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INTERNATIONALES

No 2009 – 07
April

DOCUMENT DE TRAVAIL

# Term of Trade Shocks in a Monetary Union: An Application to West-Africa

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Benjamin Carton and Gilles Dufrénot

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# TERM OF TRADE SHOCKS IN A MONETARY UNION: AN APPLICATION TO WEST-AFRICA

## NON-TECHNICAL SUMMARY

Monetary regimes in West Africa are divided in two groups of countries that almost match a linguistic divide. On the one hand, French-speaking countries of the West African Monetary Union (WAEMU) are in a monetary union, and their currency, the West-African CFA franc, is pegged on the euro. On the other hand, English-speaking countries have independent currencies with mostly managed floating exchange-rate regimes. Still, both group of countries are part of the Economic Community of West-African States (ECOWAS) grouping, a free trade area.

Since 1993, monetary union has been an objective of ECOWAS. In 2000, an impetus was given to this project through the creation of the West-African Monetary Zone, which groups together five of the non-WAEMU members of ECOWAS (The Gambia, Ghana, Guinea, Nigeria and Sierra Leone). The intention was to proceed to monetary union within this sub-group by 2003, and then organize monetary union with WAEMU. However, the first step of this plan was several times re-scheduled due to insufficient progress in terms of convergence. In June 2007, a 'single-track' approach was adopted to proceed to monetary union directly at the ECOWAS level in 2012. The pros and cons of monetary integration in West Africa has been extensively discussed in the literature. The inclusion of a very large, oil-exporting country (Nigeria) in the project has especially been shown as a serious handicap.

In this paper, contrasting with the previous literature, we assume that the project goes through, and we discuss the monetary regime to be chosen by the future, ECOWAS monetary union. More specifically, we study how the monetary union can deal with asymmetric commodity-price shocks: oil-price shocks in Nigeria that may spill over other members of the union; and non-oil commodity-price shocks that the single central bank may have more difficulties to tackle given the weight of Nigeria, whose non-oil exports are a minor share of the economy.

We simulate, in a two-countries DSGE model representing WAEMU and Nigeria, the impact of oil-price and other commodity-price shocks under three monetary regimes, successively: (i) a flexible exchange-rate with fixed money supply, (ii) a flexible exchange rate with accommodating monetary policy (where export receipts are monetized), and (iii) a fixed exchange-rate regime with unsterilized official interventions. We also study the implication of having an oil stabilization fund in Nigeria.

We find that an increase in the oil price has a positive impact on Nigerian consumption, although this economy suffers from a Dutch disease (a fall in the production of non-oil commodities exports) that can hardly be erased by appropriate monetary regime in a monetary union. Absent a stabilization fund, a flexible exchange rate with exogenous money supply (at the union level) produces the lowest level of volatility in consumption, whereas a fixed exchange rate leads to the highest volatility.

Conversely, the fixed money-supply regime produces the highest volatility of consumption in WAEMU in the face of oil-price shocks, whereas a fixed exchange-rate regime isolates the economy from the

shock. However the two economies can agree on a fixed money-supply regime if they are hit by both oil- and agricultural-price shocks (we take the case of cocoa beans, that count for a large share of agricultural exports of both WEMU and Nigeria).

Finally, we find that an oil-stabilization fund can be very successful in stabilizing both economies and reduce their possible disagreements on the common monetary policy.

We conclude that, in the presence of a well-functioning oil stabilization fund, the fixed money supply regime (with a flexible exchange rate) seems to be the best for both economies. However, should the stabilization fund not play its role in allowing financially-constrained households to smooth their consumption inter-temporally, a disagreement may arise between the two economies on the conduct of monetary policy.

**ABSTRACT**

We propose a two-country DSGE model of the Dutch disease in a monetary union, calibrated on Nigeria and WAEMU. Three monetary regimes are successively studied at the union level: a flexible exchange rate with constant money supply, a flexible exchange rate with an accommodating monetary policy, and a fixed exchange rate regime. We find that, in the face of oil shocks, the most stabilizing regime for Nigeria is a fixed money supply whereas it is a fixed exchange rate for WAEMU. However, the introduction of an oil stabilization fund can reduce the disagreement on the common policy rule. Furthermore, the two zones may agree on a fixed money-supply rule in the face of both oil and agricultural price shocks.

*JEL Classification*: E52, F41, Q33.

*Keywords*: Dutch disease, DSGE, Monetary union, Optimal monetary policy.

## CHOCS DES TERMES DE L'ÉCHANGE EN UNION MONÉTAIRE : UNE APPLICATION À L'AFRIQUE DE L'OUEST

### RÉSUME NON TECHNIQUE

Les régimes monétaires des pays de l'Afrique de l'Ouest se répartissent en deux groupes correspondant, à peu de choses près, à leur division linguistique. D'un côté, les pays francophones, rassemblés dans l'Union économique et monétaire ouest-africaine (UEMOA), ont hérité d'une monnaie unique, le franc CFA d'Afrique de l'Ouest, qui est en change fixe vis-à-vis de l'euro. De l'autre, les pays anglophones ont des monnaies indépendantes, la plupart en régime de flottement administré. Néanmoins, les deux groupes de pays font partie d'une zone de libre-échange, la Communauté économique des États d'Afrique de l'Ouest (CEDEAO).

Depuis 1993, l'union monétaire est un objectif de la CEDEAO. En 2000, ce projet a été relancé par la création de la Zone monétaire ouest-africaine qui regroupe cinq pays de la CEDEAO qui ne font pas partie de l'UEMOA (Gambie, Ghana, Guinée, Nigeria et Sierra Leone). Le projet était alors de créer une union monétaire au sein de ces pays dès 2003, avant d'envisager à terme la fusion avec l'UEMOA ; mais cette union monétaire fut à plusieurs reprises ajournée en raison d'une insuffisante convergence des économies. Dès lors, il fut décidé en juin 2007 de créer directement l'union monétaire de l'ensemble des pays de la CEDEAO à l'horizon 2012 (approche 'single-track').

Les avantages et inconvénients d'une intégration monétaire en Afrique de l'Ouest ont été abondamment discutés dans la littérature. En particulier, la participation d'un grand pays exportateur de pétrole comme le Nigéria est apparue comme un risque important.

Notre travail suppose que le projet d'union monétaire aboutit et discute le régime monétaire qui pourrait être adopté par cette union. Plus précisément, nous étudions comment la politique monétaire peut répondre aux chocs asymétriques liés à la volatilité des prix mondiaux. Ainsi, la volatilité du prix du pétrole qui affecte le Nigeria pourrait aussi toucher les autres pays de la région via la politique monétaire commune. A l'inverse, la volatilité des prix agricoles, qui touche plus particulièrement les pays de l'UEMOA, pourrait s'avérer plus déstabilisante pour ces pays en union monétaire avec une banque centrale tenant compte également du Nigéria.

Nous simulons dans un modèle DSGE à deux pays, représantant respectivement l'UEMOA et le Nigéria, l'impact d'un choc de prix du pétrole et d'un choc de prix agricole successivement sous trois régimes monétaires : (1) un taux de change flexible avec offre de monnaie exogène ; (2) un taux de change flexible avec politique monétaire accommodante (où les recettes d'exportation sont monétisées) ; et (3) un régime de change fixe avec interventions officielles non stérilisées. Enfin, nous analysons le rôle d'un fonds de stabilisation au Nigeria.

Nous trouvons qu'une hausse du prix du pétrole a un impact positif sur la consommation au Nigeria, même si cela s'accompagne d'un syndrome hollandais (baisse de la production agricole d'exportation) qu'il est difficile de combattre en union monétaire. En l'absence de fonds de stabilisation, le régime le

plus stabilisant pour le Nigeria est un taux de change flexible avec offre de monnaie exogène (au niveau de l'union), alors que le régime de change fixe est le plus déstabilisant.

Au contraire, le régime le plus stabilisant pour l'UEMOA est le régime de change flexible avec offre de monnaie exogène, tandis que le change fixe immunise presque l'économie des chocs pétroliers. Cependant, les deux économies peuvent s'entendre sur un régime d'offre de monnaie exogène face à des chocs à la fois de prix du pétrole et de prix agricoles (nous prenons le cas des fèves de cacao, lesquelles représentent une part très importante des exportations non pétrolières des deux économies).

Enfin, nous montrons qu'un fonds de stabilisation au Nigeria peut être très efficace pour stabiliser les deux économies face aux fluctuations des prix du pétrole, et ainsi limiter leurs divergences d'intérêts quant au régime monétaire.

Ainsi, avec un fonds de stabilisation bien géré au Nigeria, un régime de change flexible avec offre de monnaie exogène pourrait être la meilleure option en union monétaire. Cependant, une défaillance de ce fonds pour permettre le lissage inter-temporel de la consommation pourrait déclencher des conflits sur la manière de gérer la monnaie unique.

**RÉSUMÉ COURT**

Nous présentons un modèle DSGE à deux pays avec maladie hollandaise en union monétaire, calibré sur le Nigeria et l'UEMOA. Nous comparons trois régimes pour cette union monétaire : un taux de change flexible avec offre de monnaie exogène, un taux de change fixe avec politique monétaire accommodante, et un régime de change fixe. Face aux fluctuations du prix du pétrole, nous trouvons que le premier régime est le plus stabilisant pour le Nigeria tandis que c'est le dernier qui convient le mieux à l'UEMOA. Cependant, l'introduction d'un fonds de stabilisation au Nigeria est de nature à atténuer ce différent monétaire. En outre, les deux économies peuvent s'entendre sur une règle d'offre de monnaie exogène si l'union fait face à une volatilité non seulement du prix du pétrole, mais aussi des produits agricoles.

*Classification JEL* : E52, F41, Q33.

*Mots clés* : Maladie hollandaise, DSGE, Union monétaire, Politique monétaire optimale.

# TERM OF TRADE SHOCKS IN A MONETARY UNION: AN APPLICATION TO WEST-AFRICA[1]

Loïc Batté*, Agnès Bénassy-Quéré†, Benjamin Carton‡, Gilles Dufrénot§

## 1. INTRODUCTION

Monetary regimes in West Africa are divided in two groups of countries that almost match a linguistic divide. On the one hand, French-speaking countries of the West African Monetary Union (WAEMU) are in a monetary union, and their currency, the West-African CFA franc, is pegged on the euro.[2] On the other hand, English-speaking countries have independent currencies with mostly managed floating exchange-rate regimes.[3] Still, both group of countries are part of the Economic Community of West-African States (ECOWAS) grouping, a free trade area (see Figure 1).

Since 1993, monetary union has been an objective of ECOWAS. In 2000, an impetus was given to this project through the creation of the West-African Monetary Zone, which groups together five of the non-WAEMU members of ECOWAS (The Gambia, Ghana, Guinea, Nigeria and Sierra Leone). The intention was to proceed to monetary union within this sub-group by 2003, and then organize monetary union with WAEMU. However, the first step of this plan was several times re-scheduled due to insufficient progress in terms of convergence. In June 2007, a 'single-track' approach was adopted to proceed to monetary union directly at the ECOWAS level in 2012.

The pros and cons of monetary integration in West Africa has been extensively discussed in the literature. The inclusion of a very large, oil-exporting country (Nigeria) in the project has especially been shown as a serious handicap.[4]

In this paper, contrasting with the previous literature, we assume that the project goes through and we discuss the monetary regime to be chosen by the future ECOWAS monetary union. More specifically, we study how the monetary union can deal with asymmetric commodity-

[1]We are grateful from Marc Lanteri and the participants in seminars at Banque de France (Paris) and CERDI (Clermont-Ferrand) for helpful remarks on a preliminary draft of this paper. All errors remains all.
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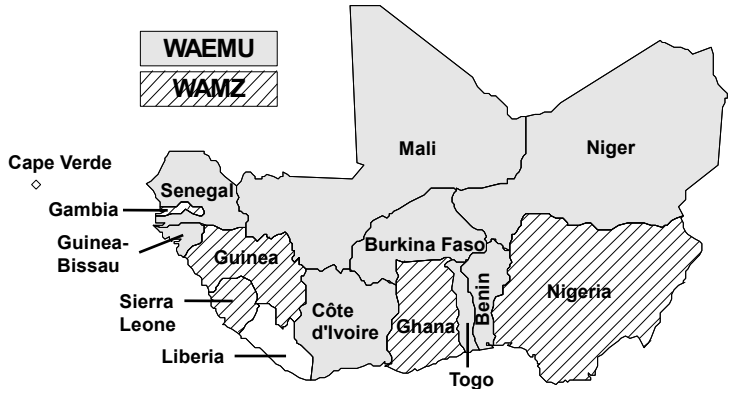
[2]WAEMU includes Bénin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Mali, Niger, Sénégal, Togo.
[3]Sierra Leone is pegged on the dollar and Cape Verde on the euro.
[4]See Masson & Pattillo (2001) and Bénassy-Quéré & Coupet (2005).

