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FOOD PRICE VOLATILITY IN CAMEROON: determinants, transmission and consequences

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by

KANE Gilles Quentin

Supervisors

Professor **Ngoa Tabi Henri**
University of Yaoundé II
Cameroon

Professor **Isabelle PIOT – LEPETIT**
National Institute for Agricultural Research (INRA)
France

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Devant le jury ci-après

Président :

M. le Professeur TOUNA MAMA
Université de Yaoundé II- Cameroun

Membres:

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Université de Yaoundé II - Cameroun / Directeur de Recherche

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Excusé.

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“The University of Yaoundé II does not intend to give any approval or disapproval to the opinions expressed in this dissertation. They should be attributed to the author, who takes the full responsibility.”

To my parents;

To late Professor Fondo Sikod;

To my dear Adele Alexis…

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ABSTRACT

This thesis analyzes food price volatility in Cameroon. First, we examine the determinants of food price volatility in Cameroon. Second, we analyse the transmission of food price volatility in Cameroonian markets. Third, we analyse the supply response to price and volatility for some major staple crops grown by agricultural households in Cameroon. Fourth, we analyse the welfare effects of food price volatility on Cameroonian households. Using diverse econometric methods, results show that food price volatility in Cameroon is determined by the volatility of the price of other local agricultural crops, and not by factors coming from international markets such as volatility of crude oil price and price volatility of import of cereals. This result is confirmed in the case of rice, where there is no price volatility transmission between the world market and Cameroonian markets. Furthermore, results also indicate that producers respond to price volatility by principally increasing their surface area for cultivation and reducing investment in agricultural inputs to improve yield. Finally, poor households are the most affected by food price volatility, with welfare losses from food price volatility depending on the extent of the price hikes. Two main policy lessons are drawn from this thesis. Firstly, it may be important to implement more specific development projects based on commodities such as local cereals, roots and tubers and find ways to improve the efficiency of existing development programs in the agricultural sector. Secondly, knowledge capacity on how household structure and spatial repartitioning of households are affected by changes in food prices, and the responsiveness, can be necessary to implement efficient policies to fight against hunger and poverty.

Key words: Food price volatility, Price volatility transmission, Supply response, welfare

RESUME

Cette thèse a pour objectif d'analyser la volatilité des prix des produits agricoles au Cameroun. Premièrement, nous examinons les déterminants de la volatilité des prix des produits agricoles au Cameroun. Deuxièmement, nous analysons la transmission de la volatilité des prix des produits agricoles sur les marchés camerounais. Troisièmement, nous analysons la réponse de l'offre à la volatilité des prix agricoles pour les principales cultures de base cultivés par les ménages agricoles au Cameroun. Quatrièmement, nous analysons les effets de la volatilité des prix agricoles sur le bien-être des ménages camerounais. A partir de diverses méthodes les résultats montrent que la volatilité des prix des produits agricoles au Cameroun est déterminée par des facteurs locaux à savoir la volatilité du prix des autres produits agricoles. Elle n'est pas déterminée par des facteurs provenant des marchés internationaux à l'instar de la volatilité des prix du pétrole brut et la volatilité des prix des céréales importées. Ce résultat est confirmé dans le cas du riz, où il n'y a pas de transmission de la volatilité des prix entre le marché mondial et les marchés camerounais. En outre, les résultats indiquent que les producteurs réagissent à la volatilité des prix par une augmentation des surfaces cultivées et une réduction des investissements dans les intrants pour l'amélioration de la productivité. Enfin, il apparaît que les ménages pauvres sont les plus touchés par la volatilité des prix agricoles et les pertes de bien-être dues à la volatilité des prix des produits agricoles dépendent de l'ampleur de la hausse des prix. Deux principaux enseignements en termes de politique économique sont tirés de cette thèse. premièrement, il peut être plus important de mettre en œuvre des projets de développement plus spécifiques basés sur d'autres produits tels que les céréales locales, les racines et tubercules, et trouver des moyens d'améliorer l'efficience des programmes de développement existants dans le secteur agricole. Deuxièmement, la connaissance de la façon dont les différents types de ménages dans différents milieux sont affectés et sont sensibles à la volatilité des prix des produits agricoles peut être nécessaire pour mettre en œuvre des politiques de lutte contre la faim et la pauvreté efficientes.

Mots clés: Volatilité des prix agricole, Transmission de la volatilité des prix, Réponse de l'offre, Bien-être

ABBREVIATIONS

ADF	:	Dickey-Fuller unit root test
AIDS	:	Almost Ideal Demand System
APARCH	:	Asymmetric Power Autoregressive Conditional Heteroskedasticity
ARCH	:	Autoregressive Conditional Heteroskedasticity
ARDL	:	Autoregressive Distributed Lag
ARMA	:	Autoregressive Moving Average
BEKK	:	The Baba-Engle-Kraft-Kroner
CCC-GARCH	:	Constant Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity
DCC-GARCH	:	Dynamic Conditional Correlation - Generalized Autoregressive Conditional Heteroskedasticity
DSCE	:	Strategic Document on Growth and Employment
DSRP	:	Poverty Reduction Strategy Paper
ECAM	:	Cameroonian Household Survey
ECM	:	Error Correction Model
FAO	:	Food and Agriculture Organization
GARCH	:	Generalised Autoregressive Conditional Heteroskedasticity
GDC-GARCH	:	General Dynamic Covariance - Generalized Autoregressive Conditional Heteroskedasticity
HLPE	:	High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security
IFPRI	:	International Food Policy Research Institute
IMF	:	International Monetary Fund
KPSS	:	Kwiatkowski, Phillips, Schmidt and Shin unit root test
LOP	:	Law of One Price
MGARCH	:	Multivariate Generalized Autoregressive Conditional Heteroskedasticity
MINADER	:	Ministry of Agriculture and Rural Development
MINEPAT	:	Ministry of Economy, Planning and Regional Planning
NIS	:	National Institute of Statistics
OECD	:	Organization for Economic Co-operation and Development
OLS	:	Ordinary Least Squares

QUAIDS	:	Quadratic Almost Ideal Demand System
TAR	:	Threshold Autoregressive model
UECM	:	Unrestricted Error Correction Model
VAR	:	Vector Autoregressive
VECM	:	Vector Error Correction
WFP	:	World Food Programme

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GENERAL INTRODUCTION

1. Background

In the economic literature, it is commonly held that agriculture contributes significantly to economic development. Indeed, agricultural growth contributes more to development due to its significant multiplier effects on economy. Food prices are on a primary interest for policy, since it can have impact on farmers prosperity, consumers, agribusiness, exporters, importers and, indirect effects on the income and employment of many others Sectors (Norton, 2005). Therefore, food price volatility is one of the threats in agriculture, especially in developing countries (Subervie, 2007). Moreover, since the world food crisis of 2007-2008 and the resulting urban riots observed in about forty developing countries, the question of food price volatility is at the very heart of the debate (Galtier, 2009).

The world food market is characterized by high volatility (FAO, 2012; Grimoux et al., 2005). The volatility of agricultural prices implies that prices fluctuate greatly, rapidly, and suddenly over time. Therefore, one can distinguish between three types of price volatility: "*natural*" price volatility[1], food price volatility that can be "*imported*"[2], and finally, "*endogenous*"[3] price volatility (Galtier, 2009).

Agricultural price volatility requires a distinction between the average price level and price volatility over time, since the costs and benefits of higher prices level differ from the costs and benefits of the price volatility (FAO, 2011). As noted by the Food and Agriculture Organization (FAO), although high price levels are generally correlated with high volatility, it is possible to have a situation where the price volatility remains unchanged when one observes a change in the price level and vice versa. However, the average price level and the price volatility are both determined by supply and demand. Additionally, high price levels are advantageous for producers who witness market surpluses. In the case of poor producers, who buy more food than they sell, the rise in food prices can increase poverty, insecurity, and undernourishment (FAO, 2011). But, when price changes are unpredictable, as it is the case

[1] The food price volatility is called natural because it is the result of the effects of natural hazards and environmental conditions (locusts, rainfall, temperature, etc.) affecting the production and supply from one period to another.
[2] Food price volatility can also be imported from international markets.
[3] Endogenous food price volatility refers to the variability of stakeholders expectations in the market.

with price volatility, poor farmers are exposed to the poverty trap and they reduce their investment[4].

In the long-term, food price volatility reduces access to food, and poor households generally adapt by reducing their non-agricultural expenditure. This generally tends to affect the living standards of children and their overall development prospects in the future (FAO, 2008). When food price volatility negatively affects consumers, effects on producers is ambiguous. Food price volatility increases uncertainty, making household prediction and planning about their food expenditure more difficult. When this situation persists, it can lead to great losses for producers because the changes in prices are too fast for them to adjust to the changing market prices (IFPRI, 2011). Thus, food price volatility leads to greater difficulty in making optimal decisions about production.

International food price volatility has a direct impact on the ability of African households to feed themselves, as made evident by the 2007-08 food crisis. According to the FAO Commodity Market Review, in 2008 the prices of traditional staples crops (such as rice, maize, and wheat) increased significantly and suddenly, reaching their highest levels in nearly thirty years. A year earlier, the largest increases in the number of undernourished in the world occurred in sub-Saharan Africa (SSA), and in the Pacific and Asia. Moreover, as shown by the FAO (2008), 24 additional million people in SSA have shifted under the poverty line because of rising prices.

One of the direct consequences in such a situation of agricultural price volatility can be reduction of incentives to invest in production and therefore reducing the increase in supply. It should be noted that in rural areas in Africa, the distinction between producer and consumer is unclear. Indeed, many households are both producers and consumers. Therefore, when prices are volatile, households will reduce their inputs spending and this may have an impact on the quantity and quality of the food supply (IFPRI, 2011). Additionally, the food price volatility deteriorates the balance of payments for the government, for both net importers and net exporters of agricultural commodities and thus affects their investment capacity and ultimately growth.

Cameroon was one of those developing countries in SSA strongly affected by the 2008 food crisis. This has raised the debate on the role of agriculture in this country, food security and

[4] A reduced use of fertilizer and innovative inputs can leads to a decrease in productivity and hence a decrease in production.

even food self-sufficiency because Cameroon depends heavily on food imports. In Cameroon, agriculture is the main source of income and employs around 45% of the labor force (NIS, 2015). Additionally, the agricultural sector generates foreign exchange accounting for 50% of non-oil exports (WFP et al., 2011). This suggests that this sector, indisputably, occupies a strategic place in the national economy in terms of foreign exchange earnings, employment generation, wealth creation, social stability, food security, food self-sufficiency, and poverty alleviation. However, two major features characterize agricultural supply in the country: firstly, production is growing at a rate of 2.4% that is smaller than the population growth rate (2.8%), with urbanization growth rate of 4.5% per years (WFP, 2016). Secondly, Cameroon witnessed a decrease in rural population, which represents 71.5% of the total population in 1976 and nearly 50% in 2008 (Medou, 2008). The resulting effect was an increase in the gap between rural production (the main food provider) and national food demand. Consequently, imports increased to balance supply and demand, thereby making the country vulnerable to external shocks.

In addition, even if inflation was moderate during the 2000s, the low economic growth and the increase in prices of some essential goods has helped to erode the purchasing power of households in Cameroon (Awono and Havard, 2011). Thus, in this period, the agricultural price volatility has had dramatic consequences for the state and households. For example, between 2005 and 2007, the prices for rice, chicken, beef and fish increased by 50%, 103%, 44.5% and 30% respectively. More importantly, the price of a liter of palm oil has increased by 72% between June and December 2007 (Medou, 2008). In an environment where 37.5% of the population lives below the poverty lines (NIS, 2015), price volatility negatively affects the purchasing power of households leading to adjustments in the structure of their expenditure. In such a situation, households may substitute and even sacrifice their health spending, education spending, etc. and this can directly affect the nutrition status and household food security.

Further, the recent world food crisis, revealed a weak performance of agricultural sector in Cameroon (DSCE, 2009). Food importation indicates that Cameroon depends strongly on international food market. For example, the import of wheat has increased by 40%, those of cereals, milk, and dairy products by 50%, and those of rice and meat by 70% and 13%, respectively, between 1961 and 2007 (Awono and Havard, 2011). Despite the implementation of an emergency plan in recent years by the Ministry of Agriculture and Rural Development to increase agricultural production, the question of the lack of food supply still remains unanswered. In addition the civil riots of February 2008 in Cameroon have shown the vulnerability of urban households to food price volatility (Ntsama Etoundi, 2011).

2. Statement of problem

According to the FAO, the 2007-2008 food crisis increased the number of undernourished from 850 million in 2007 to about 1.23 billion in 2009. Moreover, between 2007 and 2008, for example, prices rose by 37.5% for sugar, 224% for rice, 77% for maize, and 118% for wheat. The food price volatility, which characterized the 2008 crisis, affected millions of people in their nutritional status and food security. Likewise, the food price volatility has reduced the growth prospects and increased poverty in developing countries (HLPE, 2011). This crisis situation generated riots in many developing countries like Cameroon in 2008. Furthermore, food price volatility is likely to continue in the future, particularly as a result of climate change, increasing the uncertainty and instability of agricultural production (Blein and Longo, 2009; FAO, 2012), the increase in demand due to use of biofuel, and the anticipated rise in input costs related to energy (FAO, 2011; FAO and OECD, 2011), amongst others. According to the OECD and FAO perspectives, all food prices will increase above average in 2020 compared to the previous decade. The price of rice and maize, for example, should increase by 15% and 20% compared to the average of the last decade. It appears, in this context, that households are vulnerable to food price volatility. In order to take advantage of opportunities of food price volatility, states and actors, especially the most vulnerable among them, must have alternatives and appropriate actions to reduce risks and uncertainties (Grimoux et al., 2005).

