leads to an increase in domestic inflation, a tightening of monetary policy and a fall in both output and employment.

Figure E1.10 shows the impulse response to a monetary policy shock. The interest rate shock can be thought of as a contractionary monetary policy shock. Following an unanticipated surge in the policy interest rate, a decline in inflation and output is observed whereas the exchange rate depreciates due to this shock before returning to its equilibrium level. This shock also reduces domestic and foreign investment by increasing business cost and yields a fall in aggregate employment as well. Following this shock, the Central Bank (BEAC) needs to react strongly to a real interest rate shock to bring the inflation rate to its optimal path. However, all variables tend towards a steady state (equilibrium) in the long run.

Eventually, figure E1.13 shows impulse responses to a positive shock to government spending. This shock forces the domestic policy to increase the interest rate and thus creates a burden on firms willing to invest in private capital. It results in a crowding-out effect on domestic investments vis-à-vis foreign investments. This shock also lowers aggregate wage and increases employment at the cost of inflation. This shock results in current account deficit and in exchange rate depreciating before it returns to its equilibrium.

4- Forecast error variance decomposition (FEVD)

Unlike impulse response functions which trace out the responses of current and future values of each of the observe variables to a one-unit increase (or to a one-standard deviation increase, when the scale matters) in the current value of one of the errors in the model, this section focuses on the identification of the main driving forces of the key macroeconomic variables of Cameroon, over the 1960-2012 period covered. To do so, we exploit the forecast error decomposition and account for innovations in the variance of each observable variable at various horizons that could characterize the short-run, the medium-run, and the long-run. We define the short-run as a period that lasts a year, the medium-run as a period that lasts three years and the long-run as a period that lasts more than three years. We classify the identified shocks into four groups. The first group contains domestic supply shocks: productivity shocks, commodity production shocks, investment adjustment cost shocks, and labour supply shocks[41]. The second group includes the domestic demand side shocks of the economy: preference and government expenditure shocks. The third group comprises monetary policy shocks only. Eventually, the fourth group contains shocks that are associated with external factors: commodity-price shocks, international oil price shocks, foreign demand shocks, foreign interest rate shocks, foreign inflation shocks, and imported good price shocks. The variance decomposition is reported in Table 6 below.

Table 4.6: Variance decomposition of shocks (% contribution of each type of shock)

year-h	Variables	Supply shock	Demand shock	Monetary shock	External shock
1	Real GDP	30%	13%	2%	55%
	Consumption	54%	19%	3%	24%
	Investment	19%	4%	2.5%	74.5%
	Current account	4.2%	15.8%	3%	77%
	Core inflation	23%	10.5%	14.5%	52%
	Real exchange rate	25%	2.1%	7.9%	65%
2	Real GDP	46%	28%	28%	28%
	Consumption	63%	15%	5%	17%
	Investment	12.7%	16%	5.3%	66%
	Current account	07%	10%	10%	73%
	Core inflation	45%	28%	2%	25%
	Real exchange rate	31.6%	3%	1.4%	64%
3	Real GDP	39%	2.3%	3%	55.7%
	Consumption	55%	8.7%	12%	24.3%
	Investment	07.5%	12%	10.4%	70.1%
	Current account	11.2%	2%	2.8%	84%
	Core inflation	57%	13%	7%	23%
	Real exchange	18.5%	4.5%	2%	75%

[41] Investment shocks are classified as supply shock because they correspond to changes in the technology used to transform new capital goods into installed capital. Alternatively, these shocks could be classified as demand shocks since they capture movement in the incentive to investment not captured by the monetary policy rate and the marginal productivity of capital.

	rate				
4	Real GDP Consumption Investment Current account Core inflation Real exchange rate	43% 57% 08.5% 14% 35% 18%	3.2% 5.7% 12% 12.8% 20% 3.3%	2.8% 7.3% 15.5% 1.2% 12.5% 3.7%	51% 30% 64% 72% 22.5% 75%

Domestic supply shocks explain 30 to 55% of GDP growth fluctuations with some variations depending on the horizon. Domestic demand shocks explain between 10 and 25% of output fluctuations with a relative importance that is bigger at the medium term horizon. Monetary policy shocks account for about 2-3% percent of output fluctuations in one year horizon. In the second year, monetary policy shocks have a larger contribution to real activity movements accounting for about 9 to 10% of it. The identified external shocks can explain around 65% of output fluctuations in the one- and four-year horizons whereas its contribution is lower in the 2-3 years horizon.

Regarding inflation dynamics, external shocks account for most of the fluctuations in the short-run with a lower contribution in the second year. In contrast, domestic supply shocks explain only 20% in the one-year horizon, but a range of 40-60% beyond the second year. Despite domestic demand shocks explaining less than 10% of the inflation movements in the short-run, they do explain 20 to 30% of inflation fluctuations in longer horizons. Monetary policy shocks do account for 15 to 20% of fluctuations in inflation in the short-run, but with a marginal relative importance afterwards.

External shocks account for approximately two thirds of the real exchange rate fluctuations. Domestic supply shocks can explain 20 to 30% of real exchange rate movements. Monetary policy shocks seem to explain 7% of real exchange rate swings in the short-run, but its relative contribution is lower after the first year and this is even lower for the monetary policy of the second period. Domestic demand factors do not seem to have any contribution in short-run fluctuations of the real exchange rate, but their relative significance after the first year increases to a range between 6 and 11%.

Turning to investment, most of its variance is accounted for by external shocks. In fact, in the first year, external shocks explain around 40-45% of its movements, but this range goes approximately to 70-80% from year two. Domestic demand shocks account for one fourth of the cyclical variation in investment in the short-run, but at a longer horizon its contribution is less significant. Domestic supply shocks also play a more important role in the short-run variation of investment, explaining some 20% of it. Monetary policy deviations of the rule seem to capture more than10% of the fluctuations in investment.

As expected, most of the current account to GDP ratio variation is explained by external factors. In the short-run, domestic demand shocks can account for 40% of the current account to GDP fluctuations. Monetary policy and domestic supply factors account jointly for less than 10% of current account movements in the first year. However, domestic supply factors gain relative importance for longer horizon explaining up to 15% of current account fluctuations.

5- Historical decomposition (HD)

This section provides information about the relative importance of each shock in affecting the endogenous variables in the DSGE model of Cameroon. This is done using the backward substitution and the Wald decomposition and by writing the variables in the model at each point of time as a function of initial values and structural shocks. The complete historical decomposition is depicted in appendix E2. In these figures for each variable, we graph the cyclical variation attributed to each identified shock. As for the variance decomposition, we classify shocks into domestic supply shocks, domestic demand shocks, monetary policy shocks, and external shocks.

Between 1990 and 1997, output grew above its sample average, whereas from 1998 onwards, it grew below its average. Figure E2.1 shows that domestic supply shocks were important between 1990 and 1993. According to the model, the post 1998 recession is mostly explained by domestic factors: a slow-down in productivity and a contraction in demand. Monetary policy appears to have been relatively tight over the whole sample, except for the last four years where its contribution to growth has been positive. Except for the period 1990-1993, core inflation has been on average below the target. This is mostly explained by monetary shocks that have tended to push inflation down. Also, productivity shocks have contributed to keep inflation below target. The sharp discrepancy of inflation from its constant target is attributed to external shocks and negative demand shocks.

The evolution of inflation is dominated by three shocks: transitory productivity shocks, foreign financial shocks and monetary shocks. Transitory productivity shocks, that explain the fast growth at the end of the 80s and the beginning of the 90s, pushed inflation below target for several periods. However, the slowdown of this type of productivity shocks in the mid 90s led to important inflationary pressures. The effect of these transitory productivity gains at the end of the 80s were counterbalanced by relatively tight foreign financial conditions that kept the real exchange rate above its trend and slowed down the reduction in inflation. Also, tight domestic monetary conditions over most of the sample period account for reduced inflationary pressures.

The real exchange rate at the beginning of the 90s for example was 10% above its sample mean, during the period 1994-2001 it was on average around 8-10% below its mean, and over the last years it has been about 7% above mean. As one would expect, these large swings in the real exchange rate are mostly explained by external factors. In particular, the important appreciation in the mid 90s is to a larger extent explained by these shocks. The monetary contraction at the end of the 90s also explains an important share of the appreciation during those years. The employment rate – employment as a share of the working age population– was well below its trend at the end of the 70s, explained by a combination of detrimental domestic supply and external shocks. Looking at domestic supply shocks, it seems that the negative impact on employment is associated to positive rather than negative shocks, as we will see below. The weakness in employment over the last years is explained, according to our model, by negative demand shocks and, albeit to a lesser extent, by the remaining effects of the monetary contraction at the end of the 90s that lead to an important fall in employment.

The complete historical decomposition of the main aggregate variables is depicted in the Figures reported in Appendix E2. For each variable we graph the cyclical variation attributed to each of the identified shocks. The evolution of output over the whole sample is dominated by productivity shocks. Investment shocks also explain an important share of the fluctuations in output growth in the sample, although these type of shocks do not exhibit a clear trend. Notice that the model identifies a negative shock to the relative price of imported goods (a fall in this relative price) at the end of the 90s.

Conclusion

Using the DSGE model designed and estimated in the previous chapters, we investigated the likely responses of key endogenous variables of the Cameroonian economy to domestic and external shocks..

Obviously, the forecasting performance of the model under consideration is crucial in this context. An analysis of forecast performance where the outcome from our DSGE model is compared to that from a classical VAR, a Bayesian VAR and a Random-Walk models suggests that the DSGE model is outperformed in shorter year horizons.

The impulse response analysis helped to examine the dynamic properties of the model, to check its stability, and to identify the variables that display complex and interesting dynamics. Thus, as main results, productivity shock has a positive impact on output, with as main implication, an immediate fall in inflation, as it reduces marginal costs of firm’s production; an increase of labour productivity which allows firms to keep their production levels with less employment. While the investment shock leads to a depreciation of the real exchange rate, the consumption shock on the contrary results in a real appreciation of the currency. The policy response to those two later shocks leads to an interest rate increase. The commodity-price shock generates an output expansion, an increase in employment and a fall in inflation. The oil price shock has a direct impact on marginal cost which increases and provokes an increase in inflation whereas both output and employment fall. A foreign interest rate negatively affects investment decisions, it contracts consumption and leads to a fall in output and in employment. It generates both a nominal and a real depreciation of the currency. The interest rate shock is thought as a contractionary monetary policy shock. A decline in inflation and output is observed whereas the exchange rate depreciates due to this shock before returning to its equilibrium level. It reduces domestic and foreign investment by increasing business cost and yields a fall in aggregate employment as well. Finally, the government spending shock forces the domestic policy to increase the interest rate and thus creates a burden on firms willing to invest in private capital. It results in a crowding-out effect on domestic investments vis-à-vis foreign investments. This shock also lowers aggregate wage and increases employment at the cost of inflation. This shock results in current account deficit and in exchange rate depreciating before it returns to its equilibrium.

The decomposition of the forecast error variances of observable macroeconomic variables into latent exogenous shocks that drive their dynamics shows that foreign shocks and domestic supply shocks account for a large share of output and investment fluctuations. Relatively tight domestic monetary conditions have contributed to the moderation of inflationary pressures arising from other shocks. Foreign factors also appeared to be behind the large swings exhibited by the real exchange rate and current account, although a monetary condition explains part of the delayed adjustment of the exchange rate in times of crisis.

Historical decomposition provides information about the relative importance of each shock which affects endogenous variables in the DSGE model. Thus, the evolution of output over the whole sample is dominated by productivity shocks. Investment shocks also explain an important share of the fluctuations in output growth in the sample, although these type of shocks do not exhibit a clear trend. Furthermore, the post 1998 recession for example is mostly explained by domestic factors: a slow-down in productivity and a contraction in demand. Monetary policy appears to have been relatively tight over the whole sample, except for the last four years where its contribution to growth has been positive. Core inflation has been on average below the target. This may mostly be explained by monetary shocks that have tended to push inflation down. Also, productivity shocks have contributed to keep inflation below target. The evolution of inflation is dominated by three shocks: transitory productivity shocks, foreign financial shocks and monetary shocks.

Appendix E

Appendix E1: Impulse response to shocks

Note: Figures below represent the estimated impulse responses as a standard deviation of a given shock. They plot the median (thick line) impulse response together with the 5th and 95th percentile (grey band). The horizontal axis represents the horizon in years, while the vertical axis gives the percentage deviation from the balance growth of the steady-state.