**Figure 1 – ECOWAS countries**




ECOWAS:
Economic Community of West-African States

WAEMU:
West-African Economic and Monetary Union

WAMZ:
West-African Monetary Zone

price shocks: oil-price shocks in Nigeria that may spill over other members of the union; and non-oil commodity-price shocks that the single central bank may have more difficulties to tackle given the weight of Nigeria, whose non-oil exports are a minor share of the economy.

To our knowledge, the question of how to tackle commodity-price volatility in a monetary union has not been studied yet in the literature. Indeed, existing models of the Dutch disease concentrate on the single-country case. This is not surprising since large, specialized oil and gas producers (Saudi Arabia, Russia, Norway, Venezuela...) have so far retained independent currencies. Only countries of the CAEMC (Central African Economic and Monetary Community) have experienced the difficulty in mixing together heavy oil-exporting countries (Gabon, Equatorial Guinea, Congo) with non-oil exporting ones (Central African Republic).

We construct a stylized, two-country model that extends the single-country Dutch disease models proposed in the literature (Collier & Gunning, 2005; Adam & Goderis, 2008; Adam et al., 2006; Sosunov & Zamulin, 2007). Specifically, we propose a dynamic stochastic general equilibrium model whereby monetary policy is introduced through a money-supply behavior that is related to the exchange-rate regime, together with some nominal rigidities *à la* Calvo and a proportion of financially-constrained households. The model is calibrated and simulated using the key structural characteristics of Nigeria and WAEMU countries. We then simulate the impact of oil-price and other commodity-price shocks under three monetary regimes, successively: (i) a flexible exchange-rate regime with fixed money supply, (ii) a flexible exchange rate with accommodating money supply (where export receipts are monetized), and (iii) a fixed exchange-rate regime with unsterilized official interventions.[5] For each monetary regime, we study the implications of having an oil-stabilization fund in Nigeria.

We find that, depending on the common monetary regime, WAEMU may react very differently to an oil-price increase: it would benefit from the shock under a flexible exchange rate with

[5]We implicitly make the assumption than WAEMU leaves the CFA franc in regimes (i) and (ii). In the fixed exchange rate regime (iii), the new common currency is pegged to the import invoice currency.

accommodating monetary policy, suffer from it under a fixed money-supply regime and be almost isolated from it in the case of a fixed exchange rate.[6] In contrast, Nigeria would of course benefit from the shock, although it would suffer from a Dutch disease, whatever the monetary regime.

In the face of oil shocks, the two zones would likely disagree on the common monetary regime, because a fixed money-supply regime is more stabilizing in Nigeria whereas a fixed exchange rate is more stabilizing in WAEMU. Introducing an oil-stabilization fund would help solving this disagreement since the fund would tax and save when the oil price, and pay transfers when the oil price is low. In doing so, the stabilization fund would provide consumption smoothing for those consumers that lack access to financial markets. This would be stabilizing for the union's economy.

Finally, we find that both economies would behave similarly, although to different extents, in the face of non-oil commodity shocks, and that they would be best stabilized by a fixed money-supply regime.

We conclude that, in the presence of a well-functioning oil stabilization fund, the fixed money supply regime (with a flexible exchange rate) seems to be the best for both economies. However, should the stabilization fund not play its role in allowing financially-constrained households to smooth their consumption inter-temporally, a disagreement may arise between the two economies.

The rest of the paper is organized as follows. Section 2 provides some basic stylized facts on the Dutch disease in Nigeria during the past oil-price surges. Section 3 presents the model. Section 4 and 5 analyze the impact of an increase in the oil price and in the non-oil commodity price, successively. Section 6 performs sensitivity analysis. Section 7 presents welfare analysis and Section 8 concludes.

## 2. THE DUTCH DISEASE IN NIGERIA AND HOW TO MITIGATE IT

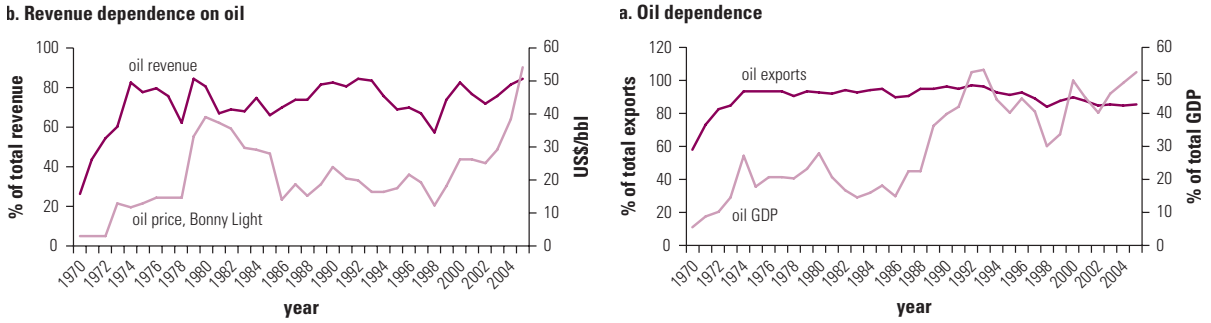
### 2.1. Nigeria and the Dutch disease

The Dutch disease phenomenon was first pointed out by Corden & Neary (1982), Corden (1984) and van Wijnbergen (1984). It happens when a rise in the price of oil (or of whatever commodity) crowds out the non-oil tradable sectors of a resource-abundant country through a real appreciation of the currency that reduces the price competitiveness of non-oil exports. More specifically, the rise in oil-export receipts induces a higher demand for non-oil goods and services. Because the supply of non-tradable is limited (no imports), the price of non-tradable goods increases relative to tradables. Hence, there is a reallocation of production factors away from the non-oil tradable sector toward the oil sector and the non-tradable sector. In practice, the

[6] Here we disregard the negative effect of the oil-price shock in WAEMU through domestic oil consumption in order to focus on the role of monetary policy.

Dutch disease translates into an increase in the share of public spending in aggregate demand, a rise in the fiscal deficit (on a cash basis), a rise in employment, wages and capacity utilization in the non-tradable sector, a fall in price competitiveness in the non-oil exporting sectors, and a real exchange-rate appreciation.

**Figure 2 – Oil Dependency of Nigeria**



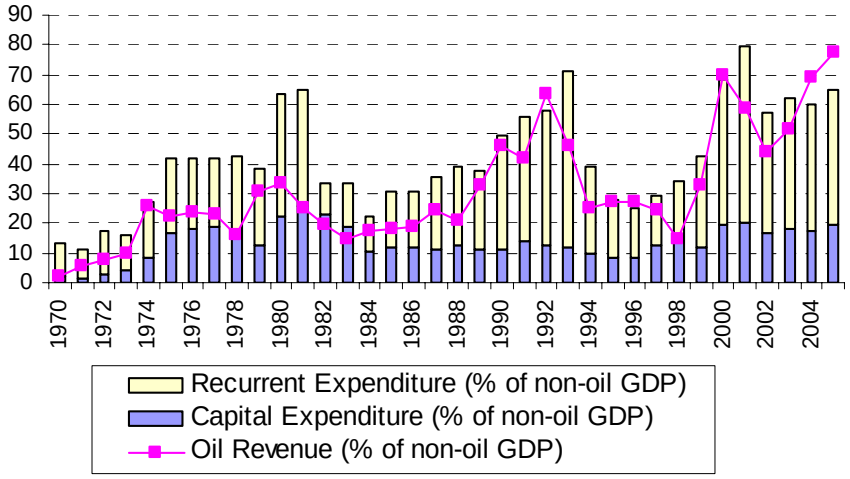

Source : Budina & van Wijnbergen (2008)

Since the 1970's, oil has been a dominant factor in the Nigerian economy, accounting for 90% of the country's exports, representing almost four-fifths of fiscal revenues and amounting to 47% of GDP (see Figure 2). The cumulated oil rent (defined as the returns in excess of production costs) over the last 30 years is estimated USD 231 bn (Ross, 2003). Figure 3 shows that public expenditures in Nigeria have generally absorbed the entire oil windfalls (if not more) since the first oil price shock, in 1974. Furthermore, current expenditures have proved much more cyclical than public investment. Figure 4 illustrates the failure of Nigeria to translate oil-price surges into sustained non-oil growth: the share of agriculture in GDP declined from 70 % in 1965 to 40 % since 1981; that of the manufacturing was never able to significantly exceed 10%; meanwhile, the share of non-tradable sectors (including the government) increased from 20% in 1965 to more than 40% in the 1990s. Finally, Sala-i-Martin & Subramanian (2003), Ayadi (2005) and Adejumo & Olomola (2006) present evidence a positive correlation between the real exchange rate (measured either in terms of official or parallel rate) and the oil price, as predicted by Dutch disease models (though the strength of the relationship is still a matter of discussion).

In recent period of oil-price increase (from 2004 to 2008), a substantial part of the oil revenues were spent, with the (cash) non-oil primary deficit jumping from 30 % of GDP in 2002 to 35 % in 2004 and 40 % in 2005 (van Wijnbergen et al., 2007). Furthermore, the Government accumulated domestic payments arrears, meaning that despite comfortable oil revenues, the true non-oil primary deficit might have been higher than recorded.

Whether Nigeria has truly experienced a Dutch disease during the past oil windfalls is nevertheless debated in the literature (Pinto, 1987; Gelb, 1988; Sala-i-Martin & Subramanian, 2003; van Wijnbergen et al., 2007; Collier et al., 2008). While there is an agreement that Nigeria has been a victim of an oil natural resource curse, opinions are still divided over the origin of the country's impoverishment. Some authors see poor institutional quality stemming from oil

**Figure 3 – Nigeria: Expenditure and oil revenue (% of non oil GDP)**

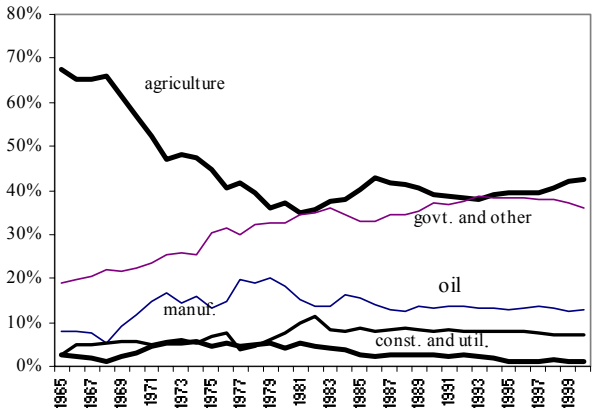



Source : van Wijnbergen et al. (2007)

as the main cause of the poor economic performance (Sala-i-Martin & Subramanian, 2003). Others argue that we cannot distinguish between the Dutch disease and misguided policies, for instance those leading to debt overhang (van Wijnbergen et al., 2007). It is also suggested that the key problem is not that of Dutch disease, but of oil-price volatility (Poelhekke & van der Ploeg, 2007), which is especially detrimental when monetary authorities have an exchange-rate target and try to stabilize inflation (Adam et al., 2006). In fact, the literature, although not discarding the Dutch disease hypothesis, tends to draw the attention on possible 'omitted' factors that could have contributed to the hollowing out of non-oil exports in Nigeria.

It remains that oil-price volatility has proved to be a major source of economic volatility in Nigeria since the early 1970s, which calls for strong stabilization policies.

**Figure 4 – Shares of Sectors in Nigeria's GDP**




Source : Sala-i-Martin & Subramanian (2003)

### 2.2. The role of fiscal and monetary policies in Nigeria

There are several ways to combat the Dutch disease and, more generally, to immunate the economy from oil-price volatility. One is the adoption of **fiscal rules**. Three different fiscal rules are usually envisaged, all of them aiming at smoothing intertemporal consumption. First, a *stabilization fund* can be built up, with funds saved in booming times and drawn out when the oil price decreases. Clearly, a disadvantage is the risk of exhaustion of the fund if the actual price moves down below the benchmark price. A second scheme is to set up a *saving fund* which requires a percentage of oil revenues to be saved in order to compensate resource depletion. The third solution consists in setting up a *financing fund*. The latter rules are referred as 'the Norwegian model' and apprehended as a 'below-the-line' scheme in the sense that, below some threshold price, oil revenues are used to finance non-oil deficits.