One of the main problems of food price volatility in developing countries at the micro level is the variability and instability of incomes of both producers and consumers. In addition, excessive price fluctuations influence investment decisions in the agricultural sector by creating additional uncertainty for the producer (HLPE, 2011). Indeed, in economics, the price evolution over time is normal. However, when agricultural price fluctuations are important, suddenly, and unpredictably around their trend, this becomes problematic for both producers and consumers. This generates uncertainty for producers, traders, consumers, and governments. This uncertainty can lead to sub-optimal decisions (FAO and OECD, 2011). In Addition, due to the variability of the agents' income, their welfare can be affected in a context where they are price takers as it is the case in developing countries such as Cameroon.

On the other hand, at the macro-level, to manage the problem of food price volatility, policy makers have to address the issue of its causes, since the solutions for this problem depends largely on the nature and type of these causes (Boussard, 2010). Therefore, before analyzing the effect of the food price volatility on the well-being of households, it seems imperative to look at the determinants and the transmission mechanisms of food price volatility. In fact, in the African context, these questions seem to have never been addressed simultaneously in a unique study, to the best of our knowledge. In Cameroon, given the importance of the agricultural sector, knowledge about food price volatility seems to be important. Thus, the fundamental question of this thesis attempts to answer is: ***what are the determinants, the transmission and the consequences of food price volatility in Cameroon?***

To answer the main research question, the following specific questions are formulated:

- What are the determinants of food price volatility in Cameroon?
- How is the transmission of food price volatility in Cameroon?
- How does food supply respond to food price volatility in Cameroon?
- What is the effect of food price volatility on the household's welfare in Cameroon?

3. Objectives of the study

The main objective of this study is to analyse food price volatility in Cameroon. Specific objectives are to:

- Determine and analyze the determinants of food price volatility in Cameroon;
- Analyze the transmission of food price volatility in Cameroon;
- Examine and analyze the supply response to food price volatility in Cameroon;
- Analyze the effect of food price volatility on the welfare of consumers in Cameroon.

4. Significance of the study

The present study can be justified by the fact that the issue of food price volatility has become a major concern across the globe. Indeed prices are very important in economics and they can also be the conduit through which economic policies can affect agricultural variables such as supply, output, exports, and income (Dercon, 1993). Therefore, it is important to know what determine food price volatility, its transmission, supply response, and its effect on household's welfare in least developed countries such as Cameroon, in order to adopt adequate policies that provide accurate price incentives and manage risks and uncertainties of agricultural production. A better comprehension of all these issues about food price volatility seems to be the primary condition to sound policy advice for the country. Furthermore, according to Molua (2010a), an analysis of agricultural supply responses to price volatility is a crucial element in assessing the effects of increasing openness of the economy. Finally, in the literature, there is a dearth of studies on the impact of food price volatility on household's welfare in least developing countries such as Cameroon. Therefore, this study aims to fill this gap.

5. Brief literature review

Several studies in the literature analyses theoretically and empirically the determinants, transmission, consequences of food price volatility.

Determinants of food price volatility

Theoretically, at least two assumptions explain food price volatility: the exogenous explanation and the endogenous explanation. Regarding the first assumption, price volatility is due to the nature (Grimoux et al., 2005; Roll, 1984). In this case, price volatility is caused by the variability of food production from one year to the other due to climatic variables which affect production (Galtier, 2009). Volatility is thus exogenous and stochastic. According to the second hypothesis, food price volatility is endogenous and volatility is generated by the functioning of the market (Boussard, 1996, 2007, 2010; Burton, 1993; Deaton and Laroque, 1992; Muth, 1961; Samuelson, 1971). In this case, one can have at least two set of explanations. First, recall that agricultural production is characterized by uncertainty and risk such as production uncertainty[5], price uncertainty[6], technological uncertainty[7] and policy uncertainty[8]. Price and production uncertainties therefore may cause

[5] Production uncertainty is due to the fact that production function is stochastic. Indeed, in agricultural production, farmer may not be able to predict exactly the amount and quality of output that will result for production process.
[6] Price uncertainty is caused by the sequence of decision and delay between production decision and selling final product.
[7] Technological uncertainty means that the technology used by producer may give less than expected yield.

price volatility (Moschini and Hennessy, 2001). Second, the endogenous explanation of food price volatility can be theoretically be based on the cobweb model due to Ezekiel (1938). This model is based on the time lag between supply and demand decisions.

Recalling that food price volatility can be explained by exogenous and endogenous factors, Ajakaiye and Adam (2011), following Abbott and Borot de Battisti (2011), showed that, although the recent food price volatility in 2006 and 2008 can be explained mainly by a fundamental shift in patterns of demand, the importance of climate change and the greater use of oilseeds and grains as oil substitutes are not negligible. However, the importance of financial factors remains a subject of debate in the literature. On the other hand, Mitra and Boussard (2011) proposed to model the market functioning using a chaotic model with storage. These authors have shown that it is still very difficult to decide between the endogenous and exogenous explanations of food price volatility by the experimental method. Balcombe (2010) using both a random parameter models with time varying volatility and a panel regression concluded that past volatility, transmission across price, stock level, oil price, and exchange rate explain agricultural price volatility. In Cameroon, Minkoua Nzie (2008), in the case of market gardeners and plantain farmers, concluded that price volatility can be explained by the formation of expectations as an endogenous factor, using the cobweb approach. The latter author also identified the perishability of the product, transport costs, and policies, as exogenous factors. Gerald (1996) using the Autoregressive Conditionally Heteroskedastic (ARCH) model in Ghana, show that adopting economic reform will increase maize price volatility before slightly reduced price variability. In this case, devaluation in 1983 due to a structural adjustment has briefly caused rise in maize price volatility. Chavas and Holt (1993) showed that the rigidity of the demand can explain price volatility as endogenous variable. In the case of the dairy sector in the US, these authors suggested that the most price inelastic demand is the more chaotic the dynamics of the model becomes. Moreover, Roll (1984) showed that although the orange juice production in Florida is concentrated in the less temperature area, price volatility in this market is partially explained by climatic risks.

While similar issues are addressed, this chapter extends the existing research work in several important ways: our focus is on a different country and a wider variety of crops. In addition, while most studies of agriculture in the Cameroon revolve around the cash crops (cocoa and

[8] Policy uncertainty is one major source of risk in agricultural investments. In fact many orientations of economic policies have an impact on agricultural production such as land tenure reforms, trade liberalization, taxes, regulation, interest rates, provision of public’s goods, exchange rates and so on.

coffee), the importance of food crops such as grain, root and tuber cannot be overlooked. In this research work, we assume that the volatility of food prices in Cameroon can be determined by a set of domestic factors such as policies shocks but also by elements of the international markets which can be viewed as exogenous shocks on the prices formation.

Transmission of food price volatility

In the neoclassical theory, price transmission can be theoretically justified by the Spatial and Temporal Price Allocation Model by Takayama and Judge (1971) and the Mashallian Law of One Price. According to Takayama and Judge (1971), when a market is related to the international market, the prices applied in this market are aligned on the international prices expressed in the same currency.Therefore, it is the spatial arbitration of the actors which generates price transmission. Given an optimal situation, when markets are integrated in the long-term, the price differences between regions are reflected only by the transaction costs according to the law of one price[9] (Marshall, 1936).

It is worth noting that, even if price volatility transmission is very close to price transmission since they both deal with links between spatially separated markets or along the value chain, there is a fundamental difference in the literature between these two concepts. Indeed, price transmission is related to the transmission of the predictable "portion" of prices between spatially separated markets, contrary to price volatility transmission that focuses on the transmission of the unpredictable "portion" of prices between spatially separated markets (Assefa et al., 2015).

Empirically, price volatility transmission has been well-documented in financial markets, but has received relatively less attention in agriculture. In most of the cases, price volatility transmission is detected along the value chain (Buguk et al., 2003; Khan and Helmers, 1997; Khiyavi et al., 2012; Natcher and Weaver, 1999; Rezitis, 2012 amongst others; Uchezuba et al., 2010; Zheng et al., 2008) and among spatially separated markets (Cipollini et al., 2015 amongst others; Hernandez et al., 2014; Rapsomanikis and Mugera, 2011; Von Ledebur and Schmitz, 2009; Zhao and Goodwin, 2011).

[9] Nevertheless, this is possible if at least four conditions are effective: transparency of information, the absence of trade barriers, the absence of risk aversion, and the existence of one or more competitive markets.

Supply response to food price volatility

In the literature, the majority of studies estimate the price elasticity of agricultural supply within the Nerlove (1958) framework. In this approach, a dynamic element is introduced into the response equation by creating expectation (Tripathi, 2008). Furthermore, hypotheses of lower aggregate agricultural supply response in the case of developing countries was suggested by (Thiele, 2000). The main reason is that, the response takes time to be realized and the supply factor such as land is fixed in the short term. The use of time-series techniques such as co-integration analysis becomes current for estimating supply response. Since this approach does not require any restriction on the behavior of quantities and prices, it only assumes a co-movement of the variables in the long-run (Thiele, 2000). Finally, the data constraint is a guide in the choice of the appropriate approach for analyzing supply response.

On the producer's side, price instability directly affects the food aggregate supply, but this effect depends on the characteristics of countries[10]. Food price volatility in long-run can also affect directly income and then, infant youthful survival (Subervie, 2007) since the contribution of the agricultural sector to the economy is largely dependent on the producer’s responsiveness to economic incentives (Kanwar, 2006; Tripathi, 2008). Molua (2010b), using both the Nerlovian model and the Error Correction Model (ECM), suggested that the rice production responds to increasing prices and depends on weather and irrigation in Cameroon. Development of infrastructure, promoting irrigation technology, building capacity of producer etc. are therefore important factors that would be taken into consideration in agricultural policy promoting supply response to price incentives. Mythili (2008) showed that, in response to price incentives, more intensive applications of non-land inputs used by famers. Finally Kwanashie et al. (1998) confirmed two major results of the supply response literature: (i) in long-run, price elasticities of individual crops are higher than short-run elasticity and (ii) the response for commodity sub-sectorial aggregates in prices of individual crops is not significant. Similar results were obtained by Alemu et al. (2003). Alternatively, some authors have confirmed the hypothesis that, in long-run, the agricultural supply response to price is inelastic in developing countries (Abou-Talb and El Begawy, 2008; Muchapondwa, 2009; Mushtaq and Dawson, 2003). The main reason can be the structural constraint and the conviction that producer responds to price incentive when the price change is viewed as permanent. However, for other authors as Yunus (1993), there can be a conflict between the

[10] Infrastructures, financial system, and inflation.

high response for cash crops and the low response for subsistence crops which can be viewed as a zero sum game.

Literature on supply response in the case of Cameroon is relatively rare. To the best of our knowledge, there are just two studies from Molua (2010a, 2010b) on the estimation of supply response. Even if these studies confirm the responsiveness of farmers to price incentive, they focus only on rice, which is not amongst the major crops grown by farmers. The present study is an attempt to fill this gap by analysing the supply response for the major staple crops grown by agricultural households in Cameroon, namely maize, groundnut and cassava.

Impact of food price volatility on household welfare

In the microeconomic theory, the impact of changes in prices on household welfare is generally analysed in two ways: the compensating variation and the consumer surplus framework. Firstly, the analyses of the impact of the change in food prices on household welfare using the compensating variation were introduced by Deaton (1989) and this approach is the most often used in the literature (Ackah and Appleton, 2007 etc.; Deaton, 1989, 1997; Friedman and Levinsohn, 2002; Niimi, 2005). The focus of this approach is that, when a change in prices occurs, there is a certain amount of money that the consumer can accept and require to compensate this price change. Secondly, for the classical view, the effect of changes in prices on the household welfare can be estimated in the resulting change in the consumer's surplus (Ferreira et al., 2011). For these two approaches, the Hick's compensating variation can be used. However, as noted by Turnovsky et al. (1980) the consumer's surplus as a measure of economic welfare is not a subject of consensus in the literature.