Figure E1.1: Impulse response to a productivity shock

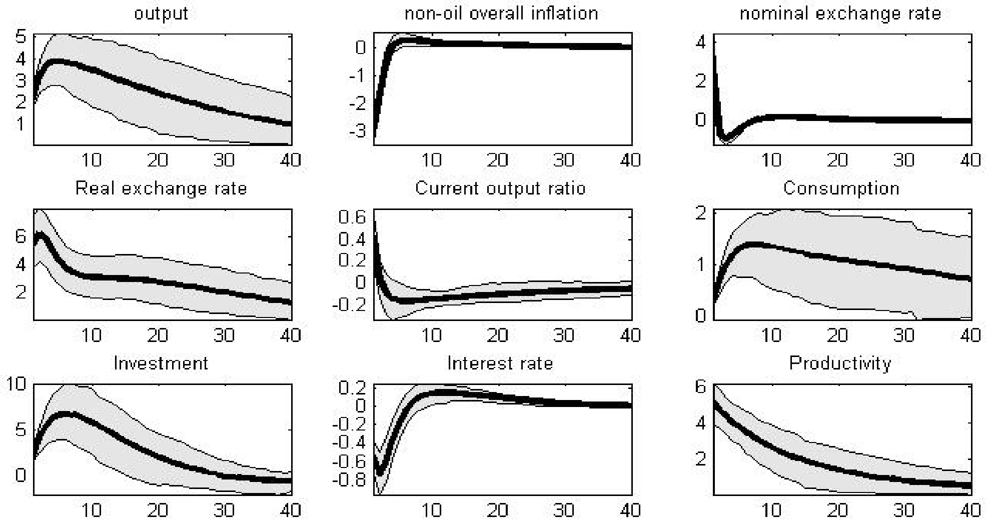


Figure E1.2: Impulse response to a commodity production shock

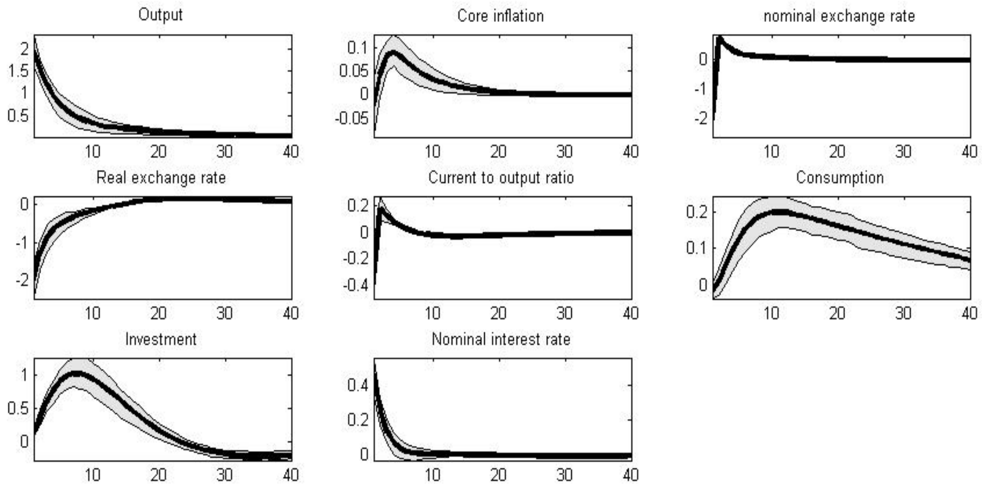


Figure E1.3: Impulse response to an international price of commodity shock

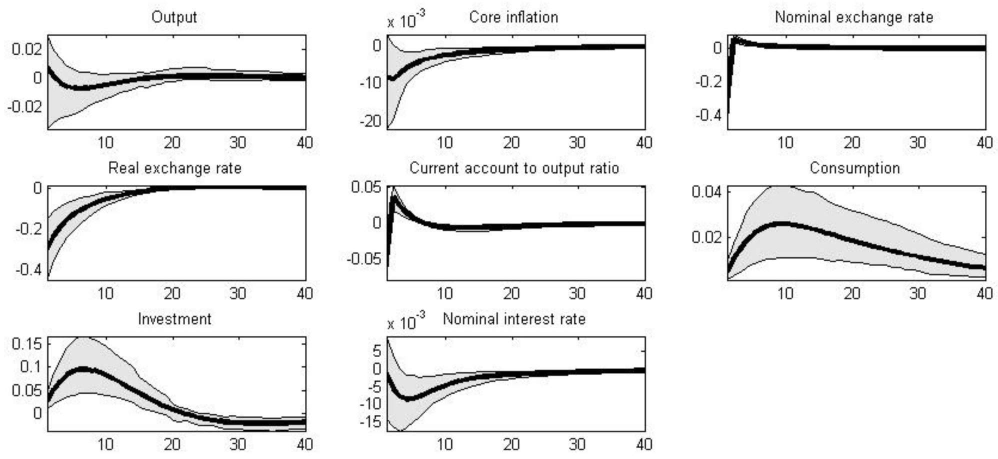


Figure E1.4: Impulse response to a foreign output growth shock

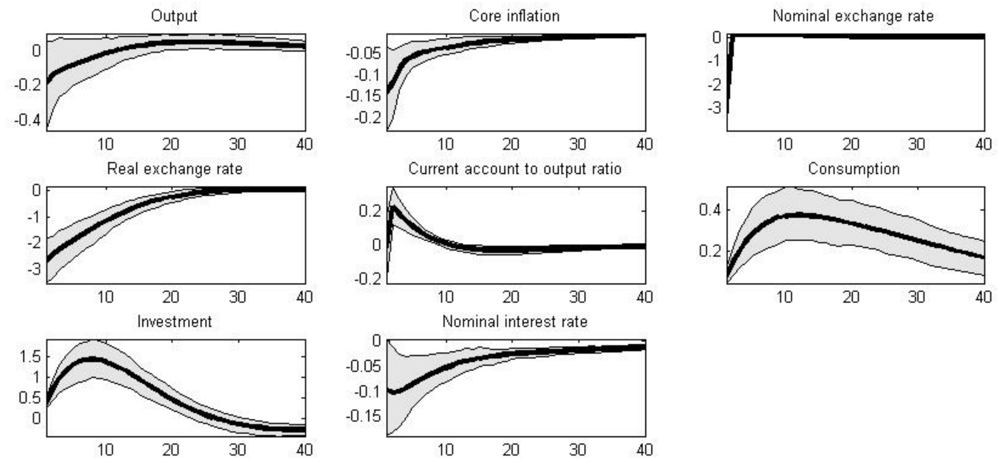


Figure E1.5: Impulse response to an international interest rate shock

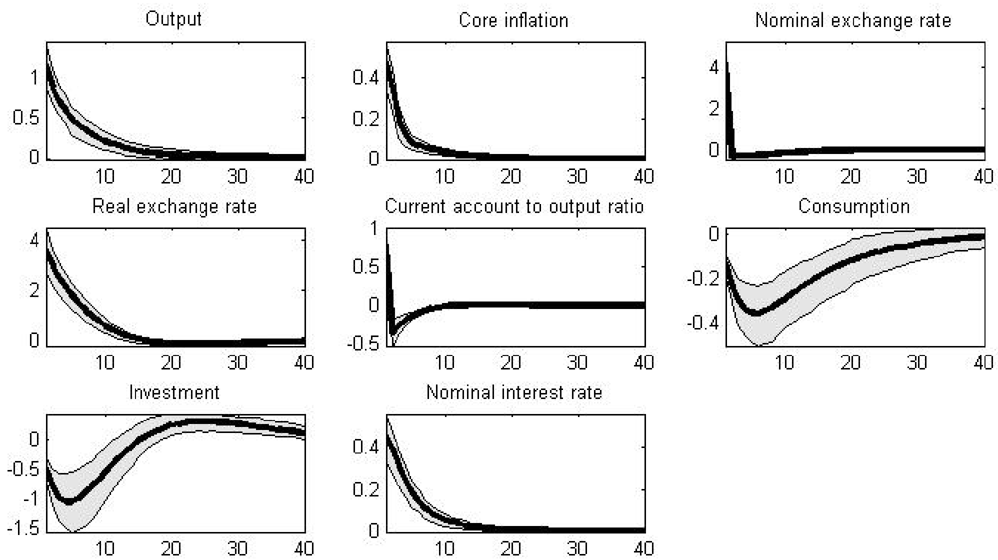


Figure E1.6: Impulse response to an international inflation shock

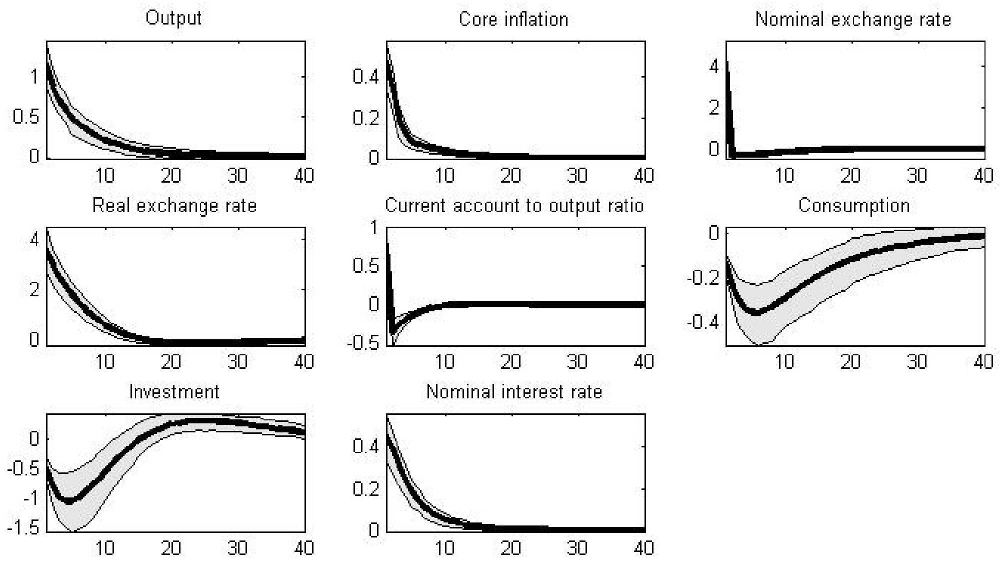


Figure E1.7: Impulse response to an investment shock

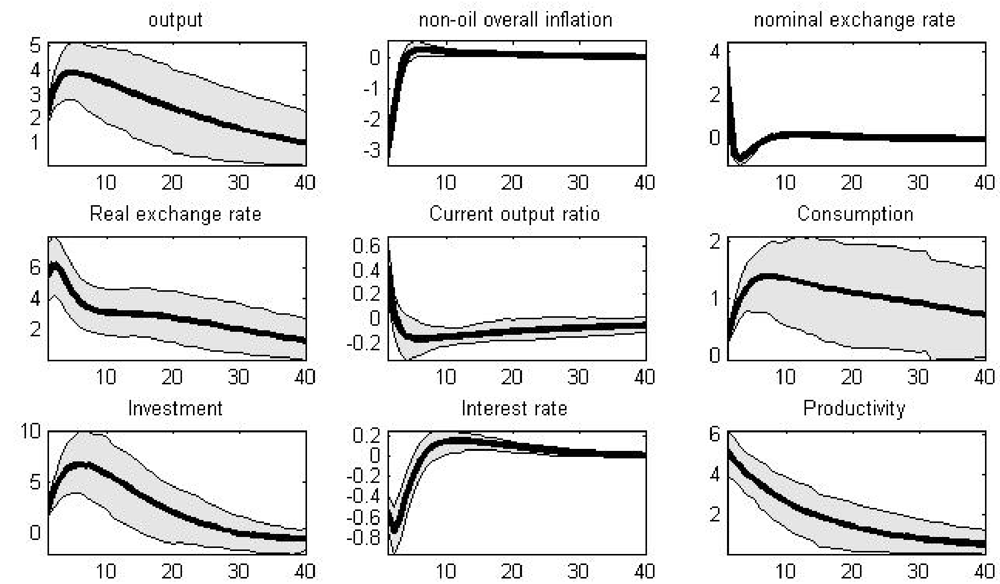


Figure E1.8: Impulse response to a financial shock

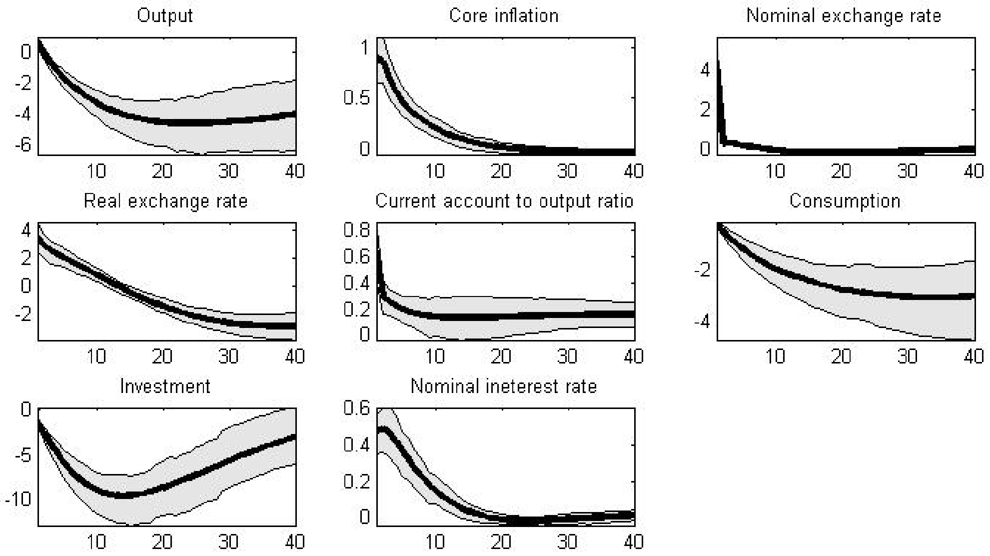


Figure E1.9: Impulse response to a consumption shock

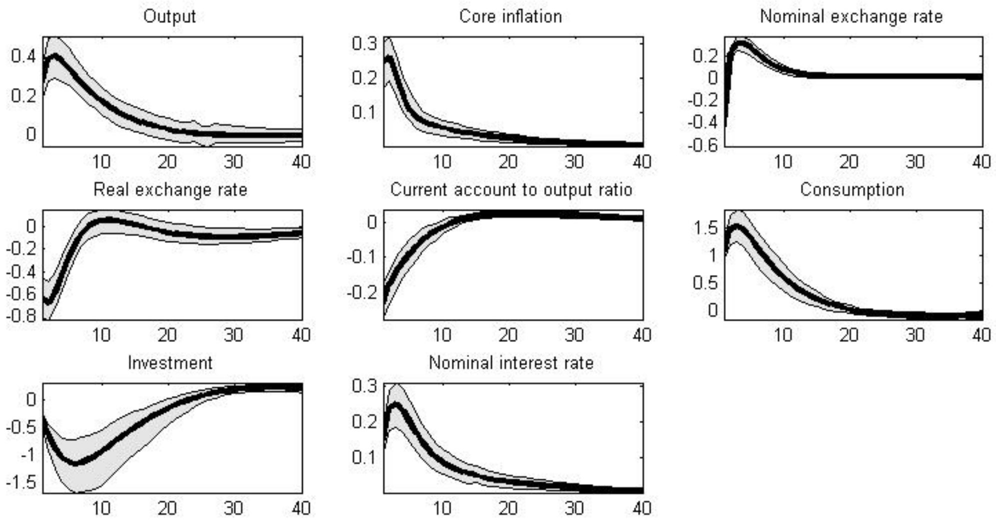


Figure E1.10: Impulse response to a monetary policy shock

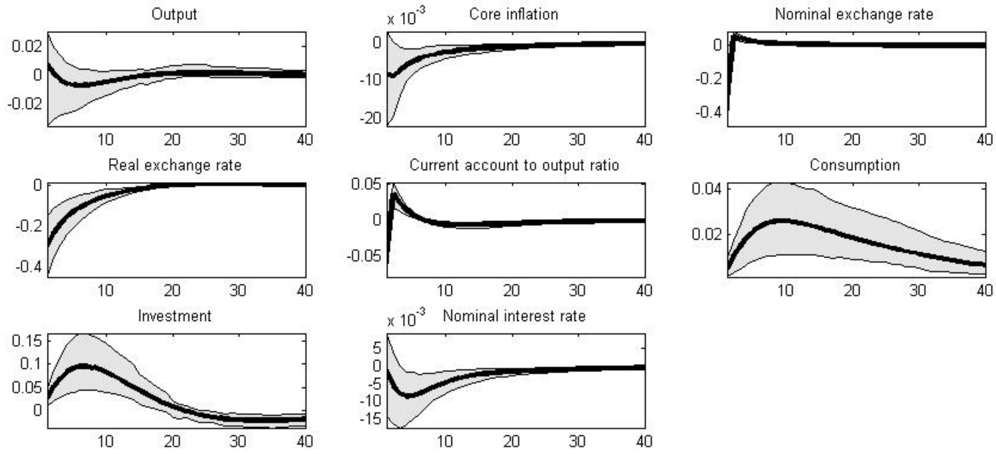


Figure E1.11: Impulse response to a foreign price shock of imported goods

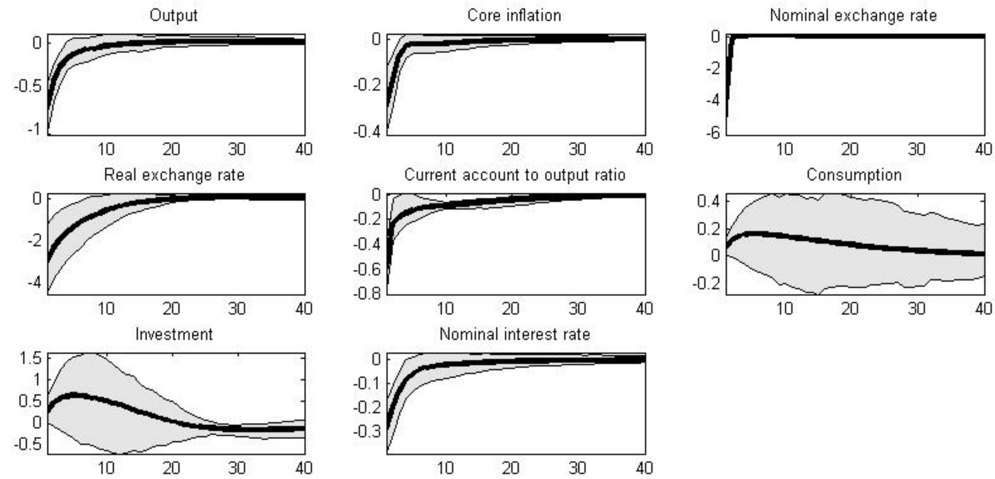


Figure E1.12: Impulse response to an international oil price shock

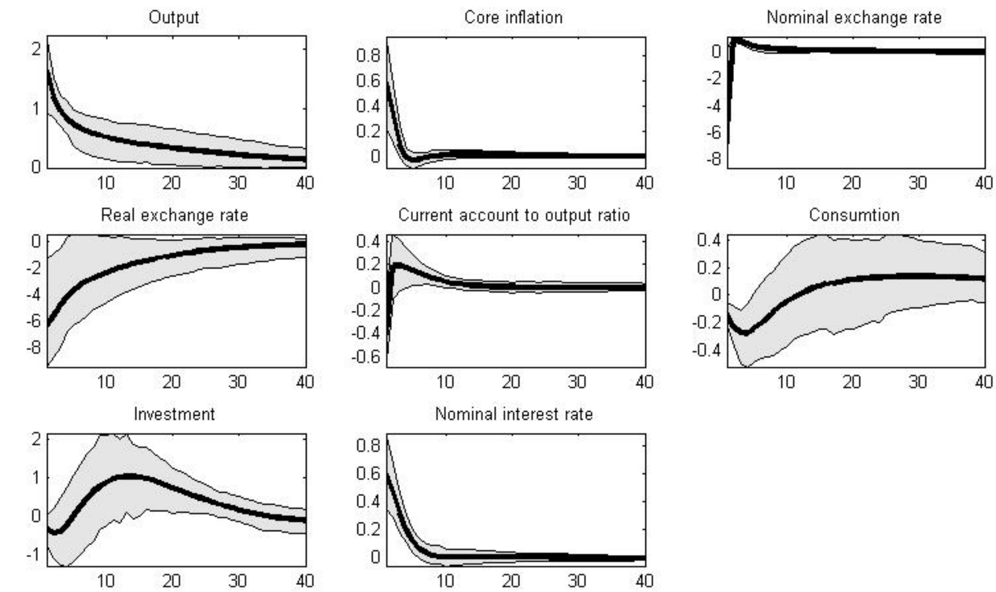
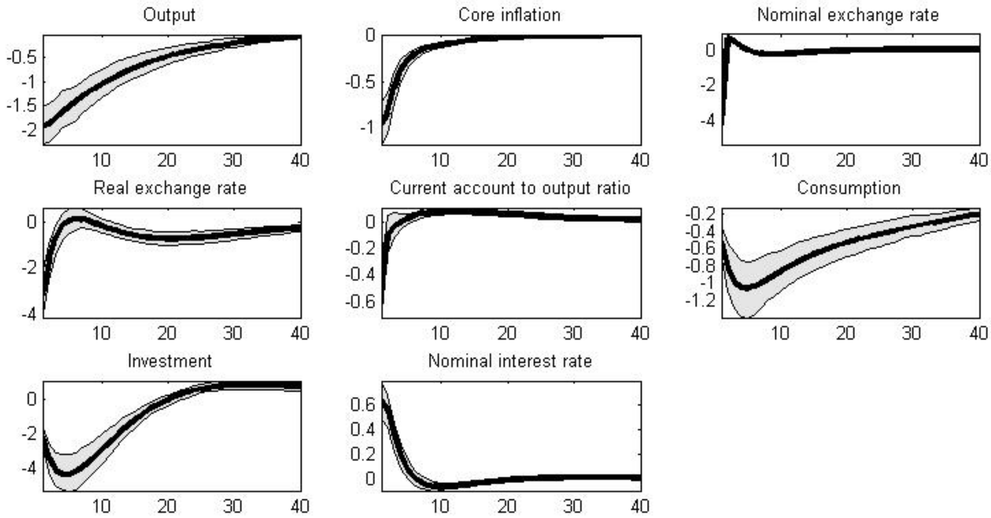


Figure E1.13: Impulse response to a government expenditure shock



Appendix E2: Historical decomposition of shocks

Figures below represent the historical decomposition. The horizontal axis represents the horizon in years, while the vertical axis gives the importance of a shock to a variable. At each point of time, a given variable in the model is written as a function of initial values and structural shocks.