In 2004, Nigeria sets up an hybrid of stabilization, saving and financing fund, whereby current spending is based on a medium-term oil price (a moving average of observed prices). The windfall oil revenues in excess of this reference price are saved in an 'excess crude oil account' (ECOE). Savings are used for clearing foreign debt, thereby allowing a reduction in government's global deficit in booming times. For instance, in the context of huge price increases during 2006-2007, the balance of the excess crude account stood at USD 9.64 bn in 2007. The well-functioning of the Nigerian fund relies on credible fiscal actions from the government that refrains from raising public spending when the oil price is rising. In their letter of policy statement at the IMF in 2007, the Nigerian authorities committed to (i) cutting primary expenditure; (ii) increasing in the import content of capital expenditure; (iii) covering fully public spending by medium-run fiscal revenues based on a moving-average of historical oil prices (see IMF (2007)). Additionally, a Fiscal Liquidity Assessment Committee (FLAC) was created, comprising the Central Bank of Nigeria (CBN) and representatives of the Ministry of Finance and Budget, in order to monitor the liquidity implications of fiscal spending.

Still, during this recent oil-price boom, the consolidated non-oil primary balance *declined* from +11 % in 2005 to +6 % in 2006 and +1 % in 2007. Meanwhile, foreign exchange reserves increased sharply, from USD 22 bn in 2005 to USD 42.62 bn in 2007, as a result of increased export receipts and capital inflows in a context of a managed float exchange-rate regime. Consistently, the nominal effective exchange rate did not appreciate; but buoyant domestic demand resulted in a marked real exchange-rate appreciation: the real effective exchange rate index jumped from 105.8 (in 2004) to 124.2 (in 2005), 133.1 (in 2006) and 129.3 (in 2007). This observation is in line with the empirical findings of the literature that changes in oil prices do affect the real exchange rate in Nigeria.[7] They illustrate the limitations of the saving fund in preventing the Dutch Disease to hurt Nigeria. In late 2008, the rapid fall in oil prices (in the wake of the global financial crisis) raised controversies about the possible depletion of the fund.

On the **monetary policy** side, the main choice concerns the exchange-rate regime. In a floating

[7]Using a VAR model on quarterly data, Olomola & Adejuno (2006) find that shocks to oil prices explain about 48 % of shocks to the real exchange rate in the first quarter, 33 % in the 8th quarter and 32 % in the tenth quarter.

regime, the inflationary effect of an oil-price increase (through booming domestic demand) can be compensated by a depreciation of the nominal exchange rate, preserving price competitiveness. Or conversely, the inflationary impact of an oil-price increase can be mitigated by allowing the nominal exchange rate to appreciate. This is no longer the case in a fixed exchange-rate regime, which reinforces spending and resource movements in favor the non-tradable sector at the expense of tradable goods (Lartey et al., 2008).

Although Nigeria's exchange-rate policy has undergone significant changes since the discovery of oil, all the experimented regimes ranged from fixed to quasi-fixed regimes (fixed exchange rate during the 1960s, pegged arrangement between the 1970s and the mid-eighties and a regime of managed float since 1986).

However, monetary strategies have differed over times. Between 1970 and 1976, the Nigerian authorities embarked in expansionary monetary policies, which accentuated the spending boom stemming from the first oil shock in a context of restriction on consumer goods imports and foreign-exchange controls. This policy resulted in strong over-valuation of the Nigerian currency. Similarly, an ill-designed monetary policy (over-valued exchange rate with loose monetary policy) resulted in an exacerbated Dutch disease during the second oil-price shock, in 1979.

In the 1990s, two important reforms were introduced in Nigeria: the adoption of an autonomous foreign exchange market in 1995, and the introduction of an inter-bank foreign exchange market in 1999. Though the main objective was to maintain a realistic exchange rate by diversifying the supply of foreign exchange in the economy, these policies failed to prevent the real appreciation of the Naira when the oil price increased again, due to expansionary fiscal policies and the persistence of excess liquidity.

In the 2000s, the monetary strategy changed substantially, with the adoption of inflation stabilization as the main target of monetary policy. The central bank of Nigeria (CBN) also adopted a reserve money target, which allowed sterilization of oil reserves through open market operations. As a consequence, despite the oil price spike, CPI inflation followed a declining path, standing below two digits in 2006 (8.5%) and 2007 (5.9%). Furthermore, the CBN managed to avoid fiscal dominance through a higher coordination with fiscal authorities, in particular through the FLAC, and through the decision to use extra oil revenues to reimburse the country's outstanding debt (Baldini & Ribeiro, 2008). Finally, the managed float regime provided more latitude to adjust the nominal exchange rate in order to correct accumulated price increases.

The example of Nigeria shows that fiscal and monetary policies can be powerful to mitigate the impact of oil-price volatility, as they can also be destabilizing if ill-designed. Then, a radical change in the macroeconomic policy framework implied by a move to monetary union with the WAEMU group needs careful examination. Additionally, the case of WAEMU countries needs to be scrutinized to find out whether these countries may suffer more from oil-price volatility due to their belonging to a monetary union with Nigeria.

## 3. A DSGE MODEL OF THE DUTCH DISEASE IN A MONETARY UNION

### 3.1. Overview

Here we present a stylized, two-country model comprising one oil-exporting country (Nigeria, representing the bulk of the West-African Monetary Zone or WAMZ), and one non-oil exporting country (WAEMU). These two countries are assumed to share the same currency that can either float or be fixed against the foreign currency.

The model is inspired by Sosunov & Zamulin (2007) who only consider a single country.[8] Here, both Nigeria and WAEMU are considered small open economies: they take the world interest rate and the world price of commodities as given, and their currency is not held by non-residents. In each country, there are two production sectors:

- a cash crop agricultural sector (henceforth designated with an $A$ subscript) that produces a good that is not consumed locally but only exported out of the region;[9]
- a 'non-tradable' sector ($N$ subscript) that produces a good that is only traded within the region: from WAEMU to Nigeria and the other way round.

Both goods are produced using a single production factor: labor. This simplifying assumption is in line with the relatively low level of capital per worker in the region.

While the price of the agricultural product is given internationally, that of the non-tradable sector is set by the producers on a monopolistic competition market. The Nigerian economy also produces oil (designated with an $O$ subscript), which comes as a pure endowment and the production of which requires no input.[10] The price of oil is given internationally.

In each country, households consume a 'non-tradable' domestic good ($N$ subscript), a 'non-tradable' good produced in the other country ($N^*$) and a good imported from international markets, designate with an $M$ subscript (for 'manufactured', although the scope of this good can be expanded at no cost, for instance to include imported food products). Households do not consume oil nor agriculture products that are assumed to be entirely exported towards the rest of the world (ROW).[11]

Money demand is introduced *via* a cash constraint on household consumption. Money supply is related to the monetary/exchange-rate regime. The non-neutrality of monetary policy is insured through the introduction of nominal rigidities *à la* Calvo: each period, only a fraction $\nu_p$ of non-tradable sector producers and a fraction $\nu_w$ of workers are able to change their prices (resp. wages) consistent with profit maximization. Additionally, only a fraction of households have access to the financial market to smooth consumption inter-temporally. There is no

[8] Additionally, Sosunov & Zamulin (2007) do not study the implication of a sovereign funds.

[9] Here, agriculture is a shortcut for non-oil exporting sectors.

[10] In fact, the production of oil requires some capital; but capital adjusts slowly while we are interested in short-run fluctuations. Furthermore, capital is not used in the other sectors, so it can be omitted in our analysis.

[11] Relaxing these simplifying assumptions would not change the results qualitatively.

public sector, except a saving fund in Nigeria that taxes current income to redistribute later to financially-constrained households.

The next subsections detail the equations for Nigeria. The model is the same for WAEMU except that there is no oil sector.

## 3.2. Households

Two categories of households are distinguished. *Optimizing* households, denoted $opt$, have access to financial markets and can buy and sell all kinds of assets and securities. In our framework, this implies that they can hold plain-vanilla domestic and foreign bonds (respectively $B$ and $B^*$). However there is a (potentially large) fraction $\mu$ of *constrained* households, labeled $no$ (for *non-optimizing*), who do not own any asset nor have any liability: their consumption in each period is constrained by their current income, be it their labor income or transfers they may receive from the oil stabilization fund. Note that both types of households do optimize *intra-temporarily* (between consumption and leisure, as well as across consumption goods), although only $opt$-type households can optimize *inter-temporarily*.

The presence of optimizing households may appear at odds with the relatively limited development of financial markets in the region. However, the households sector here includes the government which is not modeled otherwise but for the oil stabilization fund. The government does have some capacity to smooth consumption over time, although it also suffers from financial constraints.

### *3.2.1. Optimizing households*

The budget constraint of the representative optimizing household, expressed in the domestic currency, is the following:

$$\begin{aligned} &p_t C_{opt,t} + B_t + e_t B_t^* + M_{opt,t} = w_t H_{opt,t} + \Pi_t + T_t + e_t p_{O,t}^* Y_{O,t} \\ &+ (1 + r_{t-1}) B_{t-1} + e_t (1 + r_{t-1}^*) B_{t-1}^* + M_{opt,t-1} \end{aligned} \tag{1}$$

where $M_t$, $B_t$ and $B_t^*$ denote the representative household's net holdings in domestic money, domestic bonds and foreign bonds respectively, at the end of period $t$. $B_t$ is negative (net debt) and its counterpart lies on the asset-side of the central-bank balance sheet (see Sections 3.6 and 3.7.2). $B_t^*$ can be either positive or negative and its counterpart lies in the rest of the world.

$r_{t-1}$ and $r_{t-1}^*$ are the nominal returns of domestic and foreign bonds between $t-1$ and $t$ (set in $t-1$); $e_t$ is the nominal exchange rate (number of domestic currency units in one foreign currency unit), $p_t$ the consumption price index, $w_t$ the nominal wage, $C_t$ the consumption level and $H_t$ the number of hours of work supplied during period $t$. Finally, $\Pi_t + e_t p_{O,t}^* Y_{O,t} + T_t$ holds

for those sources of income that are independent from household's decisions, namely firms profits ($\Pi_t$), transfers from the central bank ($T_t$, see Section 3.6), and oil revenues ($e_t p^*_{O,t} Y_{O,t}$), where $p^*_{O,t}$ is the oil price and $Y^*_{O,t}$ the oil production,both being exogenous.

Household's instantaneous utility in period $t$ is given by:

$$u_{opt,t} = u(C_{opt,t}, H_{opt,t}) = \frac{C_{opt,t}^{1-\sigma}}{1-\sigma} - \kappa \frac{H_{opt,t}^{1+\phi}}{1+\phi} \tag{2}$$

where $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $\kappa$ and $\phi$ are positive parameters. Each optimizing household maximizes the following intertemporal utility function, where $0 < \beta < 1$ is the discount factor:

$$U_{opt,t} = \mathbf{E}_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} u_{opt,s} \right\} \tag{3}$$

subject to the budget constraint (1) and to the following cash constraint:

$$M_{opt,t} \geq p_t C_{opt,t} \tag{4}$$

Due to the cash constraint, the relation between marginal utility of wealth (i.e. the Lagrange multiplier on the budget constraint (1)) and marginal utility of consumption involves a forward-looking term:[12]

$$\lambda_{opt,t} = \frac{C_{opt,t}^{-\sigma}}{p_t} - \beta r_t \mathbf{E}_t \left\{ \lambda_{opt,t+1} \right\} \tag{5}$$

The pricing kernel (the stochastic discount factor) of optimizing households, $q^{opt}_{t,s}$ and the marginal rate of substitution between wealth and leisure, $\text{mrs}_{opt,t}$, are given by:

$$q^{opt}_{t,s} = \beta^s \frac{\lambda_{opt,t+s}}{\lambda_{opt,t}} \tag{6}$$

$$\text{mrs}_{opt,t} = \kappa \frac{H^{\phi}_{opt,t}}{\lambda_{opt,t}} \tag{7}$$

[12] See for instance Walsh (2003) Chapter 3.3.