In the literature, the choice between high food prices versus low food prices is known as the food price dilemma (Timmer et al., 1983). Although high food prices can spur employment and production, low food prices can stimulate consumption by the poor. Additionally, food price volatility can affect consumer welfare. Ferreira et al. (2011) estimated household welfare consequences of the food price rise in 2008. Using the consumer surplus framework, these authors concluded that the overall impact of food price volatility in Brazil was U-shaped. Indeed, it is the middle-income groups which suffered more of welfare losses than the very poor. Bellemare et al. (2010) analyses the willingness to pay for price stabilization, and derived a measure of multivariate price risk aversion. Their results suggested a distributional regressive benefit incidence from price stabilization policy in Ethiopia. Leyaro (2009) showed that price increases have negatively impacted the consumer welfare during the 1990s and

2000s. In particular, compared to the urban non-poor, the rural poor were mainly worst off. Similar results were obtained by Ackah and Appleton (2007), using a linear approximation of the Almost Ideal Demand System (AIDS) model for the food demand function and the compensating variation framework. Barrett and Dorosh (1996), using nonparametric density estimation and kernel smoothing techniques, suggested that increases in the variance or mean of rice prices have a significant negative effect on household welfare in Madagascar. But, this effect is higher for farm households who fall below the poverty line. On the other hand, Turnovsky et al. (1980) showed that, the consumer's preference for price instability is at least a function of demand the price elasticity, the income elasticity of demand for the commodity, the coefficient of relative risk aversion, and finally, the share of the budget spent on the commodity for which the price is stabilized.

Despite the abundance of literature, little is known about how households in Cameroon respond to food price changes and the welfare effects of such a situation. Previous studies used statistical methods to measure the effect of food price volatility on the purchasing power of households (Medou, 2008; MINEPAT, 2008). They showed that food price volatility adversely affected the purchasing power of households and subsequently their nutritional status. This research work goes further and analyses the impact of food price volatility on household's welfare in Cameroon using data from the third Cameroonian household consumption survey. Since socio-economic and demographic characteristics of households play an important role in determining their demand patterns, the demand model is estimated taking into account heterogeneity across households.

6. Methodology

This study applies four methods to respond to each specific objective:

- ***Determinants of food price volatility in Cameroon***

Secondary time series data from the International Monetary Fund (IMF) and the National Institute of Statistics (NIS) are used to analyze the determinants of food price volatility in Cameroon. This study focuses on two groups, namely cereals[11] and the group of roots and tubers[12], that accounts for about 50% of the total demand of food consumption in Cameroon

[11] Rice and wheat coming from the world market, and local maize.

[12] Cassava, cocoyam, and plantain.

and constitute the most significant calorie contribution (Medou, 2008). We consider the period from January 1994 to December 2010, with 204 observations per variable.

In this part of the thesis, our econometric approaches to models volatility were based on the Autoregressive Moving Average (ARMA), Generalized Autoregressive Conditional Heteroskedastic model (GARCH) and GARCH-X methods as in financial time series in order to take into account the fact that volatility can change with time.

- ***Transmission of food price volatility in Cameroon***

We use the same data set as for the first objective. However, it is worth noting that this chapter focuses on rice, which can be seen as a commodity of high importance in Cameroon in terms of consumption and importation as noted by ACDIC (2006).

To analyse the volatility transmission between Cameroonian markets, a class of Multivariate GARCH models were estimated, namely a Constant Conditional Correlation model (CCC-MGARCH) and a Dynamic Condition Correlation model (DCC-MGARCH) to take into account time varying volatility. Indeed, the MGARCH models are the most appropriate techniques when analysing the transmission of price volatility (Assefa et al., 2015; Bauwens et al., 2006).

- ***Supply response to food price volatility in Cameroon***

This section uses the annual national level data from both the FAO (2015) and Jones (2014), for the period of 1966 to 2012 to estimate the agricultural supply response to food price volatility in Cameroon. This study focuses on the major staple crops grown by agricultural households in Cameroon, namely maize, groundnut, and cassava according to the 2007 Cameroonian Household Survey.

For the empirical analysis, this section (or chapter) used the Autoregressive Distributed Lag (ARDL) approach proposed by Pesaran et al. (2001). Indeed, as mentioned by Muchapondwa (2009), the choice of ARDL bounds testing approach can be justified by the fact that this procedure is simple and allows the estimation of co-integration relationship by Ordinary Least Squares (OLS) contrary to other multivariate techniques such as Johansen and Juselius (Johansen and Juselius, 1990), amongst others.

- ***Impact of food price volatility on household welfare in Cameroon***

Data from the 2007 Cameroonian household consumption survey (ECAM III), carried out by the National Institute of Statistics (NIS) of Cameroon is used in this last chapter. Data were aggregated into four groups according to the nomenclature adopted by the National Institute of Statistic: cereals, roots and tubers, animal products, and vegetables. Due to data limitation, and excluding households who do not consume the commodities retained in this study, we use a sample of 2,665 households from ECAM III.

The compensating variation framework is used to analyse the effect of food price volatility on household's welfare (Badolo and Traore, 2012 etc.; Leyaro, 2009; Minot and Goletti, 2000; Tafere et al., 2010).

7. Outline of the thesis

The thesis is divided into two broad parts. Each part consists of two chapters. Whereas the focus in the first part is on the determinants and transmission of food price volatility in Cameroon, in the second part of the thesis we look at the consequences of food price volatility in Cameroon. In chapter 1, we analyse the determinants of food price volatility in Cameroon. In chapter 2 a class of MGARCH models is used to analysed the transmission of food price volatility in Cameroon. Chapter 3 looks at the agricultural supply response for food price volatility in Cameroon. Lastly, chapter 4 evaluates the impact of food price volatility on household's welfare in Cameroon.

PART I: DETERMINANTS AND TRANSMISSION OF FOOD PRICE VOLATILITY IN CAMEROON

INTRODUCTION TO THE FIRST PART

Why does food price evolve as it does? An understanding of this issue is a central question for African economies as mentioned by Deaton (1999). Moreover, a particular attention is given to this question since the 2007/08 food crisis that has revealed the vulnerability of poor people to food price volatility. Theoretically, food price volatility can be explained by exogenous factors, which are beyond the control of farmers such as climate, innovation, governmental policies, the transmission across prices, products specificities, and non-agricultural factors, amongst others. Food price volatility can also be determined by endogenous factors such as errors in agents expectations and price series properties themselves, as shown by the cobweb phenomenon, the speculative bubbles approach, and the chaos phenomenon.

Due to the heterogeneity of approaches about the determinants of food price volatility, a better understanding of determinants and transmission of food price volatility appears necessary to manage its consequences in developing countries such as Cameroon.

The first part of this thesis focuses on the determinants and transmission of food price volatility in Cameroon. Firstly, determinants of food price volatility in Cameroon are analysed using the Autoregressive Moving Average (ARMA), Generalized Autoregressive Conditional Heteroscedasticitic model (GARCH) and GARCH-X models (chapter 1). Secondly, the linkages between different separated markets are analyzed through the transmission of food price volatility in Cameroon using a class of Multivariate GARCH models (chapter 2).

CHAPTER 1: DETERMINANTS OF FOOD PRICE VOLATILITY IN CAMEROON[13]

Introduction

The analysis of price volatility is very important in economics. Indeed, volatility often appears as one of the fundamental characteristics of agricultural markets. An analysis to understand why prices evolve as they do and mainly what explains the variations in prices is a central question for African economies (Deaton, 1999). Indeed, without such information, it would be very difficult to forecast the evolution of prices and consequently, to produce good recommendations for the design of economic policies.

The objective of this chapter is, therefore, to measure the volatility of food prices in Cameroon and to find out the factors that influence it. Specifically, the chapter seeks to analyse the price series trajectory and the determinants of these trajectories using ARMA[14], GARCH[15] and GARCH-X models. The chapter proceeds as follows: the first section discusses the theoretical explanations of food price volatility, while the second section presents the empirical analysis of the determinants of food price volatility in Cameroon.

[13] Publish as Kane, G.Q., Piot-Lepetit, I., Ambagna J.J., Mabah Tene, G.L. and Fondo Sikod. 2017. Determinants of food price volatility in Cameroon, in: Piot-Lepetit, I. (Ed.), *Cameroon in the 21st Century: Prospects and Challenges. vol. 1. Governance and Businesses*, New York: Nova Science Publishers, Inc.

[14] Autoregressive Moving Average.

[15] Generalized Autoregressive Conditional Heteroscedasticitic model.

1.1. THEORETICAL EXPLANATIONS OF FOOD PRICE VOLATILITY

The definition of price volatility is a subject of debate in economic literature. In general, price volatility can be seen as a measure of price variability (Aizenman and Pinto, 2005; Balcombe, 2010; Gilbert and Morgan, 2010a, 2010b). More simply, it is about measuring the difference between a reference value that can be the average value or the trend value. Added to that, price volatility refers to sudden, unexpected, unstable, and large amplitude of price variations. Two types of volatility are generally analysed in the literature: realised or historical volatility and implied or future volatility (Tothova, 2011). While, historical volatility is related to the observed past trend of prices, implied volatility refers to the market expectations in terms of volatility at the beginning of the period.

Food price volatility is a serious problem for developing countries, which largely depends on imports to feed their population. However, to handle this problem, it is necessary to determine what its determinants are. This section discusses theoretical explanations of food price volatility. A general consensus about the determinants of food price volatility is that it is the result of the price and income inelasticity of demand. Thus, a decrease in supply leads to an increase in the price, which is proportionally more than the fall in supply. This result amplifies the relatively small supply shock. However, unanimity disappears with regards to the origin of supply shocks (Boussard, 2007, 2010). Theoretically, there are two main approaches in the explanation of food price volatility: exogenous explanations, and endogenous explanations.

1.1.1. Exogenous explanations of food price volatility

The exogenous explanation of food price volatility supposes that food price volatility is due to factors which are beyond producer's control. The most significant among them include climate, innovation, governmental policies, transmission across prices, product specificities, and non-agricultural factors.

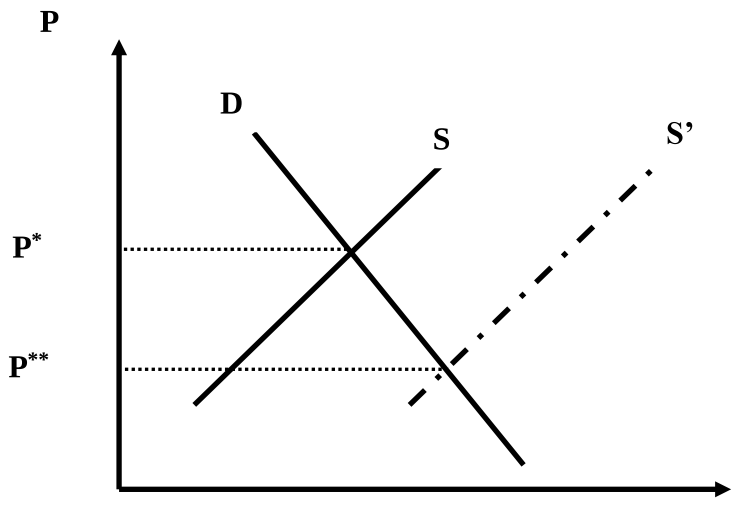
1.1.1.1. Climate

The most cited factor in the explanation of food price volatility in the literature is climate. In fact, the main idea is that the instability is generated by the period-to-period supply variability coming from the nature and climate events[16] that affects production (Boussard, 2007; Galtier, 2009; Gilbert and Morgan, 2011). For example, many observers have attributed the recent wheat price volatility to the decline in the world supply, due to a production shortage in Australia in response to unfavorable weather; Australia being the most significant world supplier. This type of volatility is sometimes called natural food price volatility. Indeed, unfavorable weather and diseases in the planted area negatively affect agricultural productivity, which becomes lower than its long run average level. Finally, this act as supply shocks and generates price volatility.

Graphically (figure 1.1), unfavorable climate conditions (curve S) lead to price **P***, while favorable climate conditions (curve S') lead to the price **P**** (with **P*>P****).

Although this explanation of the food price volatility is the most common in the literature, Boussard (2007) noted that it is important to consider other factors in the explanation of food price volatility. In fact, natural events are not sufficient in explaining food price volatility, which can be the result of the combination of several factors. Empirically, Roll (1984) concluded that, in spite of the significant contribution of climate events in the explanation of futures prices for orange juice in Florida, other factors have to be taken into account.

Figure 1.1: Natural food price volatility



Source: (Galtier, 2009)

[16] Locusts, rainfall, temperature, diseases, etc.

1.1.1.2. Innovation

Among the factors that determine food supply shocks, technological change plays an important role. Indeed, to some extent, technical progress can be defined as a parameter that causes the displacement of the production function. For example, an increase in yields due to technical progress helped to increase agricultural supply by 70% in developing countries during the 1960s, by 80% in 1970s, and even more in the 1980s (Paulino, 1986). The use of new technology, as it was the case during the green revolution, to increase agricultural supply. The impact on price strongly depends of the properties of the demand function.

When demand is not infinitely elastic, productivity gains resulting from technical progress causes an expansion of the supply leading to a decline in prices. However, producers can react by diversifying or substituting by other products, which can cause a backup of prices (Binswanger and Von Braun, 1991). In general, in such case, there is a perception of price volatility.