Figure E2.1: Historical decomposition of GDP growth

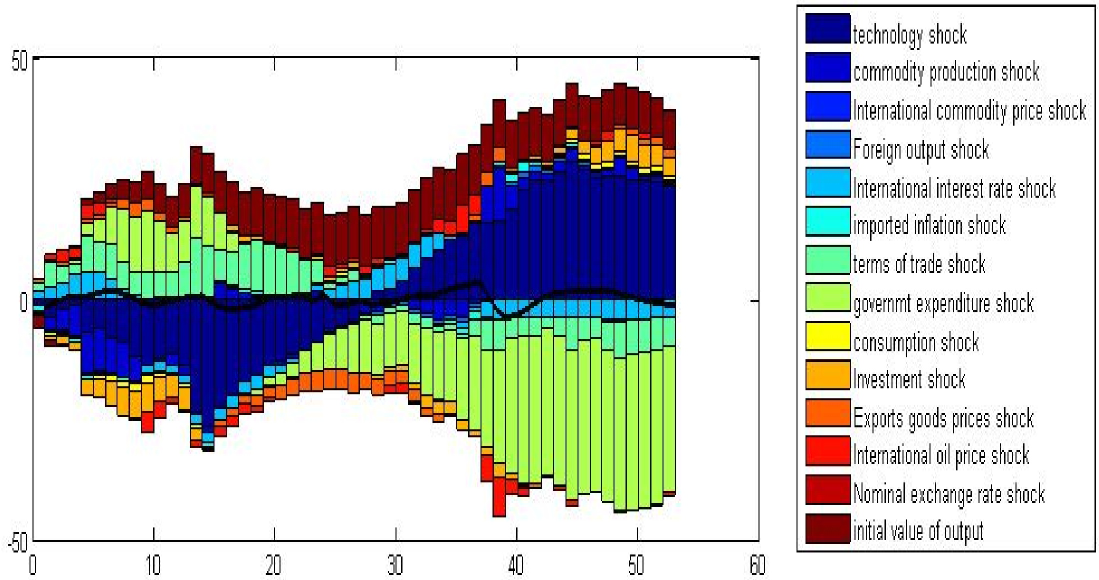


Figure E2.2: Historical decomposition of core inflation

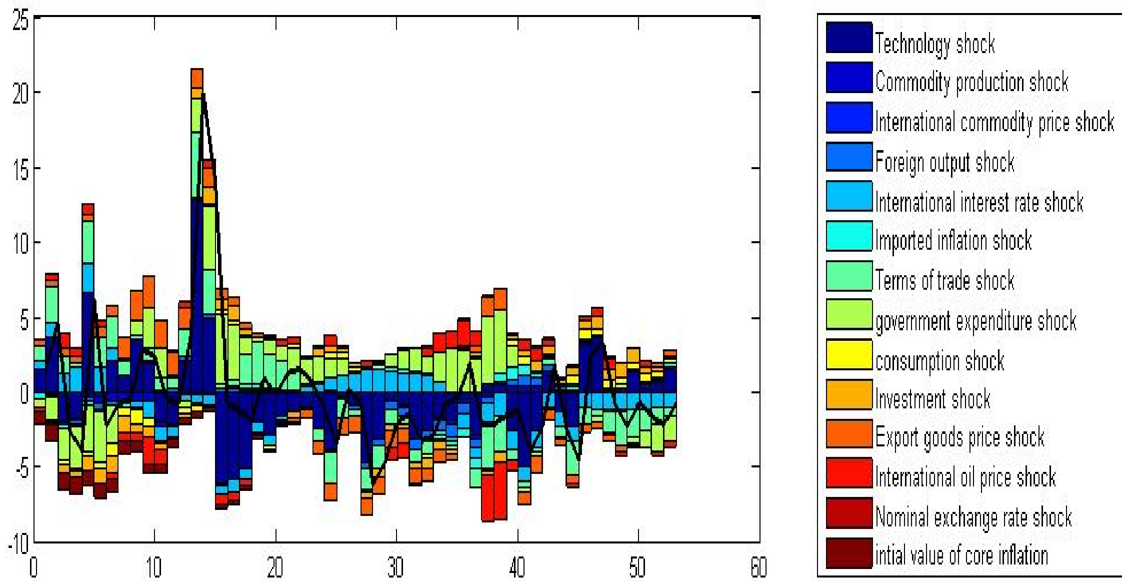


Figure E2.3: Historical decomposition of exchange rate

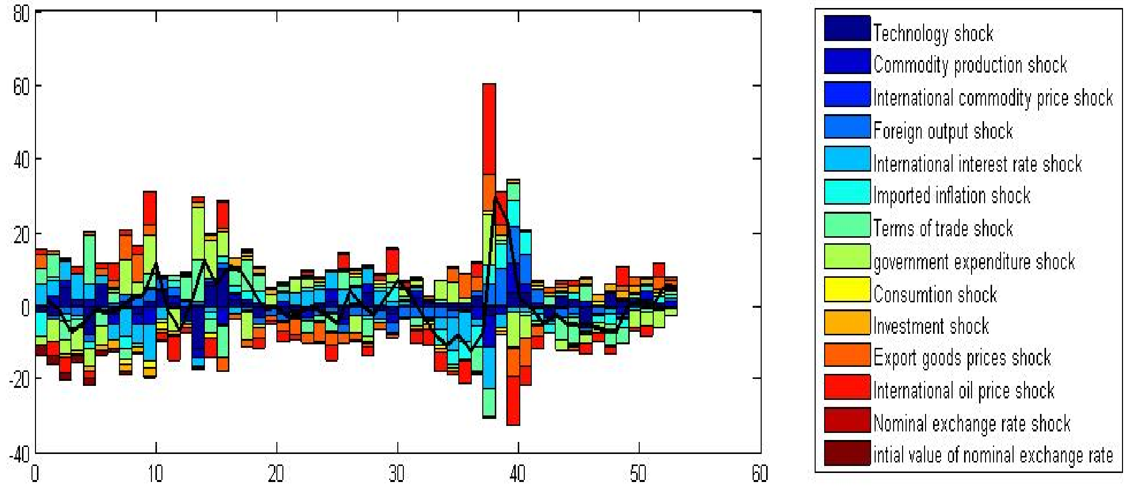


Figure E2.1: Historical decomposition of real exchange rate

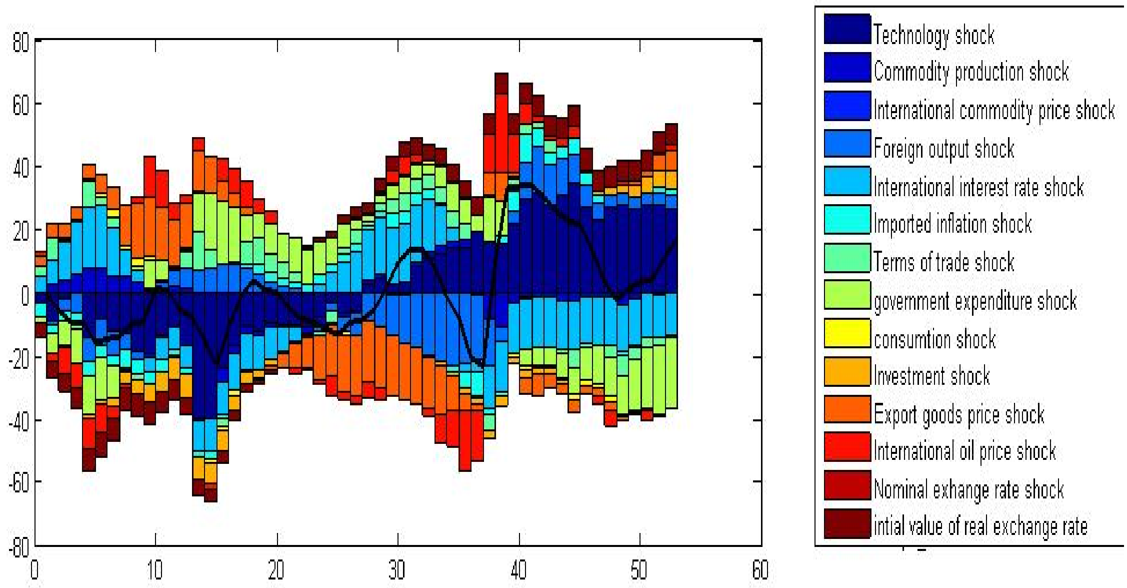


Figure E2.4: Historical decomposition of government foreign net asset

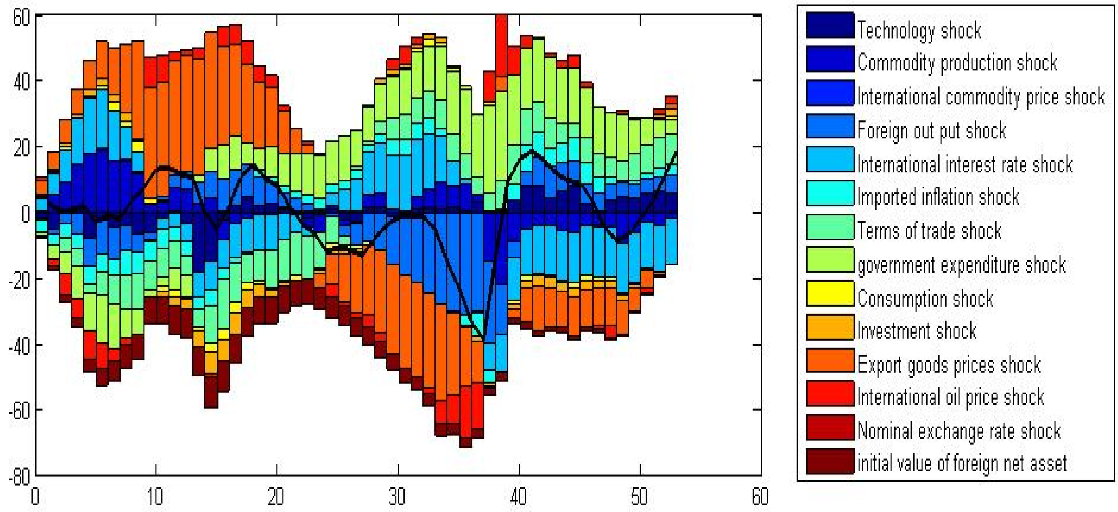


Figure E2.5: Historical decomposition of current account

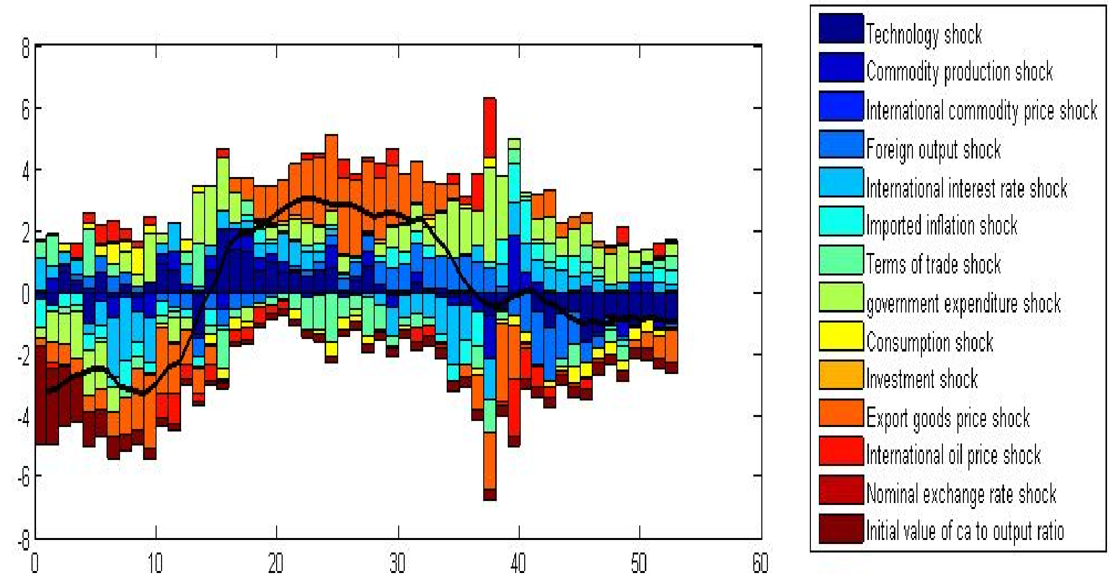


Figure E2.6: Historical decomposition of commodity production

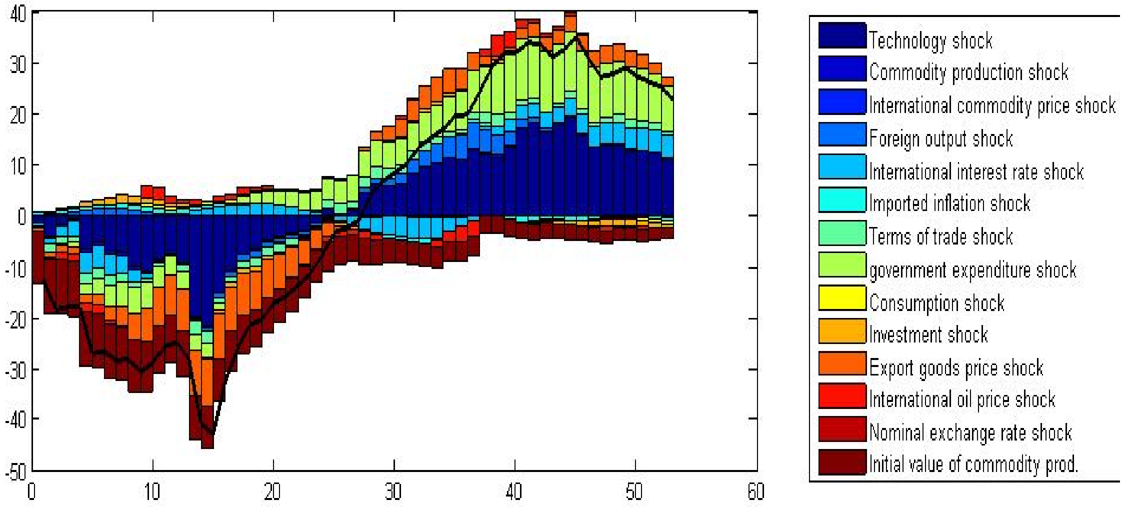


Figure E2.7: Historical decomposition of consumption