In the model, households are assumed to rent their labor to unions that will set wages on a monopolistic competition market (see Section 3.3). Solving the household's program then reduces to the two following first-order conditions:

$$\mathbf{E}_t \left\{ q^{opt}_{t,t+1}(1+r_t) \right\} = 1 \tag{8}$$

$$\mathbf{E}_t \left\{ q^{opt}_{t,t+1}(1+r^*_t)\frac{e_{t+1}}{e_t} \right\} = 1 \tag{9}$$

Equation (8) is the Euler condition that expresses the inter-temporal substitution of consumption as a function of the real interest rate compared to the individual discount factor. Equation (9) arises from the arbitrage between domestic and foreign bond holdings. It is the uncovered interest parity.

### *3.2.2. Rule-of-thumb households and the oil stabilization fund*

As stated earlier in this section, a fraction $\mu$ of households are financially constrained and have not access to financial instrument (*i.e.* domestic and foreign bonds) to optimize inter-temporarily. In Nigeria, however financially-constrained households benefit from an oil-stabilization fund that saves part of oil windfalls when the oil price is high and pays transfers to constrained households when the oil price is low.[13]

**The stabilization fund.** Consistent with the Nigerian saving fund, the stabilization fund here is fed by retaining a fraction of those 'excess' oil revenues that otherwise would be given to constrained households. 'Excess' oil revenues are defined as those revenues that appear when the oil price exceeds a certain price threshold $p^*_{thresh}$. The stabilization fund's assets, labeled $F^*$, are held in the form of foreign-denominated bonds. A fraction of the return is distributed to constrained households in each period.[14] Hence, the funds' asset holdings are accumulated as follows (in foreign currency):

$$F^*_t = (1+r^*_{t-1})(1-\zeta_2)F^*_{t-1} + (1-\zeta_1)\mu(p^*_{O,t} - p^*_{thresh})Y_{O,t} \tag{10}$$

[13]Only financially-constrained households receive transfers from the oil stabilization fund; transfers to unconstrained households would be neutral in the model since these households are able to reallocate their income inter-temporarily. We consider a 'well-behaved' stabilization fund that does provide transfers to households when the oil price falls below a certain threshold. Naturally, an ill-behaved stabilization would not provide the stabilization properties highlighted in our model.

[14]Since households are not explicitly distinguished from the public sector, the model behaves the same way whether the fund makes transfers or spends directly on consumption goods.

where $\zeta_1$ and $\zeta_2$ are positive parameters that reflect the rules set for the fund, and $\mu$ is the share of financially-constrained households. In each period, households receive oil revenues in three parts: (i) a 'medium-run' oil revenue based on the threshold price $p^*_{thresh}$; (ii) a fraction $\mu\zeta_1$ of revenues above this threshold price, and (iii) a fraction $\zeta_2$ of the fund's total assets at the beginning of the period. The higher $\zeta_1$, the quicker excess oil revenues are transferred to constrained households. The steady-state value of the stabilization fund, $\bar{F}^*$, is such as:

$$\bar{F}^* = \mu \frac{(1-\zeta_1)(\bar{p}^*_O - p^*_{thresh})}{1-(1+r^*)(1-\zeta_2)} \bar{Y}_O \tag{11}$$

where $\bar{p}^*_O$ and $\bar{Y}_O$ denote the steady-state levels of the oil price and output, respectively.

**Household program.** The representative constrained households maximizes his intertemporal utility subject to a budget constraint and to a cash constraint:

$$\begin{aligned} p_t C_{no,t} + M_{no,t} = w_t H_{no,t} + \Pi_t + e_t p^*_{thresh} Y_{O,t} + M_{no,t-1} \\ + \zeta_1 e_t (p^*_{O,t} - p^*_{thresh}) Y_{O,t} + e_t (1 + r^*_{t-1}) \zeta_2 F^*_{t-1}/\mu \end{aligned} \tag{12}$$

$$M_{no,t} \geq p_t C_{no,t} \tag{13}$$

By assuming that (13) is always binding, consumption and money holding dynamics are the mechanical results of the two constraints.[15] The marginal utility of income is given by:

$$\lambda_{no,t} = \frac{1}{2} \left( \frac{C^{-\sigma}_{no,t}}{p_t} + \beta \mathbf{E}_t \{ \lambda_{no,t+1} \} \right) \tag{14}$$

The value of the pricing kernel and marginal rate of substitution between leisure and income have the same expressions as for unconstrained households:

$$q^{no}_{t,s} = \beta^s \frac{\lambda_{no,t+s}}{\lambda_{no,t}} \tag{15}$$

$$\text{mrs}_{no,t} = \kappa \frac{H^{\phi}_{no,t}}{\lambda_{no,t}} \tag{16}$$

[15] Contrary to non financially constrained households, a strictly positive nominal interest rate is not a sufficient condition. As the steady state value of the Lagrange multiplier on the cash constraint in strictly positive, it will be always binding for small enough shocks.

### 3.3. Unions, wage setting and the labor market

Wage rigidity is introduced here through the presence of unions that, contrasting with individual households, can extract a rent from the fact that labor demand is not infinitely elastic to the wage rate. Although unions are perhaps not a major feature of West-African countries, non-market, wage setting in the public sector exerts some leading role for wages in the private sector. The use of unions allows us to conveniently introduce a wage rigidity *à la* Calvo (1983). Due to this rigidity, the labor market will not clear in the short run after a shock, which appears a reasonable feature.

Households are assumed to rent hours $H$ to unions, taking the wage rate as given. Each union $u$ aggregates hours in union-specific labor supply $L(u)$ according to a one-for-one technology. This labor supply in turn is rent to firms on a monopolistic competition market. Let $L$ denote the aggregate labor supply and $w$ the aggregate average unit wage. We have:

$$L^{\frac{\epsilon_w-1}{\epsilon_w}} = \int_u L(u)^{\frac{\epsilon_w-1}{\epsilon_w}} du \qquad \text{and} \qquad w^{1-\epsilon_w} = \int_u w(u)^{1-\epsilon_w} du$$

where $\epsilon_w > 1$ is the elasticity of labor demand to the wage rate. Unions set their wage *à la* Calvo (1983): at each period, a fraction $\nu_w$ of unions, taken at random, is unable to modify its wage rate. This wage rigidity means that the labor market does not clear in the short run: unions set the unit wages, and employment is determined by labor demand for this level of unit wage. Labor rationing is assumed to be equally distributed amongst households, despite differing marginal rates of substitution between consumption and leisure for optimizing and constrained households.

Due to differing pricing kernel and marginal rate of substitution between optimizing and financially-constrained households, the optimization program of the union is not trivial. We follow Galí et al. (2007) in assuming a linear combination of the programs that the union would solve should it face only one type of households. At time $t$, a union $u$ that can change its wage accounts for its expected future inability to change it for several periods. Accordingly, the optimal wage $w_t$ set at time $t$ is such that:

$$\max_{\tilde{w}_t(u)} \mathbf{E}_t \left\{ \mu \sum_{s=t}^{+\infty} \nu_w^{s-t} q_{no,t}^s (\tilde{w}_t(u) - \text{mrs}_{no,s}) L_{no,s}(u) \right.$$
$$\left. + (1-\mu) \sum_{s=t}^{+\infty} \nu_w^{s-t} q_{opt,t}^s (\tilde{w}_t(u) - \text{mrs}_{opt,s}) L_{opt,s}(u) \right\} \tag{17}$$

where $\mu$ is the proportion of constrained households. $L_{no,s}(u)$ and $L_{opt,s}(u)$ denote labor allocated by the union $u$ at time $s$ to constrained and unconstrained households respectively (by assumption the two kinds of representative household work the same time):

$$L_{no,s}(u) = L_{opt,s}(u) = L_s(u) = \left(\frac{\tilde{w}_t(u)}{w_s}\right)^{-\epsilon_w} L_s$$

Since a proportion $\nu_w$ of unions cannot adjust their price from one period to another, the aggregate wage dynamics is the following:

$$w_t = \left[\nu_w (w_{t-1})^{1-\epsilon_w} + (1-\nu_w)(\tilde{w}_t)^{1-\epsilon_w}\right]^{\frac{1}{1-\epsilon_w}} \tag{18}$$

## 3.4. Firms

There are two productive sectors in the economy: the tradable one (agriculture good) and the 'non-tradable' one.We also assume only one production factor: labor. While simplifying a great deal our analysis, this hypothesis can be justified by considering lands as an important factor of production, whereas capital intensity is low in developing economies such as WAEMU countries or Nigeria and not mobile across sectors. As labor is the only mobile factor, one can merge technology, land endowment and capital endowment in the productivity factor.

### *3.4.1. Tradable sector* $A$

The tradable sector operates under perfect competition. There is a single representative firm, whose labor demand is denoted $L_A$ and production $Y_A$. There are decreasing returns to scale, and the production function is modeled as:

$$Y_A = \psi_A \frac{L_A^{\gamma}}{\gamma} \tag{19}$$

where $\psi_A > 0$ is a fixed exogenous productivity factor and $\gamma > 0$. Profit maximization under perfect competition yields:

$$w = e p_A^* \psi_A L_A^{\gamma - 1} \tag{20}$$

### *3.4.2. Non-tradable sector* $N$

**Monopolistic competition** The non-tradable sector undergoes monopolistic competition: there is a continuum of firms $\{i, i \in [0,1]\}$ producing imperfectly substitutable varieties. Each individual firm $i$ has the same production function:

$$Y_N(i) = \psi_N \frac{L_N(i)^{\gamma}}{\gamma} \tag{21}$$

where $\psi_N >$ is a fixed exogenous productivity factor. The non-tradable good bundle is defined over varieties with $\epsilon_p > 1$ the elasticity of substitution across varieties.

$$Y_N = \left[\int_0^1 Y_N(i)^{1-\frac{1}{\epsilon_p}} di\right]^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{22}$$

Let $p_N = \left[\int_0^1 p_N(i)^{1-\epsilon_p} di\right]^{\frac{1}{1-\epsilon_p}}$ be the aggregate price of the non-tradable sector. Firm-specific demand writes:

$$Y_N(i) = \left(\frac{p_N(i)}{p_N}\right)^{-\epsilon_p} Y_N \tag{23}$$

**Price setting** Firms set their price *à la* Calvo (1983). This means that at every period, a fraction of firms $\nu_p$, taken at random, is unable to modify its price. Each firm supplies all the demand it faces at current price and its labor demand is set accordingly (see Equation 21). Consistent with rational expectations, a firm $i$ that can change its price accounts for its expected future inability to change again its price for several periods. Thus, its program is the following:

$$\max_{\tilde{p}_{N,t}(i)} \mathbf{E}_t \left\{ \sum_{s=t}^{+\infty} \nu_p^{s-t} \left[\mu q_{no,t}^s + (1-\mu) q_{opt,t}^s\right] \left(\tilde{p}_{N,t}(i) Y_{N,s}(i) - w_s L_{N,s}(i)\right) \right\} \tag{24}$$

The labor demand of the whole non-tradable sector is given by:

$$L_{N,t} = \int_0^1 L_{N,t}(i) di \tag{25}$$

Since a proportion $\nu_p$ of firms cannot adjust their price from one period to another, the price dynamics of non-traded goods is the following:

$$p_{N,t} = \left[\nu_p (p_{N,t-1})^{1-\epsilon_p} + (1-\nu_p)(\tilde{p}_{N,t})^{1-\epsilon_p}\right]^{\frac{1}{1-\epsilon_p}} \tag{26}$$

### 3.5. Aggregate consumption and trade

Except for oil exports, Nigeria and WAEMU share the same trade pattern. They both export all the tradable production (agricultural goods) on the world market at the international price $p_{A,t}^*$.