1.1.1.3. Governmental policies

In economics, the main reasons for government intervention in the agricultural sector are: incomplete markets in future insurance and credit, public goods and increasing return, imperfect information, externalities, and income distribution (Stiglitz, 1987). Thus, the principal reason for a government intervention in the agricultural sector is to correct inefficient market allocations. However, one of the main fears of a government intervention is that, these interventions instead of contributing to reduce market distortions can accentuate its effects. In general, one of the main objectives of these government interventions is price stability. To achieve this goal, the government can use price control that can be seen as a price guarantee policy. In one case, the government can set artificially high price (*floor price)* to provide a higher income to producers than in the case of a free market. In another case, the government can impose artificially low prices (*ceiling price*) to ensure a lesser income to consumer than in the case of a free market and thus an increase in their purchasing power. The alternative to price control policies is the "*price band*" (Holt and Aradhyula, 1990). In this last case, the government intervenes only if prices fluctuate outside a defined price band. Thus, to stabilize prices when they fluctuate outside of the band, the government can use among others: imports, exports, and changes in stocks (De Janvry et al., 1995). However, it should be noted that the effects of these measures are among the most controversial in the economic literature (Minkoua Nzie, 2008). Indeed, such measures do not allow prices to fully play their role of "signal" to stakeholders; a signal, which allow economic agents to use efficiently their scarce resources (Petkantchin, 2006). So instead of stabilizing prices in agricultural markets, these measures can act as market distortions and make it more volatile, mainly due to overproduction in one case and in the other case, it can discourage investment, innovation, and production..

On the other hand, other economic policy measures such as export restrictions and quotas can also make agricultural markets more volatile. For example, the recent rice price volatility is explained not only by the low stock level, but especially, by export restrictions imposed by rice producer countries (Abbott et al., 2008). Other measures such as taxes and subsidies, market-oriented program from government, loan ratios were mention in the literature as determining food price volatility.

In the case of developing countries, the neglect of the agricultural sector due to a low level of public investment in agriculture is often cited as one of the most important causes of agricultural price volatility (Meyers and Meyer, 2009). Indeed, the resulting low growth in agricultural productivity acts as a supply shock, which generates food price volatility. However, for taking into account the effect of the low level of investment in agricultural research in particular, it is important to distinguish the long-term effect from the short-term effect (Abbott et al., 2008). Even if some measures are taken to increase investment today, do not expect an immediate increase in agricultural productivity. By contrast, policies in favor of the adoption of a new technology can have a significant impact over the short run period in terms of increased agricultural productivity.

It should be noted that in the particular case of innovations and reforms for example, the literature is divergent. Indeed, according to Galtier (2009), a long-run price fluctuation due to innovations and reforms are not taken into account in the price volatility analysis. That is why a de-trended price time series is used in many studies. Price volatility in this approach is then a short-term phenomenon.

1.1.1.4. Transmission across prices

Food price volatility has various sources among which the production and consumption shocks. One of the main reasons that can lead to consumption shocks is the transmission of the variability in the prices of other goods (Gilbert and Morgan, 2011). The interactions between commodities can change the consumer's behaviour in the use of different goods and make some markets more volatile than others. In addition, Balcombe (2010) suggested that a positive food price volatility transmission between different commodities is generally expected. Thus, for example, for substitutable products, higher prices will reduce the demand of the concerned commodity and consumers will turn to substitutes, making at the same time the prices of the substitute more unstable (Gilbert and Morgan, 2011).

On the other hand, a simpler explanation of the transmission of price volatility between commodities can be the "*co- movement phenomenon*" (Saadi, 2011). Indeed, there can be situations where the prices of different commodities tend to have the same temporal evolution. Thus, the observed volatility for one commodity can be due to the price volatility in another commodity very close to it (substitute or complement).

It is necessary to note that the volatility transmission across commodities can be seen between two different markets (the international market and domestic market) as between different commodities in the same market. For example , when the international price of foodstuff is higher than those of their local substitutes, the demand for local products will increase, which can result in a reduction of the price competitiveness of local products (Minkoua Nzie, 2008) . Over time, this can lead to an increase in imports because international prices become more attractive and lower than local prices. In such a situation, food price becomes unstable and ultimately volatile in response to changes in relative prices between commodities.

1.1.1.5. Products specificities

The main idea here is that the storable event relates more to whether the perishable nature or not of agricultural products can explain observed price volatility. In fact, it is only very recently that economists have begun to address the issue of the price volatility for non-storable food. If it is accepted that stocks can help to stabilize food prices, this is not the case when considering the perishable products. Indeed, for the latter, the deterioration of the food quality is strongly correlated to the transaction time. In such a situation, producers cannot spread their sales over time (Vindel, 2005). Thus, it is generally accepted that storable food are on average less volatile than non-storable food (Minkoua Nzie, 2008).

In contrast, both the theoretical and empirical literature is vast in the analysis of the volatility of storable food. Indeed, it is recognized that information on stock levels are a key factor in explaining price volatility for storable food as cereals (Dönmez and Magrini, 2013).

According to Gilbert and Morgan (2011), small production or demand shocks can have large effects when stocks are low, but if stocks are important, the reverse is observed.

On the other hand Deaton and Laroque (1992) suggest that time varying volatility can be due to variations in stock levels. Nevertheless, one can easily think that this factor is more significant in developed countries than in developing ones, where the storage system is generally non-existent and even more non efficient.

1.1.1.6. Non-agricultural factors

The factors that explain food price volatility include the role of non-agricultural factors such as the energy price, the demand for biofuels, and financial factors. Indeed, during the last food crisis in 2007-2008, most of the agricultural and non-agricultural prices (energy, metals, and freight) increased simultaneously. In this case, some authors thought that the causes and determinants can be common (Gilbert and Morgan, 2011).

In the current literature, one of the most cited external causes of food price volatility is the rising energy prices (Von Braun, 2008). Indeed, a strong link between energy prices and those of agricultural products has been established in the literature (Baffes, 2011; Von Braun, 2008). This led to concerns about the price volatility transmission from energy and crude oil volatile markets to agricultural markets (Tothova, 2011). Mainly, rising energy prices had increased production costs (fertilizer prices, mechanized agriculture, and freight costs), making production more expensive and therefore food prices more volatile.

On the other hand, the major impact of increase in the energy prices has been the rising demand for biofuels. In fact, it is the political measures implemented in developed countries (the United States and the European Union) from biofuel policies that are generally implicated (Meyers and Meyer, 2009). Indeed, in response to the rising cost of energy, including the price of crude oil, biofuel production has increased. This has resulted in a diversion of the cereal world supply for the more inciting production of biofuel. In such a situation, the quantity of food available for nutrition is reduced and agricultural markets become more volatile and sensitive to external shocks (Dönmez and Magrini, 2013). The mechanism can be for example the following: an increase in crude oil prices leads to high fuel prices, which in turn generates a high price of grain-based biofuel. This increase combined with government incentives and subsidies reduces supply for food and therefore, generates higher grain prices (Abbott et al., 2008). However, it should be noted that the role of biofuel in the recent price boom has been widely discussed in the literature. For example, while Mitchell (2009) states that the most significant factor in the explanation of the 2007/2008 price boom is the United States of America and European Union biofuel production, Gilbert (2010)'s study lead to contradictory conclusions.

Finally, one of the most important group of non- agricultural factors in the explanation of food price volatility at both internationally and nationally level is the financial factors, which is however not subject of consensus among economists. In the case of the developing countries, the most important financial factors that can affect food price volatility can be the U.S dollar exchange rate. Indeed, commodity prices on the international market are generally expressed in U.S dollar, but these are purchased in the local currency, so there should be a link between the volatility of the U.S dollar exchange rate and food price in local currency (Abbott et al., 2008). The idea is usually used to find out if there are co-movements between the volatility of exchange rate and food price.

In the literature, exogenous factors generally do not fully explain food price volatility. Thus, volatility can be generated by errors in the agent's price expectation; it is then the market functioning itself which generates price volatility (Boussard, 1996, 2007). This gives rise to the endogenous explanation of the volatility of agricultural prices.

1.1.2. Endogenous explanations of the price volatility

The main idea of the endogenous explanation of food price volatility is that, contrary to the exogenous explanation, price volatility is the result of the agents' expectations errors and price series properties themselves (cobweb phenomenon, speculative bubbles, and chaos phenomenon). In addition, the empirical literature about the hypothesis of endogenous food price volatility is relatively sparse compared to the literature regarding the exogenous hypothesis.

1.1.2.1. Cobweb phenomenon

The key idea of the explanation of food price volatility by the cobweb phenomenon initiated by Ezekiel (1938) is a dynamic vision of the market functioning. Indeed, one of the fundamental characteristics of food supply is that a producer only has a vague idea of the selling price when the production decision is taken. In such a situation, a producer forms expectation about the selling price. Food price volatility is then, the result of suppliers' expectations errors. Expectation instability leads to price volatility, which in turn reinforces the instability in expectations (Galtier, 2009).

On the other hand , it seems unrealistic as noted by Ezekiel (1938) that stakeholders react instantly to changes in price and quantity available. There is always a time lag between the moment when the price is well-known, and the corresponding supply response. Therefore, the price at time t leads to a supply variation in period t +1, which will cause a change in the price and so on...

According to Ezekiel (1938), the standard cobweb model can be specified by the following equations:

$$\begin{cases} p_t^* = aq_t + b & \text{(supply)} \\ p_t = \alpha q_t + \beta & \text{(demand)} \\ p_t^* = p_{t-1} & \text{(expectations)} \end{cases} \tag{1.1}$$

Where p_t is the price and q_t the quantity at period t, respectively.

p_t^* is the expected price.

$a > 0$, b, α and β are model parameters. Additionally $\alpha < 0$ and $a > 0$

Finally, $$q_t = \frac{\alpha}{a} q_{t-1} + \beta - b \tag{1.2}$$

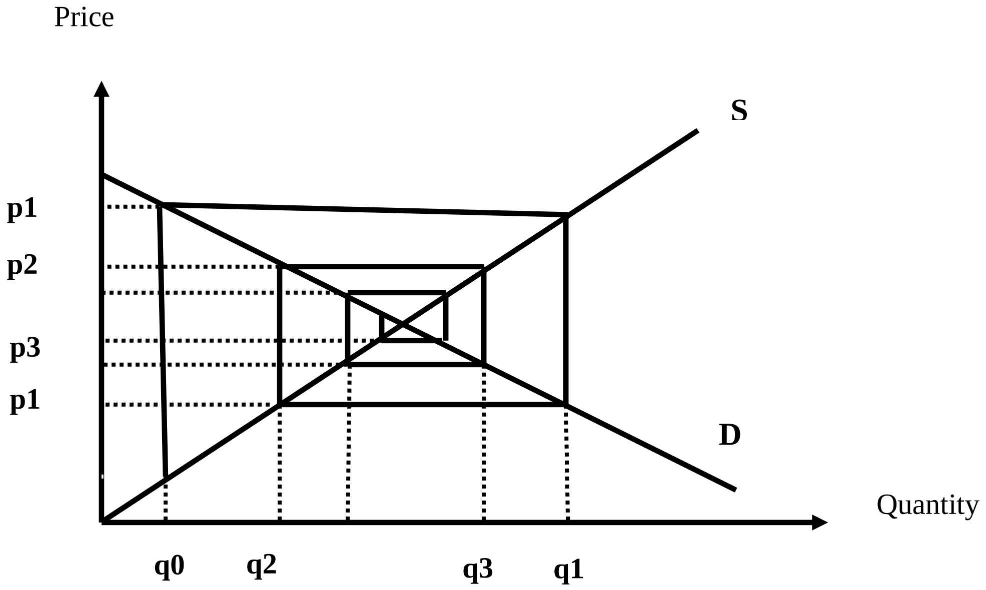
At least two cases are possible:

If $\left|\frac{\alpha}{a}\right| < 1$, then the market oscillates towards a stable equilibrium price and quantity, the amplitude of fluctuations is always decreasing. Since $|q_t - q_{t-1}| < |q_{t-1} - q_{t-2}|$.

On the contrary, if $\left|\frac{\alpha}{a}\right| > 1$, then the market oscillates towards an unstable explosive equilibrium.

Graphically (figure 1.2), supposes a high demand quantity **q1**, this quantity leads to a low price **p1**. At this price, supply is relatively low (**q2**), which leads to an increase in the price up to **p2**, and so on...

Figure 1.2 : The cobweb diagram



Source : Boussard (2007)

In general, in the cobweb model it is the properties of demand and supply functions, which determines the stability or not of equilibrium. For example, if the elasticity of demand is greater than the supply curve, then the stability is guaranteed. However, there is a consensus among economists that this is not the case in food products where the demand is inelastic (Boussard, 2007). For this author, the Ezekiel cobweb model is unsatisfactory. Indeed, this model does not take into account a key important feature of food price series, which is that the price fluctuation is never beyond a certain range. In addition, prices tend to diverge when approaching equilibrium and converge otherwise (Boussard, 2007, 2010). For this author, the analysis of such phenomenon leads at first to think that the price movement is periodic. However, if this is the case, it would be easy to forecast the prices and then, to adjust production. Assumption that does not seem to be verified looking at the facts. Thus, a new theory has emerged that suggests that price movements can follow a chaos generator mechanism. Another endogenous source of price volatility is subject to special attention since the liberalization of the futures markets: the speculative bubble explanation of food price volatility.