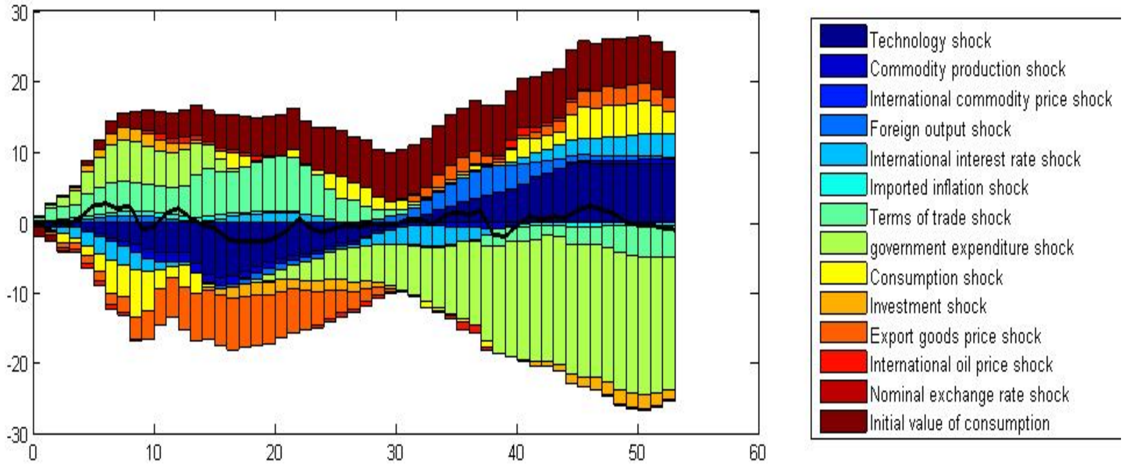


Figure E2.8: Historical decomposition of investment

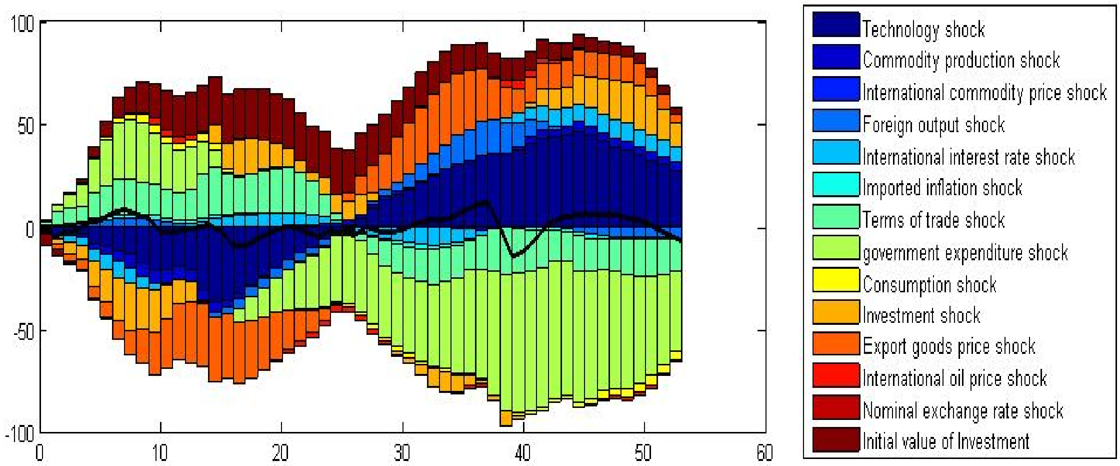


Figure E2.9: Historical decomposition of imported inflation

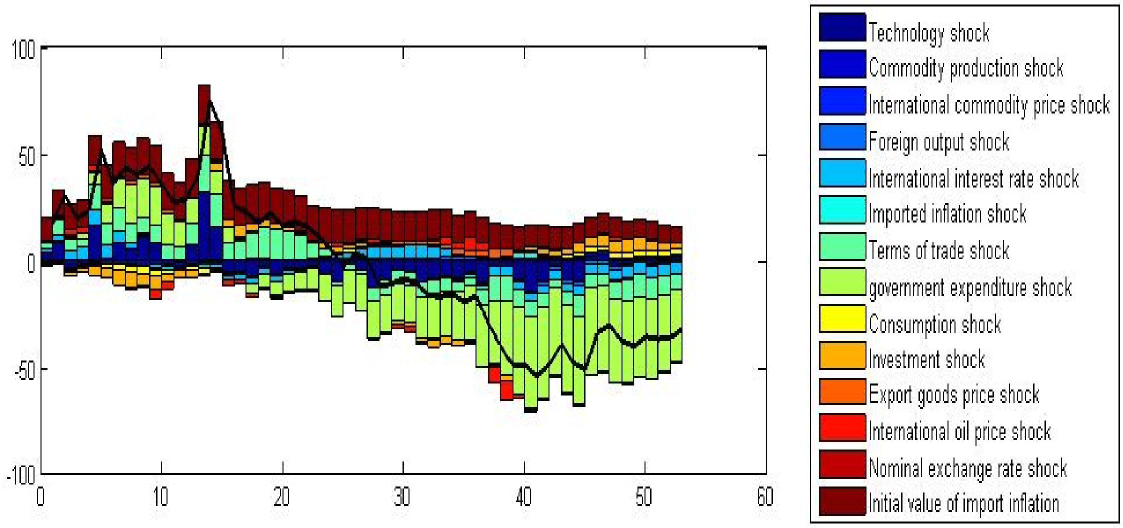


Figure E2.10: Historical decomposition of interest rate

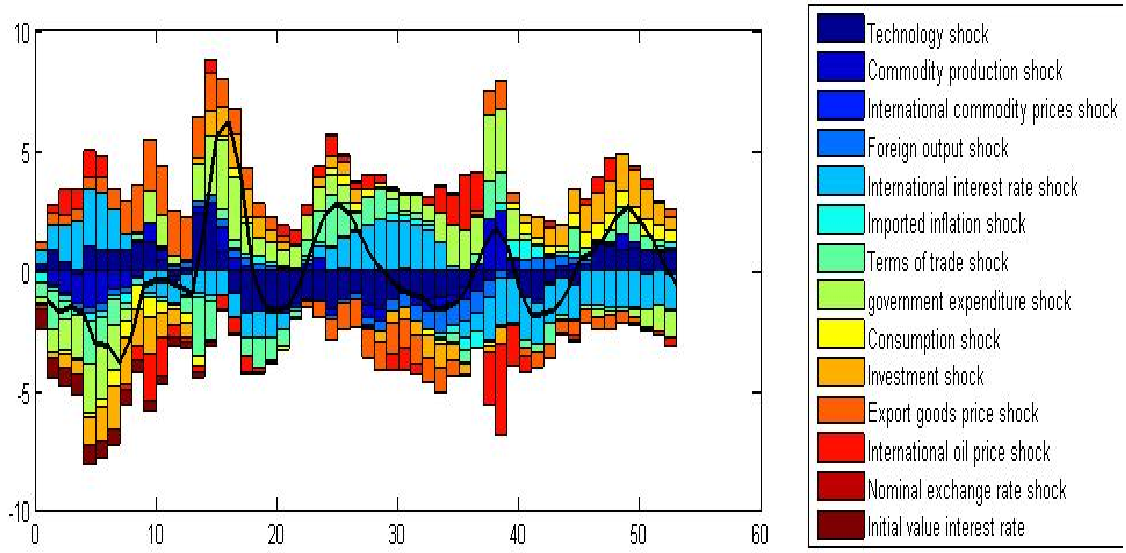
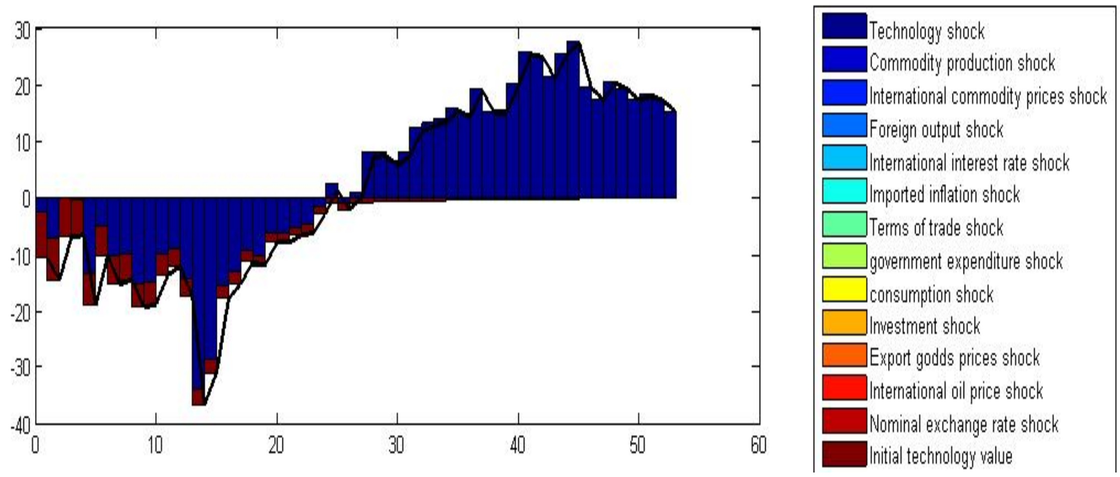


Figure E2.11: Historical decomposition of technology



Appendix E3: Forecasts performance statistics

The DSGE model must contain useful information about the future dynamics of the Cameroon business cycle since it is to aid policy evaluation. This information content is gauged by running out-of-sample forecast experiments among competing models.