Households consume imported tradables $M$, and non-tradable goods $NT$:

$$C = \left[ \alpha_m^{\frac{1}{\eta_m}} C_M^{\frac{\eta_m - 1}{\eta_m}} + (1-\alpha_m)^{\frac{1}{\eta_m}} C_{NT}^{\frac{\eta_m - 1}{\eta_m}} \right]^{\frac{\eta_m}{\eta_m - 1}} \tag{27}$$

where $C$, $C_M$ and $C_{NT}$ represent total consumption, consumption of imported tradables and consumption of non-tradables, respectively, and $\eta_m > 0$ is the elasticity of substitution between $M$ and $NT$ goods. Non-tradable goods can be domestically produced ($N$) or imported from the other West-African country or zone ($N^*$):

$$C_{NT} = \left[ \alpha_n^{\frac{1}{\eta_n}} C_{N^*}^{\frac{\eta_n - 1}{\eta_n}} + (1-\alpha_n)^{\frac{1}{\eta_n}} C_N^{\frac{\eta_n - 1}{\eta_n}} \right]^{\frac{\eta_n}{\eta_n - 1}} \tag{28}$$

With $\eta_m > 0$, $\eta_n > 0$, $0 < \alpha_m < 1$ and $0 < \alpha_n < 1$. The consumer price index is defined by:

$$p = \left[ \alpha_m (e p_M^*)^{1-\eta_m} + (1-\alpha_m) p_{NT}^{1-\eta_m} \right]^{\frac{1}{1-\eta_m}} \tag{29}$$

The consumer price index of non-tradables is:

$$p_{NT} = \left[ \alpha_n (p_{N^*})^{1-\eta_n} + (1-\alpha_n) p_N^{1-\eta_n} \right]^{\frac{1}{1-\eta_n}} \tag{30}$$

Domestic demand addressed to each good is given by:

$$C_M = \alpha_m \left( \frac{e p_M^*}{p} \right)^{-\eta_m} C \tag{31}$$

$$C_{N^*} = (1-\alpha_m)\alpha_n \left( \frac{p_{NT}}{p} \right)^{-\eta_m} \left( \frac{p_{N^*}}{p_{NT}} \right)^{-\eta_n} C \tag{32}$$

$$C_N = (1-\alpha_m)(1-\alpha_n) \left( \frac{p_{NT}}{p} \right)^{-\eta_m} \left( \frac{p_N}{p_{NT}} \right)^{-\eta_n} C \tag{33}$$

### 3.6. Monetary policy and the central bank

The central bank balance sheet is composed of money supply $M^s$ (liability side), backed by domestic bonds $D$ (exogenous) and foreign bonds or reserves $R^*$ (exogenous or endogenous depending on the exchange-rate regime) on the asset side. Three monetary regimes are successively considered for the monetary union as a whole:

- a flexible exchange-rate regime with fixed money supply ($R^* = R_0^*$);
- a flexible exchange-rate regime with current-account surpluses inflating money supply ($R^* = R_0^* + NFA_t^*$, where $NFA_t$ denotes the net foreign asset position of the monetary union);
- a fixed exchange-rate regime backed by foreign exchange interventions.

As the central bank earns interest on its assets, we assume a lump-sum transfer $T$ to optimizing households[16] in order to keep the balance sheet in equilibrium ($M_t^s = e_t R_t^* + D_t$). The budget constraint of the central banks writes:

$$T_t = [(1 + r_{t-1}^*)e_t - e_{t-1}]R_{t-1}^* + r_{t-1}D_{t-1} \tag{34}$$

## 3.7. Market equilibria, calibration and benchmark steady state

### *3.7.1. Accounting identities*

Net foreign assets are divided between central bank's reserves, $R^*$, households' net foreign assets held in the form of foreign bonds $B^*$, and, in the case of Nigeria, a saving fund $F^*$. Hence, the balance of payments at the end of period $t$ writes (in foreign currency):

$$\begin{aligned} &B_t^{*\text{Nig}} + B_t^{*\text{WAEMU}} + F_t^{*\text{Nig}} + R_t^* = \\ &(1 + r_{t-1}^*) \cdot ({B_{t-1}^*}^{\text{Nig}} + {B_{t-1}^*}^{\text{WAEMU}} + R_{t-1}^* + {F_{t-1}^*}^{\text{Nig}}) \\ &+ p_{A,t}^* \left(Y_{A,t}^{\text{Nig}} + Y_{A,t}^{\text{WAEMU}}\right) + p_{O,t}^* Y_{O,t}^{\text{Nig}} - p_{M,t}^* \left(C_{M,t}^{\text{Nig}} + C_{M,t}^{\text{WAEMU}}\right) \end{aligned} \tag{35}$$

where $Y_A$ denotes agricultural exports, $Y_O$ oil exports and $C_M$ manufactured good imports, and $p_A^*, p_O^*, p_M^*$ are their corresponding prices in foreign currency. $R^*$, $F^*$ and $B^*$ are also expressed in foreign currency.

### *3.7.2. Market equilibria*

**Domestic bond market** As already mentioned, the counterpart of optimizing households' net domestic assets (here, net domestic debts) $B_t$ appears on the asset side of the central bank's balance sheet ($D_t$). Together with official reserves $R_t^*$, $D_t$ constitutes the counterpart of money creation, $H_t$. Because optimizing households represent a fraction $(1 - \mu)$ of the population, the domestic bond market equilibrium reads:

$$D_t + (1 - \mu)B_t = 0 \tag{36}$$

[16] Constrained households are assumed not to receive this transfer because this would amount for them to indirectly hold bonds; hence this would erase their difference to optimizing households.

**Money market** Money demand is given by the cash constraint integrated over optimizing and rule-of-thumb households (Equations (4) and (13)). Money supply is described in Section 3.6. At equilibrium, one gets:

$$M_t = D_t + e_t R_t^* \tag{37}$$

**Goods market** World demand for the tradable good $A$ is assumed to be perfectly elastic at world price $p_A^*$. As for the non-tradable good, the market equilibrium writes:

$$Y_{N,t} = C_{N,t} + C_{N,t}^* \tag{38}$$

were $C_{N,t}^*$ denotes the foreign country/zone's demand for home non-traded goods.

**Labor market** Total labor demand writes $L_t^D = L_{A,t} + L_{N,t}$, which determines employment $L_t$, given the wage rate that is set by the unions:

$$L_t = L_{A,t} + L_{NT,t} \tag{39}$$

### *3.7.3. Calibration and benchmark steady state*

The model is calibrated on a quarterly basis. A first set of parameters are calibrated so as to reproduce relevant macroeconomic ratios for the two countries at equilibrium. We assume that, absent oil rent, the two regions are perfectly symmetric and only differ by their population. Introducing oil in Nigeria modifies the steady-state as the excess income leads to a higher consumption and a lower labor supply. We focus here on reproducing the relative size of the two economies (in terms of GDP and labor force), their openness ratios, and the relative size of their different production sectors (Table 1).

Table 2 reproduces the steady-state values of the main variables when oil is introduced in Nigeria. Due to money neutrality in the long run, they are the same whatever the monetary regime. Table 2 presents the case where there is no stabilization fund (*i.e.* with $\zeta_1 = 0$). Calibration assumes identical steady-state values for optimizing and non-optimizing households. It is performed so as to ensure rounded-up values for most WAEMU and Nigeria's variables while matching the basic ratios of the Table 1

Thanks to oil revenues, welfare is higher in Nigeria than in WAEMU: consumption is higher while labor supply is lower. As a result, prices are also slightly higher in Nigeria than in WAEMU, which translates into a lower value of real exchange rate RER.[17]

[17]The World Bank estimates than price level was 6% higher in Nigeria in 2007 and real consumption around 40% higher (Lufumpa & Kasekende., 2007).

**Table 1 – Main relevant aggregates for the Nigeria and WAEMU**

| Variable | WAEMU | Nigerian |
|---|---|---|
| Annual GDP (bn USD in PPP) | 88.2 | 202.8 |
| share in the union | (30%) | (70%) |
| Total population, in million inhabitants | 79.2 | 129.2 |
| share in the union | (38%) | (62%) |
| Imports (percentage of final non oil demand$^{(a)}$) | 22% | 19% |
| Non oil exports (percentage of GDP) | 25% | 2% |
| Oil exports (percentage of GDP) | 0% | 30% |

Source: IMF, *World Economic Outlook*. $^{(a)}$We use this proxy to estimate the share of imported goods in consumption bundle.

**Table 2 – Steady state variable**

| Variable | WAEMU | Nigeria |
|---|---|---|
| $C_{opt},\ C_{no}$ | 1 | 1.18 |
| $L_{opt},\ L_{no}$ | 1 | 0.80 |
| $C$ | 0.38 | 0.73 |
| $L$ | 0.38 | 0.50 |
| $Y_A$ | 0.09 | 0.09 |
| $Y_{NT}$ | 0.29 | 0.43 |
| $RER^{(a)}$ | 0.89 | 0.77 |

$^{(a)}$ $RER = \frac{e}{p}$, where $e$ is the nominal exchange rate and $p$ the consumer price index.

A second set of parameters are calibrated based on the literature. These are the probability of not being able to adjust prices or wages at each period, and the various elasticities of the model (see Table A.1 in Appendix). Section 6 shows how the steady-state with oil is affected by the calibration of the three main elasticities: intertemporal elasticity of substitution ($1/\sigma$), elasticity of labor supply ($1/\phi$)and elasticity of substitution between domestic and imported goods in the consumption basket ($\eta_m$).

When the stabilization fund is activated, we assume that oil income above the threshold price entirely pays into it ($\zeta_1 = 1$) and that financially-constrained household earn 6% of its capitalization each year. We now turn to impulse-response functions.

## 4. THE IMPACT OF AN OIL-PRICE INCREASE

In this section we compare the impact of a $50\%$ increase in the oil price under three differing monetary regimes: (i) a flexible exchange rate with constant money supply; (ii) a flexible exchange rate with an accommodating monetary policy (i.e. endogenous money supply); and (iii) a fixed exchange rate. The shock progressively fades away, with a 65% autoregressive pattern. It has no impact on the steady-state of the economy. In the short run and medium run, the

presence of nominal rigidities means that the impact of the shock is different across the three monetary regimes.

### 4.1. Impact of the shock on Nigeria

The impulse-response functions for Nigeria are reported in Figures A.1, panel (a) for the case without a stabilization fund, i.e. when the oil windfall is fully distributed to both 'hand-to-mouth' and ricardian households. For the former, this immediately translates into higher consumption, whatever the monetary regime of the union. Due to the cash constraint, these households raise their demand for money. The impact on the interest rate, and thus also on optimizers' consumption, depends on the monetary regime:

- If money supply is given at the union's level, then the nominal interest rate rises (see panel (c)). With limited inflation in this first regime, the real interest rate increases by almost as much as the nominal one. This induces unconstrained households to save more through an inter-temporal substitution effect. The net impact of the shock on their consumption is theoretically ambiguous since higher inter-temporal income allows them to consume more. Here, the consumption of optimizers falls in the short run.
- With endogenous money supply, the oil windfall causes money supply to increase gradually. This produces a marked depreciation of the nominal exchange rate, which is rationally expected in the short run and hence causes the nominal interest rate to rise sharply. The real interest rate also increases in the short run, despite high inflation. However this rise in the real interest rate is short lived: after a few quarters, the real interest rate falls below its reference level. The profile of the real interest rate leads optimizing households to progressively increase their consumption level before falling back to baseline.
- Finally, when the nominal exchange rate is held constant through unsterilized foreign exchange interventions, the nominal interest rate stays constant too and the real interest rate slightly falls in the short run.[18] In this case, Ricardian households' consumption increases slightly in the short run due to the rise in inter-temporal income.

Under the three monetary regimes, aggregate consumption increases, although less so under the fixed money-supply regime than under the fixed exchange-rate regime, and less so under the latter than with an endogenous money supply. Since part of consumption falls on non-tradables, the price of the latter increases. As for the imported manufactured product, its price expressed in the home currency depends on the exchange rate: it stays constant under a fixed exchange-rate regime, falls with a fixed money supply (because the nominal exchange rate appreciates) and rises with endogenous money supply (in this case, the exchange rate depreciates). Hence, with a fixed money supply, consumption is partially reallocated towards imports whereas with an endogenous money supply, it is reallocated towards non-tradables.

[18]The model assumes no restriction on capital flows, which leaves no room for an independent monetary policy in a fixed exchange-rate regime.