1.1.2.2. Speculative bubble approach

Among the determinants of the food price volatility, the most controversial factor is speculation (FAO, 2012; HLPE, 2011). Originally, due to the unpredictability of food prices, speculation through futures contract is an activity that allows stakeholders to protect themselves against the risk of future price fluctuations and ensure the liquidity in the market. Futures contracts, which are an important instrument to cover a price risk, imply a formal obligation to buy and sell a given quantity of product at a future date and a price decide in advance (FAO, 2012). Thus, the speculation seems to have a significant contribution on the price stabilization and the efficiency of the market. The speculators act as regulators, buying when prices are low, which leads to an increase in demand and selling when prices are high, which lead to an increase in the supply (Marchand, 2013). However, a relatively low percentage of future contracts expire because they are generally traded before the expiration date.

Since the liberalization of the futures markets and the increasing market financialization in recent years, new investors like pension funds, investment banks and hedge funds are interested in agricultural markets. These new investors are overly interested in the market fundamentals (supply and demand), but are primarily motivated by profit and asset diversification. As a result, there has been an exponential growth of transactions in the financial market and the emergence of new derivatives based on food.

The biggest problem related to speculation is that, in the case of excessive speculation the prices transmit inappropriate signals to stakeholders that in turn lead to suboptimal decisions and inefficiency allocations of scarce resources. This can cause sudden and unjustified price variations (FAO, 2012). Indeed, pricing is no longer linked to the evolution of market fundamentals, but simply reflects upward or downward speculators' price expectation (Marchand, 2013).

The role of speculation in the recent 2008 food crisis, in which food price volatility were high has been a source of controversy among economists. Indeed, the increased share of business of the new investors in the future grain markets (corn, wheat, and soybean) coincided with the 2008 price volatility. This has led a number of analysts to establish a causal relationship between food price volatility and increased speculation (FAO, 2012; Henriques, 2011; HLPE, 2011). Hence, a large part of 2007-2008 price volatility was due to emergence of a speculative bubble in agriculture according to the United Nations' (UN) special reporter in charge of food De Schutter[17]. Empirically, the verification of the hypothesis of a speculative bubble in the food commodities is relatively rare. Hernandez and Torero (2010) suggested that changes in spot prices for grains (wheat, corn, and soybeans) are induced by changes in futures prices. Consequently, speculation through its influence on prices on the futures market has had an effect, at least indirectly, on food prices. Gilbert (2010) documented evidence of speculative bubbles only in the case of soybean, but not in the wheat and corn market during the period from 2006 to 2008.

It seems like the effect of speculation depends on the products and markets under consideration. However, other authors argued that the speculative bubble hypothesis in food market is not relevant. For example, (Sanders et al., 2008) suggested that even though there has been an increase in the overall share of the speculative activity in recent years, at least two main reasons lead to skepticism about the negative effect of speculation on food price volatility. First, despite the fact that speculation was higher in the livestock market than in the cereal market, no price volatility was found in the livestock market during the 2007-2008 periods contrary to the cereal market. Second, high price volatility was observed for food products without futures market such as milk and rice.

1.1.2.3. Chaotic approach

The explanation of food price volatility in the chaotic approach is relatively new and is the result of some limitations observed in the cobweb model, the price series properties, and the supply and demand functions characteristics. A chaotic phenomenon can be explained by random fluctuations in appearance, which largely depend on its generating system and which are vaguely periodic (Boussard, 2007). Mitra and Boussard (2011) identified two main explanations for the chaotic dynamics of food markets.

First, because of the rigidity of demand, the supply and demand system is locally unstable around the market equilibrium point. Thus, as the demand is inelastic, the model exhibits a chaotic dynamics (Chavas and Holt, 1993). Second, when the system is too far from the equilibrium, a mechanism tends to bring it back. Finkenstadt Kuhbier (1992) used an augmented version of the cobweb model by incorporating an adaptive expectation and a nonlinear demand. The nonlinear demand function is also advocated by Chavas and Holt

[17] Cited by Henriques (2011).

(1993). Boussard (1996) incorporated the producer's risk aversion, while maintaining a linear demand function in the standard cobweb model. However, besides the fact that the distinction between endogenous chaotic movements and random exogenous fluctuation movements in food prices is difficult, the main limitation of the endogenous chaotic explanation comes from the non-verification of the relationship between the estimated price series from the chaotic model and the stylized facts of food prices (Mitra and Boussard, 2011).

To conclude this section it should be noted that the classification of determinants of food price volatility used in the next section is slightly different. Indeed, two set of factors will be used as determinants of food price volatility in Cameroon: external factors and domestic factors. This can be justified by the fact that Cameroon is a country heavily dependent on imports to feed its population. Thus, it can be necessary to verify if the observed local food price volatility is only or not the result of the world price. In addition, it can be useful to analyze the effect of external shocks, coming from the sub-region, on the food price volatility in Cameroon.

1.2. DETERMINANTS OF FOOD PRICE VOLATILITY: EVIDENCE FROM CAMEROON

This section presents an empirical analysis of the determinants of food price volatility using Cameroonian markets as a case study.

1.2.1. Methodology

1.2.1.1. Data

Secondary data from the International Monetary Fund (IMF) and the National Institute of Statistics (NIS) were used. Data on the prices in international markets came from the world commodity prices of the IMF and data on the prices of different agricultural products in Cameroon came from the NIS. It is worth mentioning that price series used were real prices, deflated by the Cameroonian Consumer Price Index (CPI) as it is common in the literature (Minkoua Nzie, 2008; Minten, 2006; Subervie, 2007).

Indeed, the consideration of the CPI enabled us to integrate the time effect of the variation of the cost of life in our analysis. The study was carried out for the main markets in Cameroon, where the NIS collects monthly foodstuff prices: Douala, Yaoundé, Bamenda, Bafoussam, and Garoua (see figure 1.1 in the appendix). The period under consideration in this study is from January 1994 to December 2010, with 204 observations.

The study focuses on two groups of products that account for about 50% of the total demand of food consumption in Cameroon and are the most significant in terms of caloric contribution (Medou, 2008). These are the group of cereals that is the most imported product in Sub-Saharan Africa (SSA) as indicated by Daviron *et al.* (2008), and the group of roots and tubers. In terms of calories and protein contribution, these two groups account for 36.2% and 40%, respectively, for the first group, and 30.1% and 13.8%, respectively, for the second as noted by Medou (2008). Therefore, in this research, we considered as cereals: rice and wheat[18] coming from the world market[19], and the local maize. In the group of roots and tubers, we considered: cassava, cocoyam and plantain, which are the most often used, among others, in subsistence farming in Cameroon[20]. On the other hand, products such as cassava and plantain are generally considered as the most emblematic foods in households' consumption in Cameroon, relative to imported food (Meuriot et al., 2011).

It must be noted that the importance of climate data in such type of study is not common in the literature. Indeed, for some authors (Rosa and Vasciaveon, 2012; Tothova, 2011), climate data allow to take into account the effect of climate change, while, for some others, it is not the case. Thus, in this study, we will not use such data. In fact, in Cameroon updated climate data for all the 5 markets under consideration are not available and furthermore, the period of study seems to be relatively short to capture the effect of climate change; knowing that this change take time.

1.2.1.2. Methodological framework

The following stages were followed to analyse price volatility in this chapter:

- Descriptive statistics for each real price series and deseasonalization when necessary;

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[18] At the local level, the price of bread is used as a proxy for the price of wheat.

[19] The price of maize in the world market is not included in the analysis because of the numerous uses and the transformation process, as suggested by Meuriot *et al.* (2011). Indeed, imported maize is majority used for the brewery industry and the breeding. Thus, we assume that maize presents on the market for human consumption come from local production.

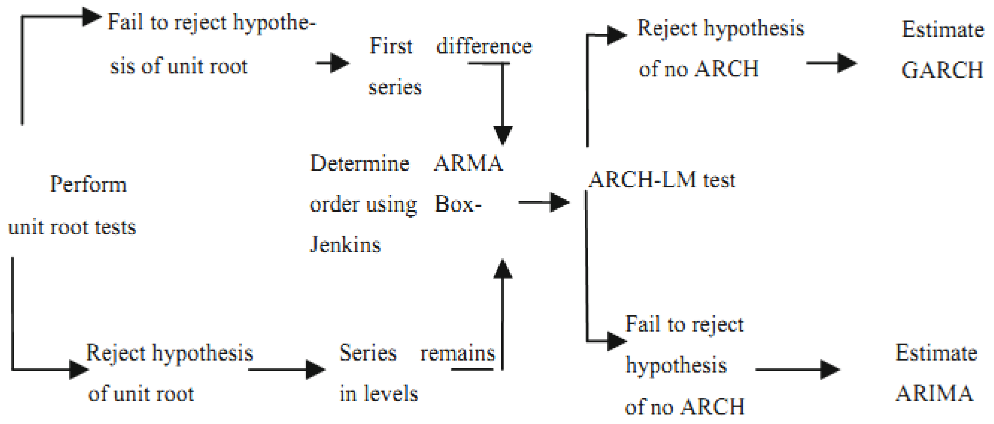
[20] As noted by the National Institute of Statistics (NIS, 2008), the most planted food for households, among others, are: maize (42.7%), cassava (28.3%), cocoyam (26.8%), and plantain (22.6%).

➢ Standard unit root tests with and without change in regime (ADF, PP, KPSS and ZA)[21] for each real price series;

➢ Evolution of price dispersion over the period under study using Coefficient of variation;

➢ Afterwards, we applied the procedure suggested by Moledina *et al.* (2003) on return series that is presented below:

Figure 1.3: Flowchart of methodology to compute conditional volatility



Source: Moledina et al. (2003)

Moreover, for the analysis of the determinants of price volatility, we put r_t and other explanatory variables in relation. We estimated for each series: a standard GARCH model, a GARCH-X model, or an Autoregressive Moving Average (ARMA) model.

- ***The ARMA model***

A stationary ARMA (p.q) model can be written as: $y_t = \phi_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j}$ (1.3)

Where y_t is a dependent variable, p and q are non-negative integers. t denotes the time period and the error terms in this model are assumed to be a Gaussian process with a mean of zero and a constant variance σ^2.

When taking into account the effect of other explanatory variables, the ARMA model becomes an ***ARMA-X model***:

[21] Dickey-Fuller unit root test (ADF); Phillips-Perron unit root test (PP); Kwiatkowski, Phillips, Schmidt and Shin unit root test (KPSS); Zivot and Andrews unit root test (ZA).

$$y_t = \phi_0 + \lambda d_t + X_t^{'}\eta + \sum_{i=1}^{p}\phi_i y_{t-i} + \varepsilon_t + \sum_{j=1}^{q}\theta_j \varepsilon_{t-j} \quad (1.4)$$

where X_t is a column vector of explanatory variables and d_t is a set of dummy variables.

- ***ARCH model***

Following Engle (1982), the ARCH model allows to rewrite the error term of the ARMA equation as an autoregressive conditional heterosckedastic process. Hence an ARCH (m) is:

$$y_t = \phi_0 + \sum_{i=1}^{p}\phi_i y_{t-i} + \varepsilon_t + \sum_{j=1}^{q}\theta_j \varepsilon_{t-j} \quad (1.5)$$

$$\varepsilon_t = z_t \sigma_t \quad (1.6)$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{m}\alpha_i \varepsilon_{t-i}^2 \quad (1.7)$$

Where $\{z_t\}$ is a sequence of i.i.d[22] random variables with a mean of zero and a unit variance. $\alpha_0 \succ 0$, $\alpha_i \geq 0$ and the conditional variance σ_t^2 may change over time.

- ***The GARCH model***

The GARCH model is practically written in the same manner as the previous ARCH model, with the only difference being in the variance equation. Hence, the variance equation of a GARCH (m,s) model is written as:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{m}\alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{s}\beta_j \sigma_{t-j}^2 \quad (1.8)$$

- ***The GARCH-X model***

The GARCH-X model is a model that allows taking into account the effect of exogenous variables on volatility. It is a model that helps to give an economic and structural explanation to volatility (Engle and Patton, 2001). The use of this model can be justified by the fact that the standard GARCH model, by ignoring the information from other variables in the measure of volatility, can lead to biased estimates (Lamoureux and Lastrapes, 1990). As opposed to the

[22] Independent and identically distributed.

standard GARCH model (1.8), the variance equation of the GARCH-X model can be modelled as follows:

$$\sigma_t^2 = \alpha_0 + \pi d_t + \sum_{i=1}^{m} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{s} \beta_j \sigma_{t-j}^2 + \varphi X_t^{'} \tag{1.9}$$

Where X_t is a column vector of explanatory variables and d_t is a set of dummy variable.

1.2.1.3. Measure of prices volatility

In literature, there is a wide range of methods that can be used to measure volatility. In general, among the most common measures of price volatility in economics, the coefficient of variation and the standard deviation of the price return are found (Minot, 2012). The coefficient of variation (CV) is the ratio between the standard deviation of the variable of interest and its mean in a given period. It measures the spread of observed data, expressed in percentage of the mean, and facilitates comparisons in terms of volatility between prices among different goods for different periods (Piot-Lepetit and M'Barek, 2011). A higher coefficient of variation implies a wider spread of the series and consequently, higher price volatility.