Table 4.1: Mean forecast errors

vble	h	DSGE	BVAR(1)	BVAR(2)	BVAR(3)	BVAR(4)	VAR(1)	VAR(2)	VAR(3)	RW
y	1	0.01%	0.08%	0.02%	0.08%	0.01%	0.07%	0.01%	0.03%	0.07%
	2	-0.03%	-0.01%	-0.01%	-0.01%	0.01%	0.05%	-0.01%	0.09%	-0.01%
	3	-0.01%	0.01%	0.07%	0.07%	0.07%	0.06%	0.07%	0.05%	0.06%
	4	-0.05%	0.07%	0.03%	0.06%	0.06%	0.08%	0.06%	0.03%	0.08%
	5	-0.02%	0.03%	0.01%	0.02%	0.02%	0.01%	0.02%	0.04%	0.01%
	6	-0.04%	0.02%	0.03%	0.06%	0.03%	0.05%	0.03%	0.07%	0.05%
	7	-0.05%	0.03%	0.05%	0.09%	0.07%	0.09%	0.07%	0.02%	0.09%
	8	0.01%	0.04%	0.01%	0.01%	0.01%	0.05%	0.01%	0.03%	0.05%
	9	-0.07%	0.01%	0.09%	0.09%	0.09%	0.07%	0.09%	0.05%	0.07%
pi	1	-0.18%	0.22%	0.11%	0.22%	0.13%	0.15%	0.02%	0.17%	0.21%
	2	-0.21%	-0.29%	0.21%	-0.11%	-0.21%	0.12%	-0.13%	0.11%	0.15%
	3	-0.12%	0.17%	0.12%	0.08%	0.17%	-0.07%	0.17%	-0.16%	0.13%
	4	-0.13%	0.15%	-0.06%	-0.16%	-0.06%	-0.21%	0.21%	-0.12%	0.15%
	5	-0.21%	-0.02%	-0.22%	-0.12%	0.12%	0.11%	-0.12%	0.10%	0.11%
	6	-0.15%	0.10%	-0.13%	0.16%	-0.13%	0.08%	0.13%	-0.13%	0.22%
	7	-0.17%	-0.09%	-0.03%	-0.17%	-0.17%	-0.13%	-0.17%	0.09%	0.19%
	8	-0.13%	-0.11%	0.11%	0.02%	0.11%	-0.12%	0.09%	0.15%	0.15%
	9	0.01%	-0.20%	-0.19%	-0.15%	-0.09%	0.22%	0.12%	0.14%	0.17%

pif	1	-0.01%	0.01%	0.15%	-0.09%	0.02%	0.11%	0.01%	0.12%	0.00%
	2	-0.02%	0.11%	0.12%	0.01%	-0.10%	0.09%	-0.11%	0.05%	-0.02%
	3	-0.01%	-0.10%	-0.03%	-0.07%	-0.01%	0.13%	0.12%	0.18%	-0.09%
	4	-0.05%	0.16%	0.16%	0.02%	0.15%	0.06%	0.00%	-0.13%	0.06%
	5	-0.11%	-0.12%	0.01%	-0.06%	0.20%	-0.11%	-0.11%	0.09%	0.03%
	6	-0.02%	0.03%	0.15%	0.13%	-0.13%	0.06%	0.08%	-0.06%	-0.03%
	7	-0.13%	0.17%	0.04%	0.09%	0.08%	-0.02%	0.15%	0.17%	0.07%
	8	-0.02%	0.01%	0.17%	0.11%	0.11%	0.18%	0.09%	0.01%	-0.06%
	9	-0.14%	0.13%	0.09%	-0.04%	-0.03%	0.15%	0.02%	0.10%	0.02%
i	1	-0.05%	0.22%	0.09%	0.11%	0.09%	0.12%	0.01%	0.03%	0.02%
	2	-0.22%	0.11%	0.11%	0.21%	0.11%	0.11%	0.24%	0.09%	0.01%
	3	-0.13%	0.19%	0.13%	0.15%	0.17%	0.17%	0.26%	0.22%	0.08%
	4	-0.14%	0.08%	0.09%	0.16%	0.22%	0.20%	0.16%	0.21%	-0.06%
	5	-0.11%	-0.17%	0.12%	0.18%	0.12%	0.22%	0.11%	0.22%	0.00%
	6	-0.21%	0.19%	0.11%	0.13%	-0.23%	0.19%	0.15%	0.13%	0.01%
	7	-0.25%	-0.07%	0.17%	0.19%	0.17%	0.21%	0.09%	-0.27%	0.00%
	8	-0.19%	0.12%	0.21%	0.11%	0.11%	0.24%	0.05%	-0.20%	0.00%
	9	-0.12%	0.05%	0.22%	0.09%	0.19%	0.21%	0.22%	0.13%	0.00%
e	1	0.02%	1.01%	0.59%	0.51%	0.22%	0.92%	1.28%	0.29%	1.01%
	2	0.31%	0.29%	0.11%	1.07%	0.51%	0.59%	1.01%	-0.21%	0.91%
	3	0.18%	0.95%	0.37%	0.37%	1.09%	-0.29%	0.15%	0.13%	0.57%
	4	0.56%	1.06%	1.02%	1.16%	0.43%	-0.63%	0.26%	0.66%	1.06%
	5	0.02%	1.18%	1.12%	0.22%	-0.23%	0.91%	1.08%	0.82%	0.32%
	6	-0.06%	0.63%	0.43%	0.63%	0.29%	1.39%	0.52%	0.71%	0.53%
	7	-0.27%	0.07%	0.17%	1.07%	-0.57%	0.17%	1.07%	-0.17%	0.17%
	8	0.12%	0.71%	1.31%	0.11%	1.02%	-0.22%	0.31%	0.37%	0.41%
	9	-0.35%	0.09%	0.29%	0.29%	0.65%	0.75%	0.19%	1.12%	1.49%

Table 4.2a: Mincer and Zarnowitz (1969) forecast efficiency test

Vble	h	DSGE			BVAR(1)			BVAR(2)		
		$\hat{\alpha}$	$\hat{\beta}$	P-val	$\hat{\alpha}$	$\hat{\beta}$	P-val	$\hat{\alpha}$	$\hat{\beta}$	P-val
y	1	0.55(0.10)	0.24(0.09)	0.07	0.86(0.01)	1.08(0.04)	0.00	0.23(0.10)	0.16(0.15)	0.00
	2	0.94(0.11)	-0.09(0.12)	0.02	1.03(0.17)	0.72(0.23)	0.00	0.78(0.12)	-0.91(0.02)	0.00
	3	1.07(0.18)	0.19(0.37)	0.00	0.56(0.21)	0.69(0.06)	0.04	1.01(0.41)	-0.77(0.23)	0.00
	4	0.78(0.24)	0.04(0.21)	0.10	0.84(0.05)	-0.32(0.11)	0.00	-0.46(0.28)	1.05(0.29)	0.05
	5	0.32(0.32)	0.43(0.20)	0.15	0.64(0.03)	-0.96(0.20)	0.00	0.78(0.18)	0.46(0.03)	0.00
	6	0.47(0.40)	0.14(0.10)	0.00	0.57(0.09)	-1.12(0.16)	0.00	1.12(0.07)	0.67(0.35)	0.00
	7	0.38(0.15)	0.09(0.01)	0.08	0.37(0.19)	0.73(0.42)	0.01	-0.94(0.30)	0.82(0.17)	0.03
	8	0.73(0.10)	0.03(0.19)	0.10	0.47(0.34)	0.65(0.29)	0.00	0.48(0.13)	-0.39(0.05)	0.00
	9	0.64(0.27)	-0.07(0.07)	0.06	0.75(0.10)	0.58(0.02)	0.00	0.58(0.21)	0.76(0.03)	0.00
pi	1	1.07(0.23)	0.29(0.65)	0.00	0.37(0.44)	0.16(0.10)	0.05	0.96(0.51)	0.14(0.20)	0.03
	2	0.87(0.31)	0.61(0.54)	0.00	0.71(0.78)	0.91(0.22)	0.00	0.93(0.33)	0.09(0.17)	0.00
	3	0.52(0.52)	0.77(0.23)	0.00	1.01(0.21)	0.77(0.36)	0.03	0.56(0.07)	0.79(0.25)	0.01
	4	0.94(0.10)	1.05(0.07)	0.00	0.46(0.29)	-0.95(0.19)	0.00	0.84(0.13)	-0.44(0.26)	0.00
	5	0.34(0.06)	0.46(0.29)	0.00	0.78(0.04)	0.76(0.43)	0.00	0.64(0.53)	0.43(0.11)	0.00
	6	0.70(0.31)	0.67(0.08)	0.00	0.72(0.78)	-0.37(0.50)	0.00	0.67(0.48)	-0.84(0.47)	0.00
	7	056(0.19)	0.82(0.27)	0.00	0.94(0.30)	0.82(0.27)	0.00	0.37(0.35)	0.09(0.50)	0.00
	8	0.92(0.20)	0.39(0.35)	0.00	0.48(0.09)	0.89(0.15)	0.00	0.57(0.29)	-0.83(0.56)	0.00
	9	0.36(0.32)	0.76(0.62)	0.00	0.58(0.52)	0.76(0.23)	0.00	0.75(0.37)	0.67(0.30)	0.00

pif	1 2 3 4 5 6 7 8 9	0.53(0.10) 0.88(0.21) 0.91(0.11) -0.46(0.25) 0.68(0.23) 1.12(0.18) -0.94(0.10) 0.48(0.53) 0.58(0.21)	0.86(0.01) 0.73(0.17) 0.56(0.26) -0.64(0.29) -0.64(0.52) -0.57(0.28) 0.97(0.27) 0.67(0.19) 0.25(0.30)	0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.05	0.58(0.10) 0.94(0.21) 1.27(0.30) 0.78(0.35) -0.62(0.20) -0.47(0.18) 0.58(0.32) 0.73(0.22) 0.64(0.27)	0.45(0.13) 1.01(0.23) 0.56(0.37) -0.84(0.38) -0.64(0.19) -0.27(0.42) 0.37(0.22) 0.97(0.26) 0.75(0.10)	0.00 0.04 0.00 0.00 0.02 0.03 0.00 0.00 0.00	0.26(0.03) 0.77(0.32) 0.77(0.33) 0.55(0.17) 0.46(0.21) 0.67(0.30) 0.72(0.44) 0.39(0.15) 0.76(0.10)	0.87(0.52) -0.71(0.78) 1.01(0.21) 0.46(0.43) 0.78(0.30) 0.82(0.29) 0.94(0.16) 0.70(0.41) 0.49(0.25)	0.01 0.00 0.00 0.00 0.00 0.03 0.00 0.00 0.00
i	1 2 3 4 5 6 7 8 9	-0.76(0.03) 1.07(0.32) -0.77(0.03) -0.55(0.10) -1.16(0.12) 0.67(0.30) 0.72(0.32) 0.39(0.15) 0.76(0.09)	0.98(0.54) -0.52(0.63) 0.69(0.19) 0.84(0.10) 1.06(0.08) 1.12(0.11) -0.73(0.05) -0.65(0.14) 0.58(0.06)	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	0.57(0.10) 1.11(0.52) -0.77(0.36) -0.95(0.19) -0.76(0.07) 0.37(0.27) 0.82(0.14) 0.89(0.05) 0.76(0.20)	0.38(0.10) 0.78(0.78) 0.91(0.21) 0.66(0.52) 0.78(0.03) 0.62(0.19) 0.94(0.06) 0.48(0.12) 0.58(0.09)	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	0.46(0.21) 0.73(0.10) 0.56(0.16) 0.74(0.25) 1.24(0.57) 0.57(0.02) 0.97(0.27) 0.67(0.19) 0.25(0.10)	0.86(0.01) 1.03(0.17) -0.56(0.20) 0.84(0.11) -0.64(0.03) -0.57(0.11) 0.37(0.19) 0.47(0.05) 0.75(0.29)	0.03 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00

e	1	0.67(0.10)	0.87(0.01)	0.00	0.45(0.03)	0.24(0.10)	0.00	0.58(0.10)	0.96(0.11)	0.00
	2	0.70(0.28)	0.71(0.78)	0.00	1.01(0.07)	-0.09(0.23)	0.00	0.94(0.21)	-0.93(0.03)	0.00
	3	1.21(0.11)	1.01(0.21)	0.00	-0.56(0.10)	0.19(0.37)	0.00	1.27(0.09)	-0.56(0.25)	0.00
	4	-0.76(0.22)	0.46(0.12)	0.00	0.84(0.38)	0.04(0.17)	0.00	0.78(0.35)	-0.84(0.20)	0.00
	5	0.78(0.10)	-0.78(0.42)	0.00	0.64(0.03)	0.43(0.09)	0.00	-0.62(0.20)	0.64(0.03)	0.00
	6	0.82(0.05)	-0.82(0.13)	0.00	0.27(0.20)	0.14(0.33)	0.00	-0.47(0.27)	0.67(0.32)	0.00
	7	-0.94(0.24)	0.94(0.08)	0.00	0.37(0.18)	-0.09(0.30)	0.00	-0.58(0.07)	0.37(0.10)	0.00
	8	-0.70(0.15)	0.70(0.10)	0.00	0.97(0.26)	-0.03(0.31)	0.00	0.73(0.18)	0.57(0.11)	0.00
	9	0.49(0.01)	0.49(0.28)	0.00	0.75(0.01)	-0.07(0.36)	0.00	0.64(0.27)	0.75(0.02)	0.00