Like the price of imported manufactured goods, the price of the non-oil export sector (agriculture) stays constant in domestic currency under a fixed exchange-rate regime, falls when money supply is constant and rises if money supply is endogenous. Since the price of non-tradables increases in the three regimes, there is a reallocation of labor from agriculture to non-tradables. Only under an endogenous money supply does employment increase in agriculture (although much less than in the non-tradable sector and only in the short run). In the two other regimes, the agricultural sector shrinks following the shock and Nigeria exhibits a Dutch disease. The impact of the shock on total employment then also depends on the monetary regime:

- Under a fixed money supply, the fall in employment in the agriculture sector compensates the rise in the non-tradable sector, so that total employment is almost unaffected by the shock. In fact, this regime isolates the rent, oil sector from the productive economy: an oil-price increase rises consumption and welfare with little effect on aggregate employment, although the non-tradable sector expands to the detriment of agriculture.
- Under a fixed exchange rate, total employment rises slightly, thanks to higher demand for non-tradables (in this case, there is less reallocation in favor of imported goods) and to a lower contraction of the agriculture sector (whose price does not fall in domestic currency).
- Finally, it is with an endogenous money supply that total employment rises the most. This is due to the large increase in consumption that feeds the non-tradable sector, and to the depreciation of the exchange rate that both redirects consumption to domestic goods and makes agriculture more profitable.

In brief, the monetary regime that stabilizes most the Nigerian economy (in terms of both consumption and employment) after an oil-price shock is the fixed money supply regime, although this is also the regime yielding the highest instability in agriculture employment. The endogenous money-supply regime yields the highest volatility of the economy after a shock and the fixed exchange-rate regime lies in-between the two other regimes.

### 4.2. Impact of the shock on WAEMU

The impulse-response functions for WAEMU are reported in Figures A.1, panel (b). The shock faced by Nigeria affects WAEMU through two distinct channels: regional trade, and the single monetary policy:

- *Regional trade*: part of the increased consumption in Nigeria falls on goods that are imported from WAEMU. These goods are the so-called 'non-traded' goods, that are not traded with the rest of the world but still traded regionally. The trade channel is always positive for WAEMU. It is maximized with endogenous money supply, because in this case the Nigerian demand for non-tradables increases the most, and so does the Nigerian price of non-tradables (substitution effect).
- *Single monetary policy*: depending on the monetary regime, WAEMU experiences a change in the interest rate, in the exchange rate and/or in available cash. Hence, this second channel

of spillover can be positive, negative or neutral for WAEMU:

- With endogenous money supply, the additional domestic liquidity spreading on the Nigerian economy thanks to higher oil receipts also spreads on WAEMU (due to higher receipts on sales of "non-tradables"). Additional liquidity is welcome by both types of households, who want to spend their additional income.
- With fixed money supply, the additional liquidity spreading on the Nigerian economy thanks to higher oil receipts involves money contraction in WAEMU. Such contraction meets the fall in money demand stemming from lower consumption by optimizing households, the latter being confronted to a higher interest rate. The demand for WAEMU's non-tradables then falls, and so does the wage rate for both types of households. Additionally, the home-currency price of agriculture falls, which reduces labor demand in this sector (an "imported" Dutch disease). The fall in the wage rate leads non-optimizing households to also reduce their labor supply an consumption level.
- Finally, a fixed exchange rate tends to isolate WAEMU from the shock since the interest rate and the exchange rate are unaffected by the shock. Consumption and total employment slightly increase thanks to the regional trade channel.

### 4.3. The oil shock in brief, absent stabilization fund

Table 3, summarizes the impact of an oil-price increase on both Nigeria and WAEMU, depending on the monetary regime. From this table, it can be inferred that the different monetary regimes do not have the same impact on both economies:

- The fixed money-supply regime is the one providing the best stabilization properties for Nigeria; but it magnifies the asymmetric feature of oil shocks: with this regime, an oil-price increase has a detrimental impact on WAEMU because of the sharp increase in the common interest rate and the associated exchange-rate appreciation.
- With endogenous money supply, monetary policy acts in a pro-cyclical way in both economies.
- Finally, a fixed exchange rate is less stabilizing than the fixed money-supply regime for Nigeria, but it provides a buffer for WAEMU.

In brief, Nigeria and WAEMU will likely not have the same preferences in terms of monetary regime when Nigeria is hit by oil shocks: Nigeria will prefer a fixed money supply whereas for WAEMU, a fixed exchange rate will be preferred.

### 4.4. The role of the stabilization fund

We now study how the introduction of a stabilization fund in Nigeria modifies the reactions of the two economies to the same, 50% increase in the oil price (see Figures A.2, panels (a) to (c), where dotted lines recall IRFs obtained without the stabilization fund).

With a stabilization fund, financially-constrained households in Nigeria almost keep the same levels of consumption and labor supply as in the baseline (except with an endogenous money

**Table 3 – Impact of an oil-price increase on Nigeria and WAEMU**

| | Nigeria | | | WAEMU | | |
|---|---|---|---|---|---|---|
| Monetary regime | $C$ | $L$ | $L_A$ | $C$ | $L$ | $L_A$ |
| **Without a stabilization fund** | | | | | | |
| Fixed money supply | $+$ | $0$ | $--$ | $-$ | $-$ | $-$ |
| Endogenous money supply | $+++$ | $++$ | $+$ | $++$ | $++$ | $+$ |
| Fixed exchange rate | $++$ | $+$ | $-$ | $0^+$ | $0^+$ | $0^-$ |
| **With a stabilization fund** | | | | | | |
| Fixed money supply | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ |
| Endogenous money supply | $+$ | $+$ | $+$ | $+$ | $+$ | $+$ |
| Fixed exchange rate | $0$ | $0$ | $0$ | $0$ | $0$ | $0$ |

Source: Authors' calculations.

supply, in which case their consumption and labor supply still increase substantially). As a result, money demand is less reactive.

In the fixed money-supply regime, the introduction of the stabilization limits the interest-rate increase and optimizers no longer reduce their consumption following the shock. The exchange rate now hardly appreciates.[19] Hence, there is less substitution of consumption in favor of the imported good and less substitution of production away from agriculture. The combination of a stabilization and a fixed money supply almost perfectly stabilizes the shock. For WAEMU, the lack of interest-rate increase and of exchange-rate appreciation makes this regime very close to that of a fixed exchange rate, i.e. it isolates the economy from the indirect impact of the oil shock.

With endogenous money supply, the oil shock still stimulates the Nigerian economy, but much less than without a stabilization fund. The consumption of both types of households increases in the short run, but the stabilization fund halves the impact of the shock on aggregate consumption and employment. The exchange-rate depreciation is also halved. For WAEMU, this means more reallocation of consumption in favor of imported goods (which limits the boom of the non-tradable sector), but also less stimulation of agriculture. As for Nigeria, the impact of the oil shock on aggregate consumption and employment is halved compared to the case without a stabilization fund, although the economy is much less stabilized than with the other two regimes.

Finally, the fixed exchange-rate regime now yields the same results as the fixed money-supply regime, i.e. an almost complete stabilization of both economies, whereas without a stabilization fund, the fixed money supply regime stabilizes Nigeria but not WAEMU while the fixed exchange-rate regime stabilizes WAEMU but not Nigeria (see Table 3, bottom lines).

[19]The stabilization fund buys foreign currencies instead of allowing 'house-to-mouth' households to consume more.

It can be concluded that the introduction of a stabilization fund reduces the divergence of both economies concerning the choice of a monetary regime: while without a fund, Nigeria would prefer a fixed money supply and WAEMU a fixed exchange rate, both regimes yield the same results in terms of stabilization when a fund is introduced. However this conclusion is valid only to the extent that the sub-continent is hit only by oil prices, which is obviously not the case.

## 5. THE IMPACT OF AN INCREASE IN THE AGRICULTURAL PRICE

We now turn to the impact of a 50% increase in the world price of agricultural tradables under the same three monetary regimes: (i) flexible exchange rate with fixed money supply, (ii) flexible exchange rate with endogenous money supply, and (iii) fixed exchange rate.

Two main differences appear in comparison with oil price shocks. First, contrary to the oil pure endowment sector, the agricultural sector employs labor. Therefore, labor can flow to this sector when its relative price increases. Second, the two regions are less asymmetric for agriculture than for oil: Nigeria also exports agricultural products, although to a lesser extent than does WAEMU. The IRFs for Nigeria and WAEMU are reported in Figures A.3.

In the **fixed money supply** regime, employment in agriculture rises in both economies. The real wage increases essentially thanks to the exchange-rate appreciation (the home-currency price of imported manufactures declines). This increase in the real wage triggers higher labor supply. Both categories of households hence benefit from higher income. But only non-optimizers increase their consumption level. Indeed, optimizers react to the shock by consuming slightly less, because the rise in the interest rate induces them to save more (inter-temporal substitution effect). However, aggregate consumption increases in both economies, but more so in WAEMU than in Nigeria, because of a higher relative size of agriculture in WAEMU (see Table 2). The demand for non-tradables rises in WAEMU but less so in Nigeria where the (limited) increase in aggregate consumption is netted out by its reallocation towards cheaper imported manufactured goods. This first regime is the most stabilizing for both economies.

In the **endogenous money supply** regime, the increase in export receipts in both countries triggers money expansion. The nominal exchange rate gradually depreciates before falling back to baseline. Consistent with the uncovered interest parity, the nominal interest rate increases in the short run, and then falls below its baseline level. Consumption increases markedly in both economies and for both types of households, which triggers a boom in non-tradable sectors, all the more so that consumption is reallocated away from imported manufactured products that become more expensive due to the exchange-rate depreciation. In parallel, the depreciation accentuates the rise in profitability in agriculture. Hence, labor demand increases strongly in both non-tradables and agriculture. Wages increase to encourage more labor supply. As for the oil-price shock, this regime is the least stabilizing one when the economies are hit by shocks.

Finally, in the **fixed exchange rate** regime, the nominal interest rate stays constant because the

nominal exchange rate itself is constant (uncovered interest parity). Because the consumer price index increases, the real interest rate declines in both countries. Hence, optimizers raise their consumption level in the short run both due to a positive income effect and to an inter-temporal substitution effect. The consumption of financially-constrained households is boosted by the increase in money supply, deriving from unsterilized foreign exchange interventions. The fixed exchange-rate regime has stabilizing properties that lie in-between the fixed money supply and the endogenous money supply regimes.

Table 4 below summarizes the preferred regimes for each country/zone in terms of the lowest medium-run consumption volatility, for each type of shock. In the presence of a well-functioning oil stabilization fund, the fixed money supply regime (with a flexible exchange rate) seems to be the best for both economies. However, should the stabilization fund not play its role in allowing non-optimizing households to smooth their consumption inter-temporally, a disagreement may arise between the two economies, because a fixed money supply is more stabilizing in Nigeria while a fixed exchange rate is more stabilizing in WAEMU.

**Table 4 – Countries' favorite policy regime**

| | Nigeria | WAEMU |
|---|---|---|
| Oil shocks | | |
| without stab. fund | FMS | FEX |
| with stab. fund | FMS and FEX | FMS and FEX |
| Agriculture shocks | FMS | FMS |

Source: Authors' calculations. FMS = Fixed money supply, FEX = Fixed Exchange rate.

## 6. SENSITIVITY ANALYSIS

Among the numerous parameters of the model, three can be thought critical since their values can greatly affect both the steady state and the impulse response functions: the intertemporal elasticity of substitution $(1/\sigma)$, the elasticity of labor supply $(1/\phi)$ and the elasticity of substitution between domestic and imported goods $\eta_m$ (see Table A.1).

### 6.1. Sensitivity of the steady-state

Absent oil rent in Nigeria, the two countries are identical except for their size. When oil rent is introduced, prices increase in Nigeria and the agricultural sector shrinks leading to the 'including oil steady state' given in Table 2 (using the basic calibration where $\sigma$, $\phi$ and $\eta_m$ are set to 2, 1 and 0.75 respectively). We now evaluate how this 'including oil steady state' is modified when $\sigma$, $\phi$ and $\eta_m$ vary from 0.8 to 2.

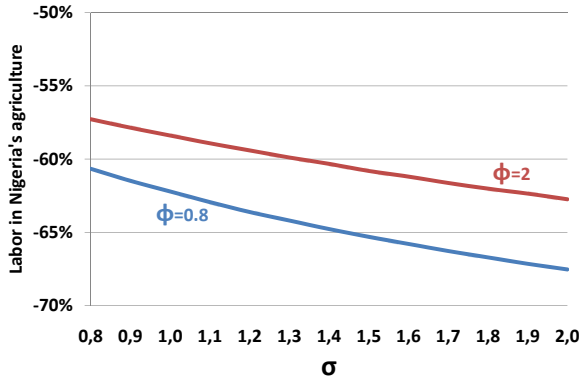
$\sigma$ and $\phi$ both play a major role in the impact of oil revenues on the steady state. The oil rent allows a higher consumption in Nigeria leading to:

- an increase in the marginal rate of substitution: labor supply shrinks;
- an increase in labor demand in the non-tradable sector.