The CV is calculated as follows:

$$CV = \frac{\text{standard deviation}}{\text{mean}} \times 100 \tag{1.10}$$

On the other hand, price volatility is increasingly measured by the standard deviation of the price return, as in financial series (Aizenman and Pinto, 2005; Gilbert and Morgan, 2010a). According to Gilbert and Morgan (2011), this standard measure, in addition to being without unity, allows taking into account the direction taken by the price variability. Thus, we adopt this approach in our volatility model as usual in the literature (Gilbert and Morgan, 2010a; Minot, 2012; Rosa and Vasciaveon, 2012).

Following Minot (2012), price volatility is measured by:

$$Volatility = stdev(r) = \left[\sum \frac{1}{N-1} \left(r_t - \hat{r} \right)^2 \right]^{1/2} \tag{1.11}$$

where $r_t = \ln(\frac{p_t}{p_{t-1}})$. r_t is the return. and $\hat{r} = \sum \frac{1}{N} r_t$

It is common, in the literature, to use econometric models for volatility like in financial series in order to take into account the fact that volatility can change with time. These models are the Autoregressive Conditional Heteroscedasticitic model (ARCH) from Engle (1982) and the Generalized Autoregressive Conditional Heteroscedasticitic model (GARCH) from Bollerslev (1986).

A precision on the type of information used in the analysis of volatility is necessary. In fact, according to some authors (Aizenman and Pinto, 2005; Gilbert and Morgan, 2011), the measure of volatility of agricultural prices should take into account the fact that the different components of the price are predictable or not, especially its trend which should be extracted before any analysis. However, the major difficulty of such an approach is that the obtained measure of volatility depends heavily on the detrending model (Gilbert and Morgan, 2011). In contrast, some authors like Piot-Lepetit and M'Barek (2011) suggested that agricultural prices series have different characteristics and properties from financial series. The distinction between the predictable and unpredictable components of the price series as in financial series is therefore not relevant. Also, we used price series (in log) in this study. The seasonal component of these price series is extracted beforehand to compute the price return or CV on which the analysis of the price volatility[23] is made.

It is also worth noting that measures of price volatility can depend on the frequency of available data (daily, monthly, and yearly). Thereby, the above described measure of volatility can be annualized according to O'Connor and Keane (2011) as:

$$Volatility = StdDev(r_1,...,r_n) * \sqrt{Number\ \ of\ \ \ periods\ \ per\,Year} \tag{1.12}$$

Where $r_1,...,r_n$ is a return series for n time periods.

Before analysing the price itself, a primary and important stage which is the treatment of the seasonality should be carried out. The following subsection will help us to address this issue.

Note: We use the popular *census X-12 ARIMA* method of the US Census Bureau in order to take into account for seasonal adjustment. Moreover, the additive decomposition model,

[23] In this case, volatility refers to the total variability in the price series studied.

which is the most often used model in the literature, is used. The output of the X12-ARIMA procedure makes possible a set of tests and allows for the control of seasonal adjustments by using the standard F-test of seasonality. Finally, it is worth noting that this method is nowadays used by a large number of national statistic institutes in the world (TSAB, 2007).

1.2.1.4. Definition of variables

The choice made for the different variables used in this study is justified by the fact that in the literature those variables are the most often used to explain the agricultural prices volatility. As mentioned in the first section, food price volatility can be explained by exogenous factors and endogenous factors. In this chapter, due to data limitation, we adopt exogenous explanation of food price volatility. Moreover, we should point out that the central hypothesis of this analysis is that the volatility of agricultural prices in Cameroon is explained by a set of internal/domestic factors, but also factors that are external to the country and can be seen as external shocks in the constitution of agricultural prices in Cameroon. We consider variables that can be used as proxy for government policies, non-agricultural factors and transmission across prices in the Cameroonian background. More precisely, we distinguish the following explanatory variables:

Internal/Domestic factors:

- **The measure of the volatility of other agricultural products** in the database: in fact, in the case of speculation, price volatility can be linked between different markets and its transmission among foodstuffs is generally expected to be positive (Balcombe, 2010); and

- **The economic policy/economic reform**: dummy variables are included to capture the potential effect of the implementation of some public measures in relation to the supply of agricultural products. Hence, one of them captures the effect of the implementation in 2002 of the development strategy of the rural sector (D1)[24], which aimed at increasing the production and the other one captures the suppression of duties and taxes on importing basic foodstuffs following the 2008 food crisis (D2)[25]. This variable is used as proxy of government policies.

[24] D1 is a dummy variable which takes 1 after December 2001 and 0 otherwise.
[25] D2 is a dummy variable which takes 1 after February 2008 and 0 otherwise.

External factors:

- **The volatility of crude oil price**: it captures the increase in the price of oil which causes an increase in the costs of fertilizers, mechanized agriculture, and freight (Ajakaiye and Adam, 2011). But also, the increasing use of bio-fuels which tighten the constraint of the supply of cereals in the world (Abbott and Borot de Battisti, 2011). This variable can be seen as non-agricultural factors affecting food price volatility in Cameroon;

- **The food demand pressure of the sub-region**: a dummy variable taking into account the increasing pressure on the demand of domestic agricultural products coming from the sub-region is included (D3)[26]. In fact, some events such as conflicts in Central African Republic, Chad, Congo, the crisis in Gabon, and the expansion in the oil industry in Equatorial Guinea since 1998 can have increased Cameroon food exportations (Dury et al., 2004; Minkoua Nzie, 2008); and

- **The monthly price of fuel**: it is considered as a proxy of transport costs. In fact, Dury *et al.* (2004) pointed out that the fluctuation of agricultural prices in Cameroon can be linked to the increase in the transportation costs due to the absence of roads maintenance and hence, to the rise in fuels prices.

1.2.2. Result and discussions

1.2.2.1. Summary of the data and seasonality tests

We have to note that the variable notation is constructed on two indications, namely a commodity indication and a market indication as mentioned in table 1.1 in the appendix.

The summary statistics for real price series are presented in table 1.1. In general, results of the Jarque-Bera statistics point out that the null hypothesis of normality is rejected in most of the cases, with relatively a few exceptions. The kurtosis coefficient suggests that most of the real price series follow a leptokurtic distribution (with the kurtosis being greater than 3). In addition, the skewness results suggest that most of the real price series are left skewed (with a negative skewness).

[26] D3 is a dummy variable which takes 1 after December 1997 and 0 otherwise.

Table 1.2 : Summary statistics of real price series

	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque -Bera	Prob	Obs
RBR_BAF	5.9951	6.0197	6.4495	5.6132	0.1217	-0.4268	4.8175	34.276	0.0001	204
RBR_BAM	5.9169	5.9304	6.1922	5.5113	0.1175	-0.5419	3.3722	11.162	0.0037	204
RBR_DLA	6.0602	6.1005	6.4058	5.6475	0.1693	-0.6526	2.4296	17.246	0.0001	204
RBR_GAR	6.0659	6.0752	6.3290	5.6135	0.1400	-0.6527	3.5616	17.169	0.0001	204
RBR_YDE	5.8098	5.7531	6.1801	5.5657	0.1722	0.69653	2.2353	21.464	0.0000	204
RCA__GAR	4.8457	4.8290	5.6191	4.1043	0.2391	0.21544	3.3451	2.5907	0.2738	204
RCA_BAF	4.8571	4.8478	5.7185	4.2454	0.1939	0.44271	4.4821	25.336	0.0000	204
RCA_DLA	4.8741	4.8711	5.3583	4.4365	0.1505	0.15400	3.4466	2.5023	0.2861	204
RCA_YDE	4.7739	4.7747	5.1343	4.2400	0.1850	-0.8412	3.7127	28.378	0.0000	204
RCATW_BAM	4.6298	4.6544	5.2535	3.2964	0.2154	-1.6302	13.993	1117.6	0.0001	204
RCOCO__BAF	4.2896	4.3346	4.8360	3.3666	0.2219	-0.9468	4.9056	61.347	0.0001	204
RCOCO__BAM	4.3475	4.3811	4.8701	3.4361	0.2580	-0.5597	3.0796	10.706	0.0047	204
RCOCO__DLA	4.4280	4.4446	4.8279	1.9924	0.2421	-5.4120	52.794	22071.8	0.0001	204
RCOCO__YDE	4.0999	4.1175	4.6271	3.5265	0.2007	-0.4631	3.3551	8.36606	0.0152	204
RMA__BAF	4.5985	4.6209	5.3329	3.9732	0.2465	-0.3697	3.5838	7.54626	0.0229	204
RMA__BAM	4.6208	4.5902	5.3923	3.9240	0.2660	0.29026	2.5664	4.46197	0.1074	204
RMA__DLA	4.7629	4.7393	5.2668	4.3505	0.2182	0.38841	2.5754	6.66181	0.0357	204
RMA__GAR	4.3480	4.3602	4.9453	3.6796	0.2705	-0.1608	2.6093	2.17677	0.3367	204
RMA__YDE	4.7237	4.7116	5.1779	4.3547	0.1850	0.32375	2.4768	5.88976	0.0526	204
RMIL_GAR	4.5390	4.5431	5.1722	3.9544	0.2255	0.28210	3.1044	2.79855	0.2467	204
RPLA__BAM	4.0094	3.9894	4.6872	3.2111	0.3087	-0.02658	2.4088	2.99439	0.2237	204
RPLA__DLA	4.4361	4.4380	4.7275	4.0545	0.1305	-0.21074	3.0683	1.54972	0.4607	204
RPLA_BAF	4.0495	4.0769	4.9188	3.1470	0.3158	-0.17519	2.7313	1.65694	0.4367	204
RPLA_YDE	4.1246	4.1033	4.7318	3.4354	0.2092	-0.00224	3.7842	5.22858	0.0732	204
RRI___BAM	5.1144	5.1434	5.4611	4.7353	0.1349	-0.49040	3.0828	8.23526	0.0162	204
RRI___GAR	5.2553	5.2761	5.7476	5.0041	0.1001	0.161614	4.9683	33.8203	0.0001	204
RRI__BAF	5.2250	5.2409	5.6239	4.8573	0.1335	-0.29014	3.0344	2.87238	0.2378	204
RRI__YDE	5.1819	5.1722	5.5371	4.7531	0.1500	-0.53496	3.4289	11.2945	0.0035	204
RRI_DLA	4.8486	4.8355	5.1037	4.6470	0.0884	0.541032	3.4585	11.7397	0.0028	204

Commodities: BRD: Bread, CAS: Cassava, COCO: Cocoyam, MAZ: Maize; MIL: Millet, PLA: Plantain, and RIC:Rice. Markets: BAF: Bafoussam, BAM: Bamenda, DLA: Douala, GAR: Garoua, and YDE: Yaoudé.

The results and the conclusion of seasonality tests are presented in table 1.2 in the appendix. We used two tests: the F-test and the Q2 parameter test. We use seasonally adjusted data for econometric models when the two tests have suggested the existence of seasonality. However, when the results have pointed out the evidence of a non-stable seasonality and lead to contradictory conclusions[27], I use non-seasonally adjusted data.

1.2.2.2. Order of integration of the real price series

In this study, we perform standard unit root tests, namely, the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test that assume the null hypothesis of non-stationarity (unit root), contrary to the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test that assumes the null hypothesis of stationarity. However, the major problem of these common tests is that, they do not take into account any structural change in the data generation process (Rosa and Vasciaveon, 2012). This is the main reason why we compared the results from these common tests with those obtained with the Zivot and Andrews (1992) test[28]. Indeed, this latter test allows for a structural break in the unit root test and determines endogenously the possible break date using full sample properties. In this research, we test the null hypothesis for the ZA test that implies that the series contain a unit root without structural break versus the alternative hypothesis that the series is trend stationary with one structural break. As usual in the literature, we perform the test for the two most popular models[29], however the result presented are just for model C.

The results of unit root tests suggest that most of real price series are stationary in level (see table1.3 in the appendix). Only maize, rice and bread in Yaoundé and Douala appear to be stationary in difference. Therefore, for series that are stationary in level, shocks are transitory, in contrast to those with unit roots, for which shocks are permanent. In general, these results were similar when taking into account a structural break (see, tables 1.4 to 1.7 in the appendix). The proposed break point suggests that in general, price behaviors were not affected by the 2007-2008 food crisis. The evidence of a change in the price series behaviour due to the recent food crisis was found only in Douala market.