Table 4.2b: Mincer and Zarnowitz (1969) forecast efficiency test

Vble	h	BVAR(4)			VAR(1)			VAR(2)		
		$\hat{\alpha}$	$\hat{\beta}$	P-val	$\hat{\alpha}$	$\hat{\beta}$	P-val	$\hat{\alpha}$	$\hat{\beta}$	P-val
y	1	0.37(0.07)	0.45(0.03)	0.00	0.98(0.41)	0.97(0.10)	0.03	1.08(0.11)	0.36(0.11)	0.00
	2	0.78(0.10)	1.01(0.24)	0.00	-0.82(0.33)	0.38(0.07)	0.00	0.52(0.63)	-0.77(0.02)	0.00
	3	0.91(0.21)	0.56(0.38)	0.01	0.69(0.27)	0.91(0.01)	0.00	0.69(0.19)	0.64(0.23)	0.03
	4	0.76(0.12)	0.84(0.17)	0.00	0.84(0.25)	0.66(0.52)	0.05	0.84(0.01)	0.55(0.12)	0.00
	5	0.78(0.27)	0.64(0.03)	0.00	-0.86(0.08)	0.78(0.06)	0.00	1.06(0.34)	0.46(0.10)	0.00
	6	0.42(0.31)	0.27(0.19)	0.00	0.72(0.22)	0.62(0.19)	0.00	1.12(0.24)	0.67(0.32)	0.00
	7	0.94(0.30)	0.37(0.23)	0.01	-0.73(0.15)	0.44(0.03)	0.00	0.73(0.26)	-0.72(0.44)	0.00
	8	0.48(0.09)	0.97(0.19)	0.00	-0.65(0.23)	0.48(0.20)	0.00	-0.65(0.10)	-0.39(0.05)	0.00
	9	0.58(0.11)	0.75(0.32)	0.00	0.58(0.41)	0.58(0.34)	0.00	0.58(0.01)	0.76(0.09)	0.01

pi	1	0.58(0.10)	0.66(0.21)	0.00	0.45(0.03)	0.56(0.18)	0.00	0.98(0.54)	0.53(0.10)	0.00
	2	0.94(0.21)	1.43(0.13)		1.01(0.10)	0.83(0.07)			0.88(0.02)	
	3	1.27(0.09)	-0.56(0.25)	0.00	0.56(0.18)	0.56(0.37)	0.00	-0.52(0.63)	0.91(0.11)	0.00
	4	0.78(0.24)	-0.74(0.15)		-	0.84(0.12)			-0.46(0.09)	
	5	-0.62(0.56)	1.04(0.07)	0.03	0.84(0.38)	-0.64(0.03)	0.00	0.69(0.19)	0.68(0.23)	0.00
	6	-0.47(0.32)	-0.77(0.20)		-	-0.50(0.17)			1.12(0.13)	
	7	0.58(0.11)	0.90(0.27)	0.00	0.64(0.03)	0.47(0.20)	0.00	0.84(0.09)	-0.94(0.01)	0.00
	8	0.73(0.06)	0.67(0.02)		-	0.47(0.22)			0.48(0.53)	
	9	0.64(0.27)	-0.25(0.19)	0.00	0.27(0.10)	0.75(0.10)	0.00	1.06(0.16)	0.58(0.21)	0.00
					0.37(0.09)					
				0.00	0.97(0.26)		0.00	1.12(0.01)		0.00
					0.75(0.14)					
				0.00			0.00	-0.73(0.10)		0.00
				0.00			0.00	-0.65(0.16)		0.00
				0.00			0.00	0.58(0.08)		0.00
pif	1	0.55(0.06)	0.75(0.01)	0.00	0.36(0.24)	0.87(0.28)	0.00	0.58(0.10)	0.57(0.11)	0.00
	2	0.81(0.01)	-0.60(0.25)			0.71(0.53)		0.94(0.21)		
	3	0.53(0.10)	0.76(0.39)	0.09	1.27(0.12)	1.01(0.21)	0.00	1.27(0.20)	1.09(0.52)	0.00
	4	-0.80(0.30)	-0.74(0.30)			0.46(0.17)		0.78(0.35)		
	5	-0.64(0.03)	0.28(0.16)	0.00	0.77(0.03)	-0.78(0.20)	0.00	-0.62(0.22)	-0.67(0.36)	0.00
	6	-0.77(0.22)	-0.49(0.20)			-0.82(0.21)		-0.47(0.05)		
	7	1.19(0.17)	0.84(0.09)	0.00	0.55(0.10)	0.94(0.13)	0.00	0.58(0.01)	-0.65(0.15)	0.00
	8	0.67(0.08)	0.94(0.16)			0.70(0.29)		0.73(0.10)		
	9	0.75(0.14)	0.35(0.22)	0.00	0.46(0.18)	0.49(0.33)	0.02	0.64(0.27)	-0.76(0.10)	0.00
				0.00	0.27(0.09)		0.05		0.77(0.20)	0.00
				0.00	0.72(0.27)		0.00		0.82(0.25)	0.00
				0.00	0.39(0.15)		0.00		0.89(0.05)	0.00
				0.00	0.56(0.11)		0.00		0.46(0.10)	0.00
i	1	0.39(0.22)	0.88(0.09)	0.00	0.86(0.01)	0.68(0.25)	0.00	0.24(0.09)	0.41(0.22)	0.00
	2				1.03(0.17)				-0.71(0.14)	
	3	0.72(0.16)	0.59(0.13)	0.00	-	-0.82(0.15)	0.00	-0.09(0.18)	0.59(0.11)	0.00
	4				0.56(0.20)				0.84(0.16)	
	5	0.69(0.06)	0.89(0.29)	0.02	0.84(0.22)	0.70(0.29)	0.00	0.19(0.20)	0.64(0.03)	0.00
	6				-				0.37(0.31)	
	7	-0.95(0.10)	0.84(0.33)	0.00	0.64(0.13)	0.84(0.01)	0.00	0.04(0.22)	-0.40(0.47)	0.00
	8				-				0.97(0.28)	
	9	0.56(0.21)	0.66(0.52)	0.00	0.57(0.55)	-0.56(0.17)	0.00	0.43(0.07)	0.75(0.37)	0.00
					0.37(0.42)					
		0.47(0.17)	1.32(0.45)	0.00	0.47(0.23)	0.72(0.61)	0.00	0.14(0.20)		0.00
					0.75(0.15)					
		-0.72(0.24)	0.73(0.20)	0.00		0.73(0.15)	0.00	-0.09(0.22)		0.00
		-0.39(0.15)	-1.65(0.33)	0.00		-0.65(0.52)	0.00	-0.03(0.54)		0.00
		0.86(0.20)	0.58(0.19)	0.00		1.28(0.29)	0.00	-0.07(0.38)		0.00

e	1	0.66(0.21)	0.45(0.08)	0.00	0.97(0.14)	0.56(0.20)	0.00	0.55(0.09)	0.87(0.10)	0.00
	2	1.43(0.18)	1.01(0.22)		0.38(0.26)	0.83(0.17)		0.81(0.12)	-0.71(0.78)	
	3	-0.56(0.24)	0.56(0.11)	0.00	0.91(0.21)	0.56(0.03)	0.00	0.53(0.20)	1.01(0.21)	0.00
	4	-0.74(0.32)	-0.84(0.38)		0.66(0.32)	0.84(0.12)		-0.80(0.31)	0.46(0.16)	
	5	1.04(0.17)	-0.64(0.13)	0.00	0.78(0.09)	-0.64(0.23)	0.00	-0.64(0.03)	0.78(0.29)	0.00
	6	-0.77(0.40)	-0.27(0.20)		0.62(0.19)	-0.50(0.35)		-0.77(0.26)	0.82(0.10)	
	7	0.90(0.27)	0.37(0.18)	0.00	0.44(0.11)	0.47(0.17)	0.00	1.19(0.11)	0.94(0.19)	0.00
	8	0.67(0.35)	0.97(0.26)		0.48(0.05)	0.47(0.10)		0.67(0.08)	0.70(0.34)	
	9	-0.25(0.18)	0.75(0.30)	0.00	0.58(0.10)	0.75(0.23)	0.00	0.75(0.33)	0.49(0.19)	0.00
				0.00			0.00			0.00
				0.00			0.00			0.00
				0.00			0.00			0.00
				0.00			0.00			0.00

Table 4.2c: Mincer and Zarnowitz (1969) forecast efficiency test

Vble	h	VAR(3)			RW		
		$\hat{\alpha}$	$\hat{\beta}$	MZ P-val	$\hat{\alpha}$	$\hat{\beta}$	MZ P-val
y	1	0.36(0.25)	0.79(0.21)	0.00	0.75(0.47)	0.96(0.33)	0.00
	2		-0.60(0.56)		-0.60(0.52)	0.83(0.17)	
	3	-0.77(0.34)	0.70(0.29)	0.00	0.76(0.16)	0.26(0.10)	0.00
	4		-0.74(0.20)		-0.74(0.29)	0.84(0.12)	
	5	0.64(0.53)	0.28(0.44)	0.00	0.28(0.14)	-0.64(0.23)	0.00
	6		-0.49(0.30)		-0.49(0.11)	-0.50(0.20)	
	7	0.55(0.42)	0.84(0.65)	0.00	0.84(0.10)	0.47(0.27)	0.00
	8		0.94(0.36)		0.94(0.26)	0.47(0.09)	
	9	0.46(0.37)	0.37(0.23)	0.00	0.35(0.20)	0.75(0.11)	0.00
		0.67(0.42)		0.00			0.00
		-0.72(0.44)		0.00			0.00
		-0.39(0.25)		0.00			0.00
		0.76(0.26)		0.00			0.00

pi	1	0.87(0.50)	0.38(0.27)	0.00	0.55(0.42)	0.66(0.71)	0.00
	2	0.71(0.78)	0.78(0.78)		0.81(0.18)	1.43(0.45)	
	3	1.01(0.21)	0.91(0.35)	0.00	0.53(0.30)	-0.56(0.30)	0.00
	4	0.46(0.52)	0.66(0.52)		-0.80(0.57)	-0.74(0.22)	
	5	-0.78(0.37)	0.78(0.40)	0.00	-0.64(0.23)	1.04(0.27)	0.00
	6	-0.82(0.18)	0.62(0.29)		-0.77(0.20)	-0.77(0.52)	
	7	0.94(0.54)	0.94(0.12)	0.00	1.19(0.78)	0.90(0.64)	0.00
	8	0.70(0.32)	0.48(0.25)		0.67(0.38)	0.67(0.25)	
	9	0.49(0.46)	0.58(0.39)	0.00	0.75(0.40)	-0.25(0.60)	0.00
				0.00			0.00
				0.00			0.00
				0.00			0.00
				0.00			0.00
pif	1	0.87(0.21)	0.55(0.28)	0.00	0.45(0.33)	0.76(0.75)	0.00
	2	-0.71(0.78)	0.81(0.14)		1.01(0.52)		
	3	1.01(0.21)	0.53(0.56)	0.00	0.56(0.22)	-1.07(0.60)	0.00
	4	0.46(0.09)	-0.80(0.30)		-0.84(0.38)		
	5	0.78(0.37)	-0.64(0.23)	0.00	-0.64(0.53)	0.64(0.43)	0.00
	6	0.82(0.30)	-0.77(0.25)		-0.27(0.20)		
	7	0.94(0.52)	1.19(0.17)	0.00	0.37(0.25)	0.55(0.19)	0.00
	8	0.70(0.29)	0.67(0.28)		0.97(0.26)		
	9	0.49(0.13)	0.75(0.40)	0.00	0.75(0.30)	0.86(0.34)	0.00
				0.00		0.67(0.57)	0.00
				0.00		-0.72(0.44)	0.00
				0.00		-0.39(0.35)	0.00
				0.00		0.76(0.40)	0.00
i	1	0.75(0.21)	0.53(0.18)	0.01	0.97(0.20)	0.57(0.28)	0.00
	2	-0.60(0.51)	0.88(0.37)		0.38(0.33)		
	3	0.76(0.44)	0.91(0.61)	0.00	0.91(0.41)	1.09(0.52)	0.00
	4	-0.74(0.33)	-0.46(0.40)		0.66(0.52)		
	5	0.28(0.28)	0.68(0.23)	0.00	0.78(0.16)	-0.67(0.36)	0.00
	6	-0.49(0.59)	1.12(0.45)		0.62(0.19)		
	7	0.84(0.15)	-0.94(0.34)	0.00	0.44(0.26)	-0.65(0.30)	0.02
	8	0.94(0.16)	0.48(0.53)		0.48(0.37)		
	9	0.35(0.35)	0.58(0.23)	0.00	0.58(0.46)	-0.76(0.19)	0.00
				0.00		0.77(0.40)	0.00
				0.00		0.82(0.48)	0.00
				0.00		0.89(0.65)	0.00
				0.00		0.46(0.37)	0.00

e	1	0.56(0.19)	0.55(0.11)	0.00	0.87(0.47)	0.66(0.21)	0.00
	2	0.84(0.27)	0.81(0.06)		-0.71(0.78)	1.43(0.36)	
	3	0.56(0.30)	0.53(0.18)	0.00	1.01(0.21)	-0.56(0.52)	0.00
	4	0.84(0.12)	-0.80(0.30)		0.46(0.60)	-0.74(0.43)	
	5	-0.64(0.13)	-0.64(0.23)	0.00	0.78(0.34)	1.04(0.67)	0.00
	6	-0.50(0.09)	-0.77(0.15)		0.82(0.29)	-0.77(0.49)	
	7	0.47(0.12)	1.19(0.10)	0.04	0.94(0.55)	0.90(0.37)	0.01
	8	0.47(0.10)	0.67(0.08)		0.70(0.42)	0.67(0.62)	
	9	0.75(0.28)	0.75(0.12)	0.00	0.49(0.27)	-0.25(0.56)	0.00
				0.00			0.00
				0.03			0.00
				0.00			0.00
				0.00			0.00