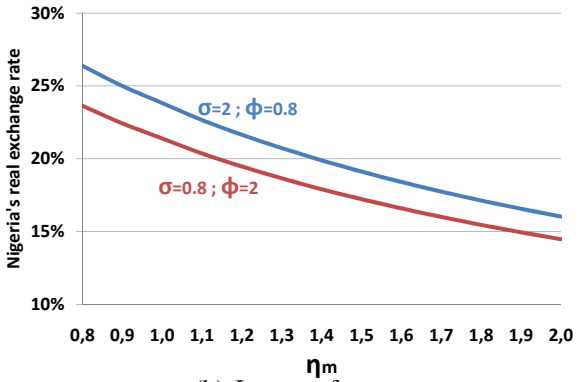
In order to balance the labor market, the wage level and domestic price increase and labor in the agricultural sector shrinks. The extent of these phenomena depends on $\sigma$ and $\phi$. Figure (5,a) and (5,b) show how the value of $\sigma$ and $\phi$ modifies employment in agriculture. The larger $\sigma$, the larger the shift in the marginal rate of substitution, and so the fall in labor is larger in agriculture. The lower $\phi$, the larger the employment drop in the agricultural sector.

As consumption increases and labor supply decreases, the real exchange rate has to appreciate to achieve internal equilibrium. If non-tradable and imported goods are complementary in consumption (small $\eta_m$)), the real exchange rate have to depreciate more (see Figure (5,c)).

**Figure 5 – Sensitivity of the steady-state: impact of $\sigma$, $\phi$ and $\eta_m$ on selected variables**




(a) Impact of $\sigma$ and $\phi$




(b) Impact of $\eta_m$

## 6.2. Sensitivity of IRFs: oil-price shock

We now turn to the sensitivity of impulse response functions after an oil-price shock. According to our simulations, $\sigma$ and $\eta_m$ are the two main parameters that modify the dynamic of the economy.

**The role of $\sigma$** The higher $\sigma$ (i.e. the lower the intertemporal elasticity of substitution), the less optimizing households are willing to sacrifice their current consumption to build assets in response to a real interest rate increase. After a positive oil price shock, optimizing households in Nigeria face an increase of permanent income, but the short run impact depends on the monetary regime:

- In the fixed money supply regime, the real interest rate increases; the lower $\sigma$, the smaller the rise in Nigerian consumption;
- In the fixed exchange rate regime, the real interest rate falls; the rise of consumption in Nigeria is magnified if $\sigma$ is low

However, the general equilibrium effect depends on how the value of $\sigma$ modifies the real interest rate dynamic. Indeed, the real interest rate is less reactive for low values of $\sigma$: consumption dynamic is therefore little influenced by the inter-temporal elasticity of substitution.

**The role of $\eta_m$** We have assumed a low elasticity of substitution between non-tradable goods and imported goods ($\eta_m = 0.75$). Assuming a higher value of $\eta_m$ does not affect the main results of the simulation except that labor demand in the non-tradable sector may not increase after a positive oil-price shock in the fixed money supply regime: as the currency appreciates, the rise of consumption entirely weighs on imported goods.

## 7. WELFARE ANALYSIS UNDER OBSERVED PAST SHOCKS

After evaluating the behavior of our model in the face of a simple deterministic price shock, we now turn to comparing the aforementioned three monetary regimes with estimated shocks based on past series of $p_O$ and $p_A$. More specifically, we estimate a $VAR(1)$ model to get an estimate of the persistence of the shocks on these two price variables, as well as an estimate of the variance of innovations. Specifically, we estimate a $VAR(1)$ model on the log-prices of oil and cocoa beans between $1990Q1$ and $2008Q1$ (both detrended with a Hodrick-Prescott filter with parameter $\lambda = 1600$, which is standard for quarterly data). We use the price of cocoa beans as a shortcut to $p_A$ because cocoa beans represent more than half of agricultural exports for both Côte d'Ivoire, WAEMU's largest economy, and Nigeria (respectively $70\%$ and $55\%$ in $2003$).[20] The results are presented in Table 5. They show that oil prices and agricultural export prices are serially uncorrelated. Agricultural prices have a somewhat higher persistence than oil prices, and they are less volatile. Finally, the two shocks appear uncorrelated.

**Table 5 – $VAR$ estimates**

| | $p_O$ | $p_A$ |
|---|---|---|
| $p_O(-1)$ | $0.65^*$ | $-0.03$ |
| $p_A(-1)$ | $-0.12$ | $0.82^*$ |
| Innovation variance | $0.0149$ | $0.0077$ |
| $R2$ | $0.48$ | $0.68$ |

$^*$ indicates significance at the $5\%$ level.

[20] Source: FAOSTAT.

We then use these estimates as calibrations for the structure of the shocks affecting our model, and perform a second-order Taylor expansion around the steady state to measure the impact of economic volatility on the households' welfare-equivalent one-period consumption changes.

In order to compare monetary regime, we compute the conditional expected welfare at time zero, when the monetary regime is decided.[21] For given monetary and fiscal (stabilization fund) policy rules $\mathcal{P}$, welfare $W_{\mathcal{P}}$ is defined as:

$$W_{\mathcal{P}} = \mathbf{E}_0 \sum_{t=1}^{+\infty} \beta^t u_t(C_t, L_t) \tag{40}$$

Tables 6 and 7 show the one-period consumption variation wich is equivalent to the welfare loss due to the shock structure and the policy rules. It is defined as:

$$\Delta c = (W_{\mathcal{P}} - W_0){C_0}^{-\sigma} \tag{41}$$

were $W_0$ denote the welfare level in the absence of shocks. The volatility of consumption and labor supply has three origins in our model:

- The volatility of commodity prices;
- Price rigidities that introduce a discrepancy between prices and optimal prices;
- The monetary rule that is not necessarily optimal.[22]

We depart from the optimal monetary-policy literature in evaluating the welfare implication of the three 'simple rules' already studied in the previous section. Restricting our investigation to three simple rules seems appropriate since such rules are easily implementable. This argument is highly appealing especially in countries where the 'art of monetary policy' is not as developed as in advanced economies. We also estimate the welfare implication of a stabilization fund.

Table 6 presents the results when considering only oil-price shocks. As expected, the endogenous money supply policy causes large welfare losses in both countries as it exacerbates real exchange-rate and price variations both upwards and downwards. In this case, mis-allocations induced by the monetary policy are greater in WAEMU than in Nigeria because the agricultural sector is relatively larger than in Nigeria, so the labor allocation problem is more acute in this

[21] At time 0, the economy lies at the deterministic steady state; agents learn the structure of the shocks that will start hitting the economy at period 1; the monetary rule is decided and agents form their expectations. Then period 1 takes place.

[22] Absent wage rigidity, there would still be a welfare loss coming from mark-up variations in the non-tradable sector. The optimal monetary regime should therefore target non-tradable prices: by stabilizing non-tradable prices, monetary policy stabilizes mark-ups. However, in a monetary union experiencing asymmetric shocks, price stability in the non-tradable sector cannot be achieved simultaneously in the two regions.

**Table 6 – Welfare-equivalent, one-period consumption changes under different regimes, oil-price shocks only**

| | Nigeria | WAEMU | Union |
|---|---|---|---|
| Fixed money supply | | | |
| without stab. fund | -0,08% | -0.22% | -0.13% |
| with stab. fund | -0.01% | -0.00% | -0.00% |
| Endogenous money supply | | | |
| without stab. fund | -6.76% | -10.31% | -8.11% |
| with stab. fund | -2.33% | -4.13% | -3.01% |
| Fixed exchange rate | | | |
| without stab. fund | -0.32% | -0.02% | -0.21% |
| with stab. fund | -0.01% | 0.00% | -0.01% |

country.[23]

Although the two economies would agree on rejecting the endogenous money-supply regime, they would unlikely agree on which regime to be chosen: according to Table 6, and consistent with Table 4 above, Nigeria's best rule is a fixed money supply whereas WAEMU's first choice is a fixed exchange rate as it insulates it from oil price shocks.

By sterilizing part of oil export revenues, the stabilization fund helps mitigating money supply instability in the endogenous money supply regime. In fact, whatever the monetary regime, the stabilization fund helps to greatly reduce the welfare loss induced by oil-price volatility. Even though the monetary regime ranking is not modified by the introduction of the fund, smaller losses are involved.

**Table 7 – Welfare-equivalent one-period consumption changes under different regimes, agricultural-price shock only**

| Monetary regime | Nigeria | WAEMU | Union |
|---|---|---|---|
| Fixed money supply | 0,02% | -0.88% | -0.32% |
| Endogenous money supply | -22.51% | -48.52% | -32.40% |
| Fixed exchange rate | -0.94% | -4.75% | -2.40% |

We now considers the combination of oil and agricultural price shocks (sum of Table 6 and Table 7). WAEMU and Nigeria now clearly show the same preference for a fixed money-

[23]The model assumes that production decisions in the agricultural sector are based on current agricultural prices, so that monetary policy has a huge factor allocation effect between the two labor-intensive sectors. Conversely, if decisions take place one or two periods in advance, the welfare cost induced by agricultural shocks or badly designed monetary policies is lowered. However, the conclusion of the analysis remains the same.

supply regime. Thus, considering both types of shocks, the gain for WAEMU to mitigate the agricultural price shocks with a fixed exchange rate is larger than the cost from suffering the exchange-rate volatility implied by oil shocks. In this case, the two countries can agree on a fixed money supply rule, be there a stabilization fund or not.

## 8. CONCLUDING REMARKS

We have built a two-country DSGE model calibrated on Nigeria and WAEMU to assess the impact of commodity-price shocks in a currency union. More specifically, we contrast the impact of an oil-price shock to that of an agricultural-price shock, accounting for the fact that only Nigeria has significant production of oil whereas both economies do produce agricultural commodities.

We evaluate how the monetary regime (fixed exchange rate, floating exchange rate with exogenous money supply, floating exchange rate with endogenous money supply) of the currency union modifies the response of the oil-exporting and the non oil-exporting country to shocks. We also study whether a stabilization fund is able to reduce the volatility of both economies and the induced welfare losses. To do so, we successively study the impulse-response functions and use stochastic simulations based on historical volatility of crude oil and cocoa bean prices.

We find that an increase in the oil price has a positive impact on Nigerian consumption, although this economy suffers from a Dutch disease that can hardly be erased by appropriate monetary regime in a monetary union. Absent a stabilization fund, a flexible exchange rate with exogenous money supply (at the union level) produces the lowest level of volatility in consumption, whereas a fixed exchange rate leads to the highest volatility.

Conversely, the fixed money-supply regime produces the highest volatility of consumption in WAEMU in the face of oil-price shocks, whereas a fixed exchange-rate regime isolates the economy from the shock. However the two economies are better-off with a fixed money-supply regime if they are hit by both oil- and agricultural-price shocks.

Finally, we find that an oil-stabilization fund can be very successful in stabilizing both economies and reduce their possible disagreements on the common monetary policy.