1.2.2.3. Price dispersion over the period under study

It is largely argued in the literature that, in the last decade, food price volatility was the highest over the last thirty years. Thus, using Cameroon as a case study, we try to verify this

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[27] When the F test suggest the presence of seasonality, but the Q2 parameter suggest the rejection of the hypothesis of seasonality.
[28] ZA test.
[29] Model A: change in level; Model C: combines one time change in both level and slope.

hypothesis by analyzing the price dispersion over the period under study. The coefficient of variation is used as a measure of price dispersion. Additionally, the period under study has been divided into two equal sub-periods (January 1994 to June 2002 and July 2002 to December 2010). The results are presented in the following table 1.2 :

Table 1.2: Price dispersion 1994-2010

Commodity	Price series	Coefficient of variation (%)			% of change between
		1994m1 2010m12	*1994m1 2002m6*	*2002m7 2010m12*	
Bread	RBR_YDE	18,18%	15,28%	6,74%	-8,54%
	RBR_DLA	15,99%	13,38%	16,01%	**2,63%**
	RBR_BAF	11,98%	13,26%	10,26%	-3,00%
	RBR_BAM	11,40%	12,44%	9,44%	-3,00%
	RBR_GAR	13,43%	16,24%	8,94%	-7,30%
Cassava	CA_YDE	17,24%	20,09%	13,81%	-6,28%
	CA_DLA	15,32%	17,20%	13,01%	-4,18%
	CA_BAF	20,76%	18,05%	22,21%	**4,16%**
	CAWF_BAM	20,10%	26,44%	8,23%	-18,21%
	CA_GAR	24,95%	29,35%	19,91%	-9,44%
Maize	MA_YDE	16,87%	14,22%	16,61%	**2,39%**
	MA_DLA	20,14%	18,71%	19,23%	**0,52%**
	MA_BAF	23,11%	29,70%	13,78%	-15,91%
	MA_BAM	25,97%	25,89%	25,28%	-0,61%
	MA_GAR	24,99%	25,32%	24,77%	-0,54%
Cocoyam	COCO_YDE	17,90%	24,08%	7,86%	-16,22%
	COCO_DLA	17,14%	20,90%	11,86%	-9,04%
	COCO_BAF	20,45%	24,89%	11,22%	-13,67%
	COCO_BAM	24,23%	28,09%	14,49%	-13,60%
Plantain	PLA_YDE	19,85%	22,06%	16,82%	-5,23%
	PLA_DLA	11,01%	13,17%	8,22%	-4,96%
	PLA_BAF	29,82%	32,69%	23,04%	-9,65%
	PLA_BAM	30,86%	31,77%	22,28%	-9,49%
Rice	RI_YDE	14,48%	11,52%	15,95%	**4,43%**
	RI_DLA	9,06%	8,54%	6,61%	-1,93%
	RI_BAF	13,13%	9,86%	10,79%	**0,93%**
	RI_BAM	13,08%	9,84%	15,28%	**5,45%**
	RI_GAR	10,17%	10,43%	8,37%	-2,06%
Others	MIL_GAR	23,52%	27,18%	16,45%	-10,73%

In general, price dispersion is higher during the first sub-period than for the entire period and for the second sub-period. The case of bread in Douala, rice in Yaoundé and Bamenda, rice and wheat in international markets are exceptions where price appear to be more dispersed in the second sub-period (which include the recent price surge) than in the entire period. Moreover, price dispersion has increased in the second sub-period only for maize and rice in

Yaoundé, maize and bread in Douala, cassava and rice in Bafoussam, rice in Bamenda, rice and wheat in international markets, where price dispersion for the remaining commodities has decreased over the time, but at various levels. This result is similar to those obtained by Minot (2012), who suggested that there is no evidence of increasing food price volatility in Africa in the last decade as suggested in the literature.

On the other hand, the highest price dispersions are for plantain and maize in Bamenda, and plantain in Bafoussam markets, while the lowest are for rice in Douala and Garoua markets. Among the commodities, price dispersions were highest for bread in Yaoundé, for cassava in Garoua, for maize in Bamenda, for cocoyam in Bamenda, for plantain in Bamenda and finally, for rice in Yaoundé. To sum up, for each market, plantain was the highest dispersed commodity in Yaoundé, Bafoussam and Bamenda, maize in Douala, and cassava in Garoua.

1.2.2.4. Time series model for food price volatility

To analyze the determinants of food price volatility in Cameroon, we have applied time series econometric models as suggested earlier. Then, we have successfully estimated the ARMA and ARMA-X model when the ARCH effect was not found. Additionally, we have estimated the ARMA, the GARCH and the GARCH-X models to take into account time varying volatility.

First, the results of standard unit root tests without and with structural break (ADF, PP, KPSS and ZA) suggest that all the return price series are stationary (see table 1.8 in the appendix). In addition, the Box and Jenkins approach has been used to determine the appropriate ARMA structure of each return price series. Also, for each ARMA model, a Breusch-Godfrey Serial Correlation LM Test has been applied and an ARCH LM test has been used to test for ARCH effect.

The summarized properties of all price return, the ARMA process, the result of the ARCH LM test, and the final process for each commodity are presented in the appendix in table 1.9. These results suggest that, the variance of return series can be considered as constant over time only for fourteen series among the twenty nine under consideration. Thus, for the remaining fifteen return series, the time varying volatility model can be used.

The estimated results for each econometric model are discussed below:

1.2.2.4.1. Determinants of food price volatility in Cameroon: results from ARMA model

The results of ARMA-X model (table 1.3) suggest that the suppression of import duties and taxes has significantly lowered volatility, but only for bread in Bafoussam and cassava in Douala. Also, the price volatility of cassava, cocoyam, maize, plantain, and millet has respectively increased the volatility of maize in Douala, plantain in Yaoundé, cassava in Garoua, cassava and cocoyam in Douala, and cassava in Garoua. But, these effects have a relatively low amplitude since the estimated coefficients are all lower than 0.50. These results suggest that these commodities can be viewed as complementary goods in each region. Opposite results are obtained for cocoyam and cassava in Douala, and for rice and cassava in Garoua; suggesting that these commodities can be seen as substitutable products.

Table 1.3 : Estimated coefficients with the ARMA-X model

	Bread	**Cassava**			**Cocoyam**	**Maize**	**Plantain**		
	BAF	**BAM**	**DLA**	**GAR**	**DLA**	**DLA**	**BAF**	**DLA**	**YDE**
AR(1) ϕ_1	-0.05	0.17^{*}	0.63^{***}	0.49^{***}	0.17^{**}	-0.88^{***}	-0.31^{***}	-1.14^{***}	-0.33^{***}
AR(2) ϕ_2	-0.25^{***}				0.13^{*}	-0.2^{***}	-0.25^{***}	-0.40^{***}	-0.18^{**}
AR(3) ϕ_3	-0.16^{**}						-0.17^{**}		0.06
AR(4) ϕ_4	-0.19^{***}						-0.12^{*}		0.14^{*}
MA(1) θ_1		-0.83^{***}	-0.99^{***}	-0.99^{***}	-0.99^{***}	0.73^{***}		0.86^{***}	
D2 λ_1	-0.01^{**}		-0.01^{*}						
R_CAS η_1						0.20^{***}			
R_COCO η_2			-0.08^{**}						0.47^{***}
R_MAZ η_3				0.25^{***}					
R_PLA η_4			0.23^{**}		0.45^{***}				
R_FUEL η_5		0.82^{**}			0.46		-1.16^{***}	-0.48^{**}	
R_RIC η_6				-0.37^{**}					
R_MIL η_7				0.22^{***}					
Prob(F)	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}
LM Stat*	4.07	1.95	3.21	1.47	0.95	0.34	0.12	0.30	4.27

Notes: Markets: BAF: Bafoussam, BAM: Bamenda, DLA: Douala, GAR: Garoua, and YDE: Yaoudé; Commodities: CAS: Cassava, COCO: Cocoyam, MAZ: Maize; PLA: Pantain, FUEL: Fuel (proxy of transport costs); RIC:Rice, and MIL: Millet;
R: price return; D2: Dummy variable capturing the suppressionof duties and taxes on basic foodstuffs after the 2008 food crisis.

Additionally, the growth rate of price of fuel, as a proxy of transport costs, has reduced the price of plantain in Bafoussam and Douala and increased the price of cassava in Bamenda, with relatively high amplitude of 0.82, and cocoyam in Douala to a lesser extent. In the specific case of Bamenda, the high coefficient can be explained by the fact that cassava is produced relatively far away from this city, in a location where transportation infrastructures are relatively poor.

The last remark on results from the ARMA-X model is that when explanatories variables were introduced in the ARMA model, expected results were an impact of the two following external factors: the price of wheat through the price of bread and crude oil. However, results do not suggest such evidence since no significant coefficients have been estimated for these two variables; suggesting that the price transmission between the world market and Cameroonian markets seems to be relatively low for wheat, even though further analyses based on specific models focusing on this issue are necessary to confirm this comment.

1.2.2.4.2. Determinants of food price volatility in Cameroon: results from GARCH model

The GARCH results are presented in two tables : tables 1.4 and 1.5. For all return series, the estimated coefficients satisfy the non-negativity condition. The results in table 1.13 suggest that a high level of persistence in volatility has been found for some return series as bread in Bamenda, millet in Garoua and cassava in Bafoussam for which the sum of alpha and beta coefficients in the conditional variance equation (0.98, 0.96 and 0.82 respectively) are close to one. For some other return series as cassava in Bafoussam and cocoyam in Bamenda, there is no persistence in volatility. Only the sum of the alpha and beta coefficient for cocoyam in Bafoussam and Yaoundé leads to an explosive behavior.

<u>Table 1.4 : Estimated coefficients with the GARCH model for bread, millet, cassava, and cocoyam</u>

Process	**Estimated coefficients**	**Return price series**						
		Bread	**Millet**	**Cassava**		**Cocoyam**		
		BAM	**GAR**	**BAF**	**YDE**	**BAF**	**BAM**	**YDE**
Mean	ϕ_1							
	ϕ_2							
	ϕ_3							
	θ_1			0.56^{**}	0.99^{***}		0.62^{***}	0.34^{***}
	θ_2	-0.15^{**}						0.26^{***}
	θ_3							0.80^{***}
Conditional variance	α_1		0.21^{***}	0.23^{**}	0.17^{***}	0.63^{***}		0.26^{**}
	α_2							0.98^{***}
	α_3							0.28^{**}
	β_1	0.98^{***}	0.75^{***}		0.65^{***}	0.37^{***}	0.20^{*}	

Note: Markets: BAF: Bafoussam, BAM: Bamenda, GAR: Garoua, and YDE: Yaoudé;

For some return series as bread in Bamenda, millet in Garoua and cassava in Yaoundé, actual volatility is mainly explained by past volatility relative to past innovations. These results are usual in a GARCH model. However, the return series for cocoyam in Bamenda appear to be an exception. Indeed, past innovations have had a higher effect than past volatility in actual volatility (the sum of alpha coefficients is more than the sum of beta coefficients). Finally we have to note that, only the relatively recent residuals have an impact on the current volatility for cassava in Bafoussam and cocoyam in Yaoundé. Indeed, those return series exhibit a short memory process as suggested by their ARCH structure.

The results in the table 1.5 suggest that the volatility is explosive for some return series as maize in Bamenda, Bafoussam and Yaoundé for which volatility is persistent only for maize in Garoua. Additionally, we can note that past volatility has a higher effect than past innovations only for maize in Bafoussam, while this is not the case for the remaining return series presented in this table. The ARCH structure has been found for rice in Douala and Bamenda, and for maize in Bamenda.

Table 1.5 : Estimated coefficients with the GARCH model for maize and rice

Process	Estimated coefficients	Return price series							
		Maize				Rice			
		BAF	BAM	GAR	YDE	BAF	BAM	GAR	DLA
Mean	ϕ_1	-0.10		-0.42***	-0.23***	-0.39***	-0.80***	-0.84***	-0.31***
	ϕ_2							-0.39***	-0.39***
	ϕ_3								-0.40***
	ϕ_4								-0.07**
	θ_1		-0.25***				0.43***	0.27	
	θ_2						-0.51***		
	θ_3						-0.21***		
Conditional variance	α_1	0.53***	1.00***	0.39***	0.65***	0.29***	0.40***	0.51***	1.47***
	α_2								0.40***
	α_3								
	β_1	0.58***		0.32**	0.46***	0.26**		0.49***	

Note: Markets: BAF: Bafoussam, BAM: Bamenda, DLA: Douala, GAR: Garoua, and YDE: Yaoudé;

To sum up, a graphical analysis of conditional standard deviations of all return series from the GARCH model (see table 1.10 in the appendix) tends to confirm the previous hypothesis that in the Cameroonian market, the volatility of food commodity was not more volatile in the 2000 decade than in the international market and some other developing countries. One explanation of this result can be the low volatility in the price transmission between the world market and the Cameroonian market for cereals. Also, this suggests that the transmission of price volatility is relatively low among the commodities under consideration, but to confirm that additional and more appropriate models should be estimated. Food price volatility seems to have been more important during the structural adjustment program period.

1.2.2.4.3. Determinants of food price volatility in Cameroon: results from GARCH-X model

As noted in the literature, the simple GARCH model for volatility does not really tell about what the economic determinant of volatility is. To overcome this weakness, we integrate some exogenous variables which can allow for an economic explanation of volatility. There are two major changes when integrating variable in the GARCH model: first, the persistence of volatility changes and second some variables significantly affect the volatility of price series (see tables 1.6 and 1.7).