Table 4.3: Root Mean Squared Forecast Errors (RMSE)

vbles	h	DSGE	BVAR(1)	BVAR(2)	BVAR(3)	BVAR(4)	VAR(1)	VAR(2)	VAR(3)	RW
y	1	0.62%	0.81%	0.89%	0.59%	0.75%	0.69%	0.69%	0.69%	0.92%
	2	0.41%	0.67%	0.71%	0.65%	0.71%	0.67%	0.71%	0.71%	0.61%
	3	0.59%	0.67%	0.83%	0.73%	0.60%	0.83%	0.93%	0.63%	0.79%
	4	0.83%	0.96%	0.86%	0.96%	0.76%	0.66%	0.86%	0.76%	0.63%
	5	0.61%	0.72%	0.72%	0.72%	0.82%	0.72%	0.62%	0.82%	0.75%
	6	0.29%	0.63%	0.61%	0.51%	0.87%	0.81%	0.78%	0.61%	0.69%
	7	0.57%	0.87%	0.77%	0.67%	0.67%	0.67%	0.67%	0.77%	0.77%
	8	0.62%	0.87%	0.91%	0.83%	0.71%	0.71%	0.61%	0.81%	0.62%
	9	0.55%	0.73%	0.72%	0.92%	0.82%	0.92%	0.72%	0.92%	0.75%

pi	1	0.82%	0.82%	1.09%	0.99%	1.02%	0.98%	1.02%	0.96%	0.09%
	2	0.91%	1.21%	1.05%	1.15%	1.08%	1.10%	1.09%	1.11%	1.15%
	3	1.03%	0.93%	1.13%	1.03%	0.99%	1.03%	0.97%	1.05%	1.03%
	4	0.93%	1.03%	1.06%	0.96%	1.13%	1.13%	1.01%	1.03%	1.04%
	5	1.08%	1.11%	1.22%	0.98%	1.01%	1.07%	1.10%	1.06%	1.09%
	6	0.79%	0.89%	1.01%	1.11%	1.09%	0.99%	1.08%	0.97%	1.11%
	7	1.07%	1.07%	1.17%	1.07%	1.17%	1.07%	1.13%	1.17%	1.07%
	8	1.02%	1.02%	0.97%	0.97%	1.06%	1.12%	1.05%	1.02%	1.07%
	9	0.95%	1.05%	1.09%	1.19%	0.95%	1.06%	1.01%	1.08%	1.09%
pif	1	1.10%	1.29%	1.36%	1.28%	1.54%	1.85%	1.27%	1.72%	1.89%
	2	1.25%	1.40%	1.75%	1.67%	1.80%	1.47%	1.35%	1.53%	1.69%
	3	1.11%	1.16%	1.53%	1.65%	1.76%	1.57%	1.47%	1.71%	1.32%
	4	1.05%	1.29%	1.92%	1.87%	1.66%	1.52%	1.51%	1.25%	1.67%
	5	1.07%	1.18%	1.26%	1.37%	1.68%	1.72%	1.55%	1.28%	1.29%
	6	1.11%	1.47%	1.28%	1.37%	1.54%	1.26%	1.22%	1.35%	1.57%
	7	1.07%	1.11%	1.18%	1.27%	1.46%	1.82%	1.47%	1.35%	1.71%
	8	1.26%	1.37%	1.28%	1.41%	1.77%	1.62%	1.41%	1.63%	1.28%
	9	1.29%	1.63%	1.23%	1.42%	1.53%	1.39%	1.18%	1.30%	1.59%
i	1	0.29%	0.37%	0.35%	0.55%	0.58%	0.40%	0.39%	0.77%	0.37%
	2	0.65%	0.45%	0.43%	0.46%	0.37%	0.52%	0.61%	0.66%	0.43%
	3	0.33%	0.59%	0.57%	0.34%	0.44%	0.49%	0.36%	0.81%	0.73%
	4	0.76%	0.87%	0.64%	0.51%	0.28%	0.56%	0.72%	0.78%	0.38%
	5	0.58%	0.66	0.73%	0.69%	0.68%	0.35%	0.61%	0.72%	0.53%
	6	0.41%	0.77%	0.54%	0.51%	0.41%	0.53%	0.53%	0.56%	0.62%
	7	0.66%	0.58%	0.77%	0.70%	0.66%	0.62%	0.74%	0.63%	0.54%
	8	0.57%	0.39%	0.60%	0.62%	0.57%	0.49%	0.52%	0.71%	0.70%
	9	0.49%	0.55%	0.69%	0.79%	0.49%	0.78%	0.59%	0.56%	0.63%

e	1	8.19%	10.45%	8.98%	9.77%	8.87%	9.58%	10.29%	10.11%	7.13%
	2	7.65%	9.88%	10.57%	9.96%	10.23%	9.81%	10.53%	8.76%	9.17%
	3	7.33%	10.71%	11.16%	10.29%	9.38%	10.54%	11.09%	9.86%	10.25%
	4	7.76%	10.58%	9.78%	10.71%	10.71%	10.47%	10.73%	10.16%	11.01%
	5	6.68%	11.13%	11.08%	10.69%	10.28%	10.56%	11.01%	11.08%	9.28%
	6	8.41%	10.29%	10.49%	11.23%	11.09%	9.58%	10.67%	12.01%	10.47%
	7	7.66%	9.97%	9.97%	10.23%	10.54%	11.06%	10.82%	11.26%	10.77%
	8	7.57%	10.19%	9.78%	10.52%	11.03%	10.71%	9.95%	10.27%	11.09%
	9	8.49%	11.08%	11.09%	9.87%	10.61%	9.90%	10.23%	9.94%	10.27%

Table 4: Diebold-Mariano Statistic for difference in the RMSE measure of DSGE versus other models

Vbles	h	DSGE	BVAR(1)	BVAR(2)	BVAR(3)	BVAR(4)	VAR(1)	VAR(2)	VAR(3)	RW
y	1	-23.32	7.84	-17.27	-12.84	9.85	-11.38	7.85	-12.54	-20.51
	2	-33.56	-15.76	-14.75	-17.58	-33.58	8.76	-19.20	10.09	-7.77
	3	1.87	10.73	9.57	7.87	4.80	-11.71	-21.38	10.18	10.13
	4	12.98	-4.91	-22.31	-20.98	-13.90	-15.75	9.91	-6.77	-1.98
	5	8.63	5.80	7.78	10.01	8.67	10.34	-18.25	-5.48	8.67
	6	15.23	2.89	-12.88	2.87	-15.27	-11.78	7.63	9.85	-15.02
	7	12.27	-18.42	8.95	-11.89	10.38	-12.54	-7.89	18.96	5.22
	8	11.56	10.19	4.59	9.63	5.72	-17.58	10.76	-18.34	-12.89
	9	18.12	-17.53	-23.52	8.55	-19.81	-2.63	10.13	-19.77	-1.87

pi	1	-9.72	10.58	9.39	7.42	10.62	3.17	7.53	9.78	-8.51
	2	-10.03	9.53	7.57	9.54	11.51	5.69	8.65	7.52	5.36
	3	0.78	4.88	2.68	10.83	8.10	10.02	10.08	5.88	10.29
	4	8.92	5.93	9.90	2.99	11.07	2.98	6.29	0.91	6.90
	5	6.60	8.67	7.78	8.61	5.27	11.03	3.37	4.35	8.77
	6	-0.29	10.28	6.37	10.22	7.61	5.75	8.51	-1.29	7.18
	7	5.29	3.29	7.77	5.27	7.76	9.34	5.22	7.78	5.39
	8	8.79	11.01	9.16	4.51	9.45	2.67	8.34	10.02	3.44
	9	1.34	6.89	8.73	3.28	10.03	6.58	1.47	5.72	-6.10
pif	1	7.02	12.19	10.82	6.33	10.78	-2.27	9.37	-3.17	-8.58
	2	4.55	5.36	6.16	10.67	4.59	-12.03	7.56	2.39	-7.87
	3	2.89	3.47	5.37	1.88	7.36	10.07	9.87	-1.70	-7.36
	4	6.90	8.91	9.28	5.19	-4.29	-1.96	10.27	-5.80	-7.50
	5	9.33	10.60	10.73	8.27	8.10	4.69	8.66	2.67	-7.13
	6	-1.78	9.37	9.29	9.45	4.74	-7.20	8.56	5.43	-8.57
	7	3.25	5.27	5.77	2.48	6.32	5.87	8.33	-3.29	-8.72
	8	10.17	8.55	8.59	8.28	7.47	8.13	-1.79	5.78	-6.59
	9	1.02	5.77	5.52	-0.11	7.63	10.01	8.18	4.29	-7.77
i	1	-33.82	-45.58	-25.47	-19.29	-22.71	19.57	-55.58	-43.51	63.52
	2	1.86	10.89	13.74	17.29	12.76	20.82	17.35	24.22	24.84
	3	-37.77	-17.39	10.88	-21.55	13.74	-37.76	-45.18	31.88	53.88
	4	-12.92	20.54	1.57	10.32	-5.94	-20.96	12.97	-19.91	38.45
	5	-25.84	8.67	10.62	-15.63	12.11	8.74	20.30	10.29	28.64
	6	-25.55	-14.98	-17.52	15.78	20.90	-27.72	9.78	15.27	56.80
	7	5.67	15.58	5.98	14.57	17.32	18.27	15.48	3.57	60.37
	8	-18.27	20.76	1.52	10.71	20.66	-37.28	-24.37	21.30	29.83
	9	5.79	14.54	11.84	21.37	8.89	13.84	10.79	12.58	37.18

e	1	-0.38	1.16	-0.81	-1.08	1.02	-0.40	-1.12	0.31	0.39
	2	-1.16	-0.53	-1.24	0.75	1.09	-1.08	-0.78	0.91	-1.06
	3	0.82	1.11	1.05	-1.03	0.98	0.97	1.08	-1.81	0.87
	4	-1.12	-0.58	-1.13	-0.78	-1.04	-0.99	-0.75	-0.85	-1.98
	5	0.71	1.09	0.62	1.12	1.03	0.71	1.08	1.02	0.63
	6	-1.09	-1.07	-1.20	-0.94	-0.29	-1.83	-0.56	0.35	-1.23
	7	0.78	1.03	1.21	-1.32	0.85	0.93	1.17	1.01	1.07
	8	1.07	0.82	0.81	1.17	1.13	1.06	0.83	0.63	0.56
	9	-1.13	-1.19	-0.15	-0.18	-1.19	-1.05	-1.32	-0.78	-0.72

Conclusion

Une des questions à laquelle nous nous sommes intéressés dans cette thèse était celle des fluctuations macroéconomiques au Cameroun. Pour répondre à cette question, nous avons mis sur pied un cadre d'évaluation quantitative à travers un modèle dynamique d'équilibre général stochastique (DSGE) pour le Cameroun. L'idée de base étant que, pour bien comprendre les fluctuations économiques dans un pays, il est nécessaire d'avoir un outil avec une meilleure spécification de l'économie de ce pays. En adoptant ce cadre d'analyse, nous nous sommes distingués de la pratique habituelle qui fait plus appel aux modèles VAR pour de telles études.

Les différents résultats de ce travail peuvent être présentés comme suit: dans le chapitre 1, nous avons proposé une première tentative de description des cycles économiques du Cameroun. Pour ce faire, un large éventail de régularités dans les fluctuations macroéconomiques au Cameroun est documenté. Cela a été fait en tenant compte de trois dimensions principales de fluctuations macroéconomiques: la volatilité du PIB comme un indicateur de la sensibilité de l'économie aux chocs exogènes ainsi que des sources endogènes d'instabilité, les co-mouvements des variables d'intérêt qui mettent en lumière la mesure avec laquelle les fluctuations observées ont trait à d'autres agrégats macroéconomiques, et la persistance de certains phénomènes. Cette analyse s'est appuyée sur trois outils statistiques de base couramment utilisées dans la littérature empirique des cycles économiques. Ce sont l'écart-type comme mesure de la volatilité, les corrélations croisées en tant que moyen d'analyse des co-mouvements, et l'auto-corrélation en tant que mesure de la persistance. Ces analyses sont pour nous une contribution à l'analyse des cycles des affaires au Cameroun. Elles sont aussi utiles dans la conception du modèle DSGE qui est discuté dans cette thèse. Par exemple, la persistance significative des prix et des salaires nominaux a permis deplaider pour l'hypothèse de rigidité nominale des prix et des salaires dans le modèle. La décomposition de la volatilité du PIB a montré que la part de la production minérale (PIB minéral) dans le PIB global était l'agrégat le plus instable, suivi du PIB global, le PIB non-minéral étant le moins volatile. Dès lors que les produits minéraux ont été considérés comme des produits de base dont la totalité de la production est vouée à l'exportation, leur instabilité a été modélisée dans notre modèle en introduisant des chocs exogènes dans leur fonction de production, et par l'introduction de chocs des prix des produits de base sur le marché international où ils sont vendus. De plus une forte corrélation entre les prix du pétrole avec le PIB nous a également permis de tenir compte de la vulnérabilité de cette économie aux chocs sur les prix mondiaux du pétrole.

C'est seulement dans le chapitre 2 que nous avons conçu un modèle DSGE décrivant la dynamique économique du Cameroun. En l'absence d'un tel modèle pour l'économie camerounaise dans la littérature, nous avons adapté celui de Smets et Wouters (2007) qui est aujourd'hui considéré comme un modèle de référence dans la modélisation DSGE aussi bien pour les économies développées que les économies sous-développées. Notons que la génération actuelle des modèles dynamiques stochastiques d'équilibre général de type néo-keynésien intègre certaines caractéristiques structurelles dont nous avons pensé qu'il était nécessaire qu'elles soient prises en compte dans notre travail. Le modèle intégrait par exemple des frictions financières qui entravent le financement des investissements et amplifient l'effet des fluctuations des taux d'intérêt et des taux de change sur les valeurs réelles de la richesse nette de l'emprunteur et les bilans de l'équilibre macroéconomique. Le modèle intégrait également le canal de transmission de taux de change dès lors que la vitesse avec laquelle les chocs des taux de change atteignant le niveau des prix domestiques semble être plus élevée dans les économies en développement que dans le monde industriel. Bien que ces deux caractéristiques ne soient pas spécifiques aux économies en développement, nous pensons qu'elles sont tout de même importantes dans le contexte du Cameroun. Le modèle que nous avons proposé tenait également compte d'autres caractéristiques supplémentaires de l'économie Camerounaise, en particulier celles liées aux faits persistants à savoir par exemple: une formation des habitudes de consommation, un coût d'ajustement des investissements, la rigidité des prix et des salaires, etc.. Le modèle tenait compte également de quatre groupes distincts de chocs. Le premier groupe contient les chocs d'offre nationaux, y compris les chocs de productivité, des chocs de production des produits de base, les chocs de coûts d'ajustement de l'investissement, et les chocs de l'offre de travail. Le deuxième groupe comprend les chocs domestiques sur la demande, tels que les chocs sur les préférences des ménages et les chocs de dépenses gouvernementales. Le troisième groupe comprend seulement le choc de politique monétaire. Le quatrième groupe, enfin, comprend les chocs qui sont associés à des facteurs externes (chocs cours des matières premières, chocs des prix internationaux du pétrole, chocs de demande étrangère, chocs des taux d'intérêts étrangers, chocs de taux d'inflation étranger, et des chocs des prix des produits importés). Dans l'ensemble, l'économie camerounaise est décrite par un ensemble de 54 équations qui expliquent le comportement des ménages, le comportement des entreprises, le comportement du gouvernement, et le comportement de la banque centrale.