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# APPENDIX

**Table A.1 – Calibration of the base model parameters**

| Parameter description | Name | Value |
|---|---|---|
| Riskless foreign interest rate | $r^*$ | 0.01 |
| Rate of time preference | $\beta$ | $\frac{1}{1+r^*}$ |
| **Inverse of the intertemporal elasticity of substitution of consumption** | $\sigma$ | 2 |
| **Inverse of the elasticity of labor supply** | $\phi$ | 1 |
| Share of non-Ricardian households in the population | $\mu$ | 0.75 |
| Returns to scale in production | $\gamma$ | 0.65 |
| **Fraction of $NT$ firms unable to reset price at every period** | $\nu_p$ | 0.8 |
| **Fraction of unions unable to reset wage at every period** | $\nu_w$ | 0.8 |
| Price elasticity of substitution in the $NT$ sector | $\epsilon_p$ | 7 |
| Share of international tradable in consumption | $\alpha_m$ | 0.3 |
| **Elasticity of substitution between $NT$ and $M$ goods** | $\eta_m$ | 0.75 |
| Share of WAEMU's non-tradable in Nigeria non-tradable consumption | $\alpha_n^{OA}$ | 0.10 |
| Share of Nigeria's non-tradable in UEMOA's non-tradable consumption | $\alpha_n^{Nig}$ | 0.06 |
| **Elasticity of substitution between domestic and foreign $NT$ goods** | $\eta_n$ | 2 |
| AR coefficient of order 1 for the $A$ sector price process | $\rho_{p_A}$ | 0.82 |
| AR coefficient of order 1 for the oil price process | $\rho_{p_O}$ | 0.65 |

**Figure A.1 – Oil price IRFs under the three monetary regimes without stabilization fund**

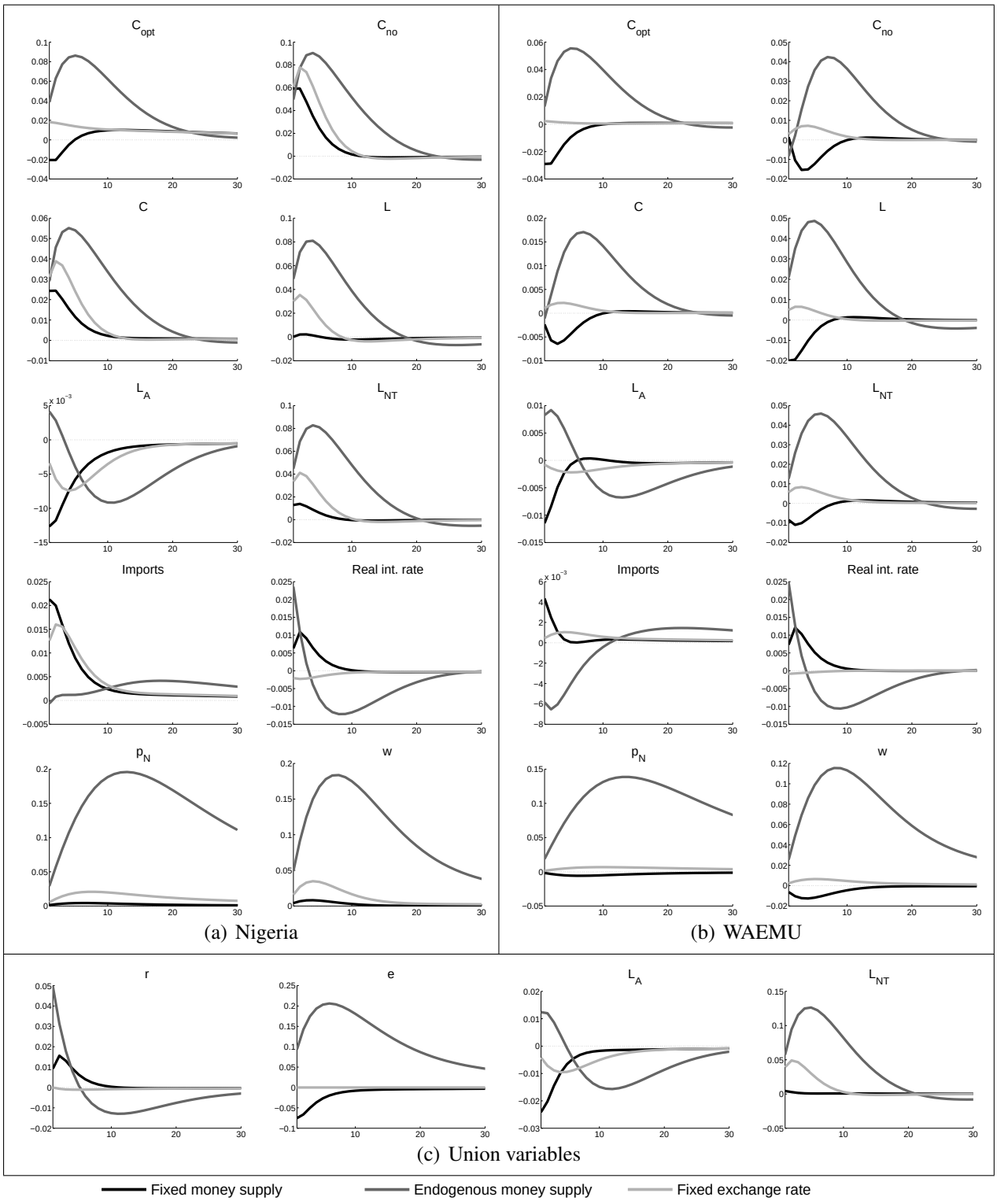


**Figure A.2 – Oil price IRFs under the three monetary regimes with stabilization fund**

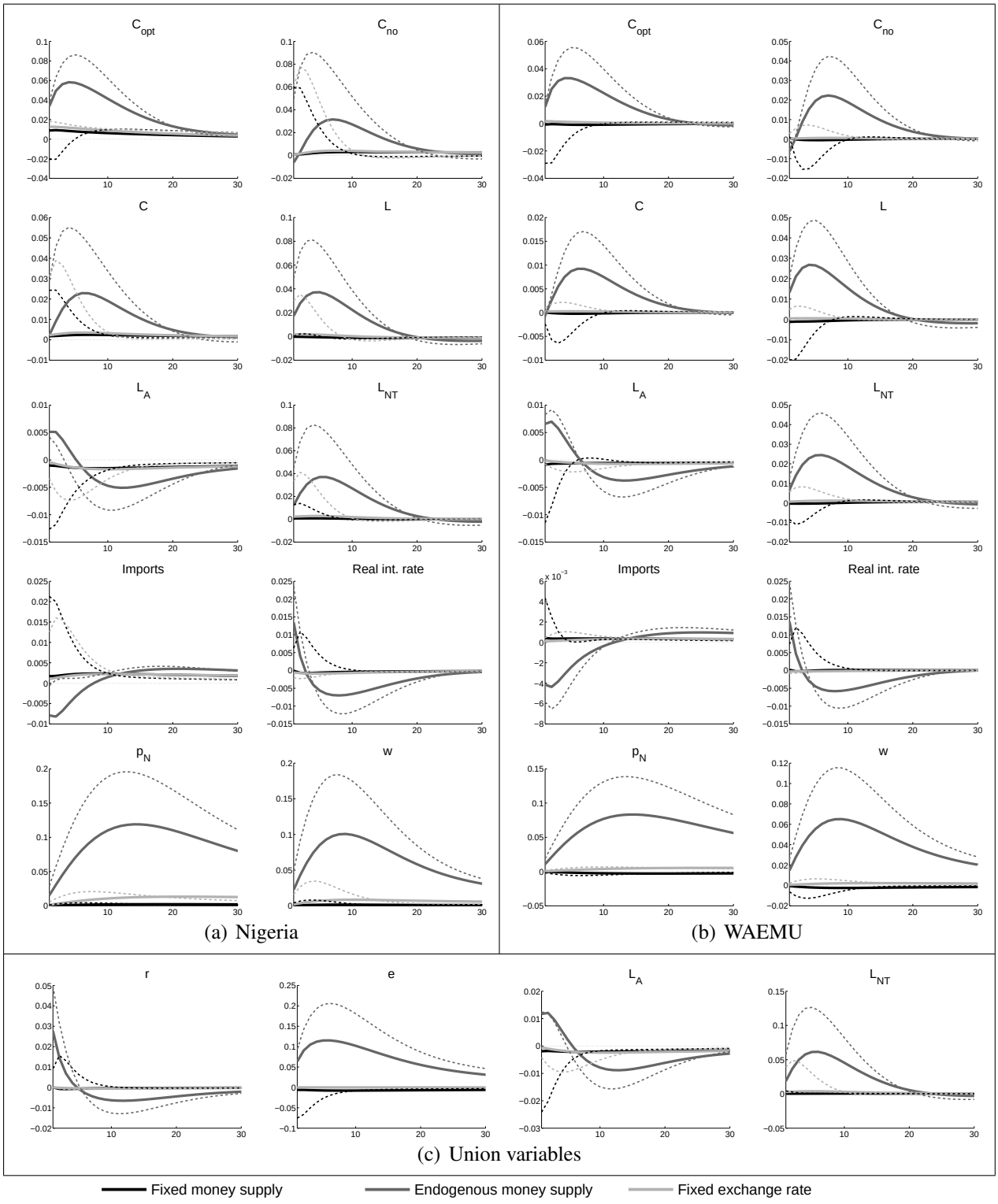
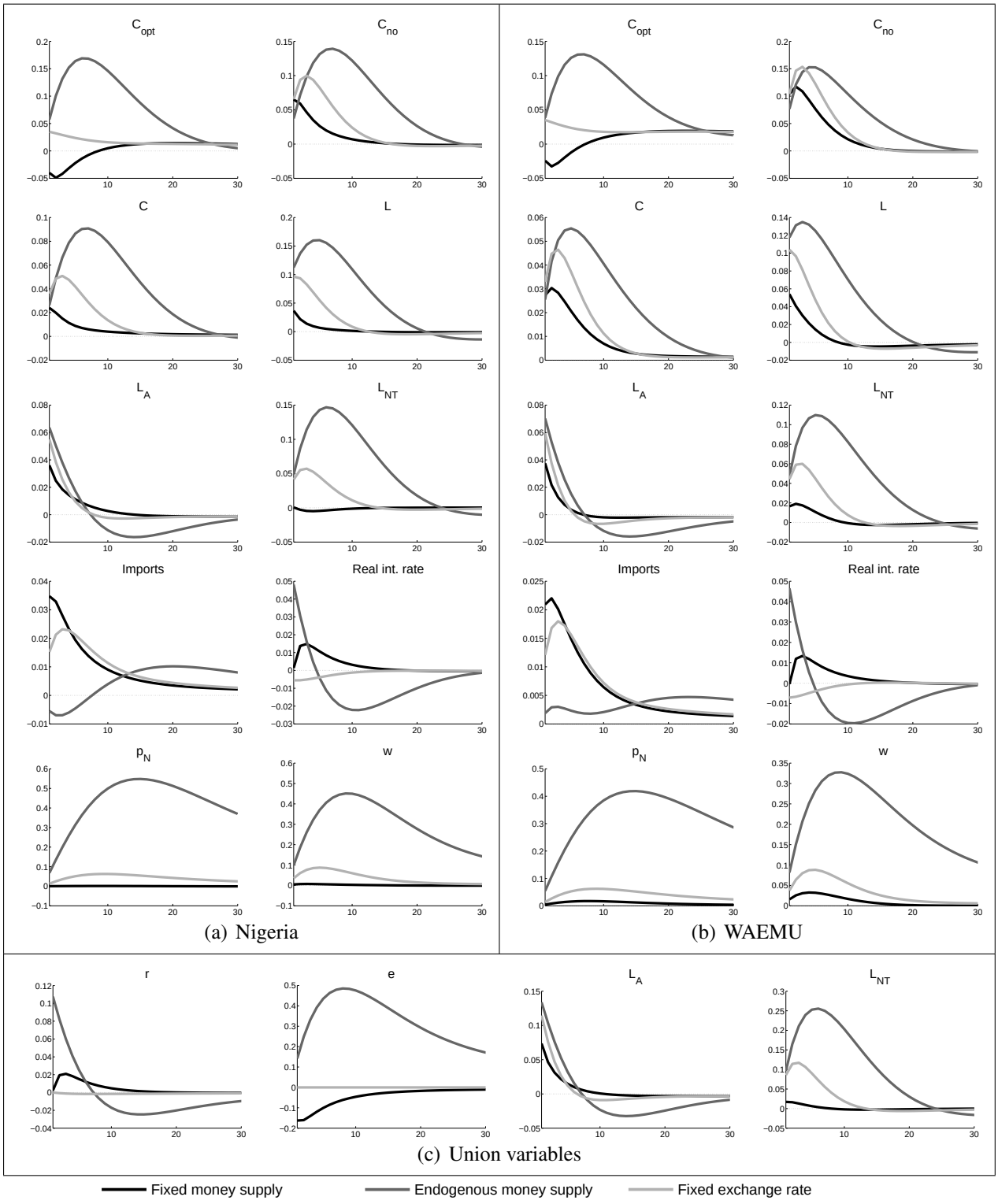


**Figure A.3 – Agricultural price IRFs under the three monetary regimes**



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ISSN : 1293-2574