Pour que le modèle conçu dans le chapitre 2 puisse être utilisé aux fins d'évaluation des politiques économiques et de prévisions macroéconomiques, nous avons utilisé les données macroéconomiques Camerounaise afin de l'estimer. Cela a nécessité un traitement empirique en 2 étapes. Un premier groupe de paramètres faiblement identifiés qui caractérisent l'état d'équilibre du modèle ont été calibrés. Cette calibration reposait sur un ensemble des valeurs des paramètres compatibles avec les propriétés de long-terme de l'économie du Cameroun et les ratios caractéristiques de l'état d'équilibre. Un deuxième groupe de paramètres qui ne sont pas calibrés ont été inférés en estimant le modèle DSGE linéarisé selon une approche bayésienne. Dans l'ensemble, les chocs exogènes et les paramètres structurels liés à ces chocs ont des estimations significativement différentes de zéro. La persistance de différents chocs ainsi introduits dans ce modèle a permis de conclure que l'économie camerounaise est confrontée à des chocs exogènes d'importantes amplitudes que celles habituellement trouvées dans les économies avancées. De plus, notre modèle considère explicitement le rôle des anticipations des agents dans le modèle. Ces attentes sont importantes car le manque d'un élément de prospection réduit considérablement la capacité du modèle à fournir une description crédible de l'économie, ce qui est une chose précieuse pour les décideurs publics. Parce quenos données suggèrent que les anticipations d'inflation au Cameroun sont rétrospectives plutôt que des anticipations prospectives, cela implique que les agents économiques au Cameroun ont tendance à avoir un regard plutôt tourné vers le passé que vers l'avenir dans la formation de leurs attentes concernant l'inflation. Ainsi, la persistance d'inflation élevée au Cameroun signifie que le taux d'inflation actuel est fortement influencé par le taux d'inflation de la période précédente et non par le taux d'inflation attendu.

Le quatrième chapitre était plus destiné à une application du modèle développé dans le chapitre 2 et estimé dans le chapitre 3. Nous avons commencé dans un premier temps par l'évaluation de la performance des prévisions de ce dernier. Trois modèles concurrents ont été utilisés: le modèle VAR, le modèle BVAR, et les modèles RW. Le test de Mincer et Zarnowitz (1969) a été utilisé pour tester l'efficacité de la prévision alors que le test de Diebold et Mariano (1995) a été utilisé pour voir quel modèle entre le modèle DSGE et ses rivaux a la meilleure performance de prévision. Les résultats trouvés indiquent que notre modèle DSGE génère les meilleures prévisions, en particulier pour les horizons de court terme et que ces prévisions sont en concurrence avec ses rivaux sur des horizons de long terme.

L'analyse des fonctions de réponse d'impulsion nous a permis d'analyser les propriétés dynamiques de l'économie du Cameroun. Certains de nos résultats vaillent peut-être la peine d'être mentionnés. Par exemple, les chocs des prix des matières premières génèrent une expansion de la production, une augmentation de l'emploi et une baisse de l'inflation. Ce dernier effet est expliqué par l'appréciation de la monnaie, ce qui réduit l'inflation importée et rend les biens d'équipement moins chers d'une part et réduisant ainsi la pression par la dynamique de l'emploi et l'augmentation des salaires réels sur le coût marginal du facteur travail. Les chocs des prix du pétrole ont un impact direct sur le coût marginal de production des entreprises qui augmente et provoque une augmentation de l'inflation alors que la production et l'emploi sont en baisse. Que le choc des prix du pétrole génère une appréciation réelle de la monnaie, ce qui serait dû au rôle que joue le pétrole dans le processus de production. Aussi un choc sur les prix du pétrole pousse l'autorité monétaire qu'est la banque centrale à relever le taux d'intérêt afin d'atténuer l'effet de l'inflation, ce qui conduit à une appréciation du franc CFA découlant de l'afflux de capitaux et de baisse de la production. Fait intéressant toutefois, toutes les variables retournent à leurs valeurs d'équilibre lorsque le choc des prix du pétrole disparaît. Un autre effet important de la flambée des prix du pétrole est une appréciation du taux de change réel, qui a tendance à pousser vers le bas le taux d'inflation.

Les décompositions de la variance de l'erreur de prévision ont également mis en évidence des résultats intéressants. Par exemple, les chocs étrangers et les chocs de l'offre domestique semblent représenter une grande part des fluctuations de la production et des fluctuations de l'investissement. Les conditions monétaires domestiques relativement serrées ont contribué à limiter les pressions inflationnistes découlant d'autres chocs. Les facteurs extérieurs semblaient également soutenir les grands sauts auxquels sont exposés le taux de change réel et le compte courant, même si les conditions monétaires peuvent expliquer une partie de l'ajustement retardé du taux de change en temps de crise.

Finalement, les décompositions historiques nous ont fourni des informations sur l'importance relative de chaque choc affectant les principales variables endogènes. Nos résultats suggèrent que l'évolution de la production sur l'ensemble de l'échantillon est principalement dominée par le choc des prix des produits de base et les chocs des prix du pétrole, comme on pouvait s'y attendre. Les chocs d'investissement expliquent également une part importante des fluctuations de la croissance de la production dans l'échantillon, bien que ce type de choc ne présente pas une tendance claire. Le modèle identifie également un choc négatif sur le prix relatif des biens importés (une baisse relative de ce prix) à la fin des années 90.

Pour résumer, la valeur ajoutée de cette thèse peut être résumée sous trois angles principaux. Premièrement, cette thèse propose ce qui semble être la première analyse empirique systématique de la dynamique économique du Cameroun. En effet, même dans les très peu d'études consacrées à l'étude des cycles économiques dans les pays en développement (Agénor, 2000; Rand et Tarp, 2002; Homme, 2010), le Cameroun n'a pas été un sujet d'enquête. Deuxièmement, la thèse exploite les données macro-économiques camerounaises et estime un modèle DSGE, un outil que rares sont les institutions de politique économique en Afrique sub-saharienne qui en ont à leur disposition. Ceci, nous le croyons, peut être une contribution importante d'autant que les pays en développement ont évidemment besoin d'outils efficaces de politique économique pour lutter contre la pauvreté ainsi que la variété des spécificités économiques qui rendent les économies des pays africains plus fragiles et plus sensibles aux chocs extérieurs que tout autre secteur économique. Troisièmement, le modèle qui est estimé n'est pas une simple reproduction de modèles existants, conçus pour le monde développé. Nous avons déployé le meilleur de nos efforts pour veiller à ce que le modèle soit une description fiable de l'économie camerounaise et n'avons eu de cesse de veiller à ce que les caractéristiques les plus importantes de l'économie camerounaises soient, autant que faire se peut, prises en compte.

Nous avons rencontré cependant un certain nombre de problèmes dont une partie a pu être surmontée tandis que l'autre est laissée pour des recherches futures.

D'un point de vue méthodologique, nous pouvons citer les lacunes liées à l'utilisation des données annuelles et que la disponibilité de données trimestrielles nous aurait évités. Tout d'abord, un échantillon de données annuelles est évidemment plus petit. Cela peut affaiblir l'efficacité des résultats ainsi que leur contenu informatif, surtout quand il repose sur la dynamique de court-terme. Si nous avons tenu à comparer chacun de nos résultats trouvés dans le chapitre 1 à ceux rapportés dans la littérature pour d'autres pays en développement, de telles comparaisons ne sont évidemment pas de nature à améliorer la précision de nos estimations, mais elles ont permis de réconforter notre confiance en ces résultats dans le sens où aucun d'eux n'a contredit les principales conclusions existant dans la littérature.

Peut-être, cependant, la principale limite de notre modèle et donc des résultats de cette recherche, est liée à un certain nombre de caractéristiques cruciales de l'économie camerounaise que nous n'avons pas pu prendre en compte. Une telle caractéristique qui se rapporte au dualisme économique, se réfère à la partition d'une même économie en deux secteurs: un secteur formel et un secteur informel. Dans la littérature, Ahmad et al. (2012) ont construit un modèle DSGE d'une économie fermée pour le Pakistan où ils tiennent compte du secteur informel dans les marchés du travail et des biens. Dans un cadre similaire, Gabriel et. al. (2010) ont construit un modèle DSGE de type neo-keynésien pour une économie fermée de l'Inde. Zenou (2007) a développé un modèle d'équilibre général à deux secteurs pour étudier la mobilité de la main-d'œuvre entre les secteurs formels et informels du marché de travail en vertu de politiques du marché du travail différentes. Dans la conception de son modèle, le marché du travail dans le secteur formel se caractérise par des frictions liées à la recherche du travail tandis que le marché du travail dans le secteur informel se caractérise par une concurrence parfaite. Antunes et Cavalcanti (2007) étudient l'impact des coûts de la réglementation et de l'exécution des contrats financiers sur la taille de l'économie informelle et le PIB par habitant en utilisant un modèle DSGE d'une petite économie ouverte. Koreshkova (2006) a étudié les conséquences de l'imposition du secteur informel pour le financement du budget qui affecte finalement l'inflation. Conesa et. al. (2002) explique la relation négative entre le taux de participation au marché de travail et les fluctuations du PIB observées dans les données croisées d'un panel de pays avec l'existence du secteur informel. A travers l'utilisation d'un modèle dynamique d'équilibre général incorporant un secteur informel dans les marchés du travail et le marché des biens, l'étude montre que les agents passent d'un secteur à l'autre lors des chocs de productivité. Les modèles considérés dans cette littérature sont en général des petits modèles théoriques dont l'objectif est de mettre en évidence les phénomènes économiques parmi lesquels la prise en compte de l'existence d'un secteur informel. Enfin une autre façon de prendre en compte le secteur informel dans les travaux futures serait de considérer deux catégories de biens échangeable et non échangeable (voir Defonkou N., 2012) en faisant l'hypothèse que les biens échangeable sont le fait du secteur informel. Notre valeur ajoutée à la littérature sur la modélisation DSGE serait donc réelle si, dans un avenir proche, nous parvenions à enrichir le modèle proposé dans cette thèse de cette dimension inhérente aux économies en développement et si les données appropriées pour estimer un tel modèle étendu se trouvaient disponibles.

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Résumé

Cette thèse propose une analyse de la dynamique macroéconomique de l'économie camerounaise. On commence par une analyse quantitative générale du cycle des affaires au Cameroun, fondée sur des données macroéconomiques annuelles que nous avons nous-mêmes assemblées. Cette première exploration laisse apparaître un certain nombre de caractéristiques qui se prêtent bien à une modélisation de type néo-keynesien. Nous construisons alors un modèle dynamique stochastique d'équilibre général (DSGE) de l'économie camerounaise. Ce modèle comporte les blocs de construction de modèles DSGE néo-keynésiens standards (par exemple, la rigidité des prix et des salaires des rigidités, et des coûts d'ajustement), mais il inclut également un certain nombre de caractéristiques spécifiques (telles que l'exportation des matières premières et les revenus du pétrole entre autre) dont on montre qu'elles jouent un rôle important dans la dynamique de l'économie camerounaise. Le modèle est estimé et évalué selon une approche bayésienne. La performance du modèle DSGE en termes de prévision est comparée à celle d'un modèle de marche aléatoire, à celle d'un modèle vectoriel auto-régressif (VAR) et, enfin, à celle d'un modèle vectoriel auto-régressif de type Bayesien (BVAR). Nous trouvons que, le modèle DSGE est plus précis en matière de prévision au moins dans un horizon de court-terme. Pour ce qui est des fluctuations macroéconomiques, les chocs des prix des produits de base génèrent une expansion de la production, une augmentation de l'emploi et une baisse de l'inflation tandis que des chocs liés aux prix du pétrole ont un impact direct sur le coût marginal de production qui augmente et provoque une augmentation de l'inflation en même temps que production et emploi baissent. Notons que, les chocs extérieurs et les chocs d'offre domestiques représentent une grande part des fluctuations de la production et de l'investissement. Aussi, l'évolution de la production sur l'ensemble de l'échantillon est dominée par le choc de prix des matières premières et le choc des prix du pétrole.

Mots clés: Modèles DSGE, néo-keynésien, Méthode bayésienne, Fluctuations Macroéconomiques, Prévisions, Cameroun

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Abstract

This thesis aims at analyzing the macroeconomic dynamics of the Cameroonian economy. It begins with a quantitative analysis of the business cycle in Cameroon, based on annual macroeconomic data, especially gathered for this purpose. This preliminary inquiry highlights a number of features that can be accounted for in a new-keynesian modelling framework. A dynamic stochastic general equilibrium (DSGE) model of the new-keynesian family is thus constructed as a mean of describing the salient features of the Cameroonian economy. It has the traditional blocks of new-keynesian DSGE models (Sticky prices and wages, adjustment costs, etc.). But it also accounts for a number of characteristics of the Cameroonian economy that are shown to be influential in the dynamics of the Cameroonian economy (e.g. oil revenues or primary goods exports). The model is then estimated and evaluated, based on a Bayesian approach. Its forecasting performance is also assessed through comparison to the performances of a random walk model, a vector autoregressive (VAR) model and a Bayesian VAR (BVAR) model. It turns out that, at least for short horizons, the DSGE model shows the highest performance. As to macroeconomic fluctuations, the estimated model suggests that commodity price shocks generate an output expansion, an increase in employment and a fall in inflation. In addition, oil price shocks have a direct impact on marginal costs which increase and provoke a rising in inflation while output and employment tend to fall. Foreign shocks and domestic supply shocks account for a large share of output and investment fluctuations. The evolution of output over the whole sample is dominated by commodity price shocks and oil price shocks as one would expect.

Keywords: DSGE Models, New-Keynesian, Bayesian Method, Macroeconomic Fluctuations, Forecasting, Cameroon