Table 1.6 : Estimated coefficients with the GARCH-X model for millet, cassava, and cocoyam

Process	Estimated coefficients	Return price series					
		Millet	Cassava		Cocoyam		
		GAR	BAF	YDE	BAF	BAM	YDE
Mean	ϕ_1		-0.65***	0.95***	-0.25***	-0.81***	0.10
	ϕ_2					-0.37***	-
	ϕ_3					-0.23***	0.36***
	θ_1	-0.19**	0.57**	0.99***	-0.33***	0.45*	-0.13
	θ_2						0.64***
	θ_3						-0.02
Conditional variance	α_1	0.12*	0.24**	0.15***	0.44***	0.21**	0.63***
	α_2				0.04		0.26**
	α_3						0.33**
	β_1	0.49***		0.53***			
	D1 π_1	-0.01**	-0.01***	-0.01***	-0.01***		
	D2 π_2			-	-0.01***		-
	D3 π_3					-0.02*	
	R_PLA φ_2		-0.01***		-0.01***		
	R_RIC φ_3	-0.02***		0.01**			

In some cases, such as millet in Garoua and cassava in Yaoundé, the inclusion of exogenous variables leads to lower the persistence on food price volatility. For some series as maize in Bafoussam and Bamenda, and rice in Garoua, the volatility, the amplitude of the volatility process is lowered by the inclusion of exogenous variables and move from explosive to persistent. Also, the explosive behavior of volatility has been lowered by the GARCH-X specification in the case of cocoyam, rice and maize in Yaoundé. We have to note that, the world price of cereals and crude oil does not have significant effect on food price volatility in Cameroon. Indeed, when these variables were included in the GARCH-X model, the effect was not significant. On the other hand, the result suggests that, food price volatility is mainly explained by the volatility of other commodities, as already noted by Balcombe (2010). However, this effect is not the same in all cases. There are some evidences of an effect of cereal price volatility on other commodities in the same local market. Then, rice volatility increases the volatility of cassava. The same effect is observed for maize in Garoua, and for millet. This latter result suggests that millet and rice can be seen as complementary products in Garoua.

<u>Table 1.7 : Estimated coefficients with the GARCH-X model for maize and rice</u>

Process	Estimated coefficients	Return price series							
		Maize				Rice			
		BAF	BAM	GAR	YDE	BAF	BAM	GAR	DLA
Mean	ϕ_1	-0.14			-0.26***	-0.40***	-0.79***	-1.32***	-0.30***
	ϕ_2							-0.38***	-0.38***
	ϕ_3								-0.39***
	ϕ_4								-0.06***
	θ_1		-0.34***	-0.38***			0.44***	0.99***	
	θ_2						-0.48***		
	θ_3						-0.20***		
Conditional variance	α_1	0.27***		0.13*	0.57***	0.14***	0.42***	0.30**	1.31***
	α_2								0.44***
	α_3								
	β_1	0.43***	0.80***	0.35***	0.50***	0.68***		0.58***	
	D1 π_1			-0.01***			0.01***		
	D2 π_2	-0.01***				-0.01***	-0.01***		-0.001**
	D3 π_3					0.001***			
	R_CAS φ_1		-0.02***	-0.02***					
	R_PLA φ_2		-0.02***						
	R_RIC φ_3	0.02**	-0.05***	0.09***					
	R_MIL φ_4			0.01				0.01***	
	R_FUEL φ_5		0.19***		0.03***				

Note: Markets: BAF: Bafoussam, BAM: Bamenda, DLA: Douala, GAR: Garoua, and YDE: Yaoudé;

Plantain volatility contributes to lower volatility for millet in Garoua, cocoyam in Bafoussam and maize in Bafoussam. According to this latter result, plantain and millet in Garoua, plantain and cocoyam in Bafoussam and finally, plantain and maize in Bafoussam can be seen as substitutable products.

The transportation cost in some cases can also affect significantly and positively the volatility of food price. This is the case for maize in Bamenda and Yaoundé. The explanation can be the fact that in this region, maize is produced relatively far from the town where the markets exist.

On the other hand, it is worth noting that the effect of policy measures, when it is significant, was relatively low. First, the implementation of the development strategy of the rural sector contributed to lower volatility only in Garoua for millet and maize, in Bafoussam for cassava and cocoyam, and for cassava in Yaoundé contrary to what would has been expected. This can be justified by the inefficiency of the development project in rural sector. Second, the suppression of import duties and taxes on basic foodstuffs contributed to lower volatility only for maize, rice and cocoyam in Bafoussam; cassava and cocoyam in Yaoundé; and rice in Bamenda.

To sum up, couples of complementary and substitutable products are different for each market under scrutiny, as shown in Table 1.8. In the case of complementary products, a rise in prices of one product is perceived in the price of the other products, and thus policy-makers can concentrate their efforts on only one product by observing its evolution in order to stabilize price volatility for this product but also for its complements. A high volatility in one of these products would be an indication of a high volatility for the others. Such information is of importance and can be useful to support effective policies aiming at the fighting against food price volatility. In the case of substitutable products, increases in price volatility of one product leads to a shortage in other products, due to a great, sudden and rapid increase in demand for substitutes. Therefore, such information can also be useful to take adequate measures, at a convenient time, as destocking or imports of commodities that will soon fail to meet the demand.

Table 1.8 : Summary results on the products' complementarity or substitutability on each market

Markets	Complements	Substitutes
Yaoundé	cocoyam - plantain cassava - rice	
Douala	cassava - maize plantain - cassava plantain - cocoyam	cocoyam - cassava
Bafoussam		plantain - cocoyam plantain - maize
Garoua	maize - cassava millet - cassava maize - rice rice - millet	rice - cassava plantain - millet

Thus, based on results of Table 1.8, we can suggest looking at the evolution of price volatility of plantain in Cameroon since it is a complement to cocoyam in Yaoundé, and cassava and cocoyam in Douala as well as a substitute to cocoyam and maize in Bafoussam and millet in Garoua. An increase in the price of plantain could imply an increase in the price of cassava and cocoyam on the market of Douala and Yaoundé, and a shortage of cocoyam and maize in Bafoussam and millet in Garoua. The other product that could be put under observation is cassava since it is a complement to rice in Yaoundé and maize in Douala, and to maize and millet in Garoua as well as a substitute to cocoyam in Douala and rice in Garoua. By following price evolutions of cassava, price evolutions of maize, millet and rice that are complement products on the market of Garoua are also under scrutiny. Thus, by observing price volatility of cassava and plantain in Cameroon, appropriate actions can be anticipated on all other products in all markets under consideration in this study. Indeed, a reduction in the price of cassava and plantain will also reduce the price of their complements, while it will increase demand for cassava and plantain on markets where they are substitute to other products, with potential risks of shortage.

Conclusion

This chapter examines the determinants of food price volatility in Cameroon, using data from the IMF and the NIS. Some exogenous variables were used as proxy for government policies, non-agricultural-factors, transmission across prices, and demand pressure to find out the economic explanation of food price volatility. We rely on the exogenous approach to explain food price volatility in Cameroon. Moreover, we have assumed that food price volatility in the Cameroonian market is a result of a set of domestic/internal factors as well as external factors coming from the world market.

All in all, three main conclusions can be set. First, although the fact that there is a general tendency to assert that food price volatility has increased over time (Gilbert and Morgan, 2010b), we are unable to confirm this hypothesis. One possible explanation can be found in the fact that in Cameroon imported cereal has many possible substitutes. However, to confirm this, more analyses are needed. This is beyond the scope of this chapter. Second, regarding the determinants of food price volatility in Cameroon, there is no significant impact of external factors such as the price of wheat and crude oil. At the opposite, food price volatility can be explained by internal factors. The most important one is the price of other agricultural commodities. This result suggests that, the price transmission between the international and Cameroonian markets is low for cereals. Therefore, we will analyze, in the second chapter of this thesis, the price volatility transmission between the world and Cameroonian markets. Third, it has been found that local commodities are more often complement to each other than substitute. In the case of complementary products, policy-makers can concentrate their efforts on only one product to stabilize price volatility for this product but also for its complements.

Three main recommendations can be suggested: firstly, it can be important to implement more specific development projects based on others commodities such as local cereals, roots and tubers, and to find ways to improve the efficiency of existing development programs in the agricultural sector. Since local cereals or roots and tubers are substitute to imported cereals, they are of real interest for decision-makers to manage food price volatility in Cameroon, since they are not dependent on what happens on international markets. Secondly, as transport costs has had an impact on local commodities, with an increase in fuel prices resulting in an increase in the price in some markets, following the evolution of fuel price as well as improving infrastructure remain relevant options for containing food price volatility of some local commodities. Thirdly, it seems necessary to update existing data on commodity prices and collect more detailed price series on consumer and producer prices, which can be really useful for a more detailed analysis and information regarding price transmission among stakeholders.

CHAPTER 2: *TRANSMISSION OF FOOD PRICE VOLATILITY IN CAMEROON*

Introduction:

The last decade, and particularly since the 2007/08 food crisis, a special attention has been given to food price volatility over the world. More importantly, the food import dependence of developing countries such as Cameroon expose farmers and consumers to world food price uncertainties. Therefore, given this background, investigating the transmission of food price volatility appears timely. The main objective of this chapter is to analyse the transmission of price volatility in Cameroonian markets, using a case study of rice. Specifically, we will analyse the price volatility transmission between international market and Cameroonian markets in one hand, and examine the transmission of price volatility between Cameroonian markets. Monthly price data from the world commodity prices of the International Monetary Fund (IMF) and the National Institute of Statistics in Cameroon are used to estimate various Multivariate Generalized Autoregressive Heteroskedasticity (MGARCH) models.

Despite the fact that local cereal production account for about 75% of the cereal available in Cameroon (WFP, 2016), rice importation seems to be a serious problem in terms of food security and nutrition. Indeed, according to the *Citizens Association in Defense of Collective Interests in Cameroon*, ACDIC (2006), three out of four households in Cameroon consume rice at least four times per week and the poor households spend 50% of their income on food, with rice accounting for about 75 % of this expenditure. Moreover, due to shortage in local production, there was a two-thirds increase in the value of rice imported between independence and 2007 (Awono and Havard, 2011) and just between 2001 and 2007, the volume of imported rice doubled. Cameroon moved form a situation where 80 % of local demand for rice in 1975 was met by domestic production to a situation where 80 % of national demand was met by imported rice (Horwitz, 2014).

This chapter is organized as follows: The first section discusses the theoretical framework for analysing the transmission of food price volatility; the second section presents the empirical analysis of the transmission of rice price volatility in Cameroon. The last section concludes.

2.1. THE THEORETICAL FRAMEWORK FOR ANALYSING FOOD PRICE VOLATILITY TRANSMISSION

After discussing the theoretical framework related to price transmission and volatility transmission in economics, we present the theoretical framework underlying market integration.

2.1.1. Difference between price transmission and price volatility transmission

The difference between price transmission and price volatility transmission is important and has to be clarified when dealing with price volatility transmission since the two concepts are very close. For this purpose, we first deal with price transmission versus price volatility transmission in terms of definition and modelling issues, and briefly present a literature review on price volatility transmission.

2.1.1.1. Price transmission versus price volatility transmission

Price transmission and price volatility transmission are very close since they both deal with price linkages between markets or along the chain (when analysing food supply chain) as noted by Assefa et al. (2015). However, there is a fundamental difference in terms of the nature of the linkages between these two concepts. In fact, price transmission refers to the linkages between the conditional mean prices, contrary to the price volatility transmission that deals with linkages between the conditional variances of prices (Natcher and Weaver, 1999). Moreover, according to Assefa et al. (2015), price transmission focuses on the transmission of the predictable "*portions*" of price between markets, whereas price volatility transmission deals with transmission of the unpredictable "*portions*" of price between markets. Apergis and Rezitis (2003) suggested that price volatility transmission expressed the degree to which price uncertainty or shocks in one market are linked to the price uncertainty or shocks in the others. Generally, the correlation between price and price volatility in locally separated markets measures the degree of price and price volatility transmission. A near to unity correlation between price and price volatility in locally separated markets imply perfect price or price volatility transmission between the considered markets. Therefore, it seems necessary to clearly state the object of the study. Indeed, there can exist cases where there is perfect price transmission, whereas there is no perfect price volatility transmission.

Depending on the aim of studies, price transmission can be modelled using different econometric specifications. According to Assefa et al. (2015) the vector error correction model has been intensively used recently. It is Von Cramon-Taubadel (1997) that first suggested the use of the error correction approach in the analysis of price transmission. Several versions of this model have been introduced for different purposes. For instance, a modified version of this model can be used to test for asymmetric price transmission and non-linearity in price dynamics[30]. Rezitis and Stavropoulos (2011) applied a threshold vector error correction model to test for non-linearity in price and Brummer et al. (2009), for example, applied a Markow switching vector error correction model.

Following Assefa et al. (2015), a Vector Error Correction (VECM) is specified in order to identify the main differences between price transmission and price volatility transmission models as follows:

$$\Delta p_t = \alpha_1 + \sum_{i=0}^{r} \beta_i^{'} \Delta w_{t-i} + \sum_{i=1}^{r} \beta_i^{''} \Delta p_{t-i} - \beta_p (p_{t-i} - \beta w_{t-i}) + u_{pt} \tag{2.1}$$

$$\Delta w_t = \alpha_2 + \sum_{i=1}^{r} \beta_i \Delta w_{t-i} + \sum_{i=0}^{r} \beta_i^{'''} \Delta p_{t-i} - \beta_w (p_{t-i} - \beta w_{t-i}) + u_{wt} \tag{2.2}$$

Where p_t and w_t are the prices for two locally separated markets at the time t. The two equations (2.1) and (2.2) are solved simultaneously to determine the degree of price transmission between two locally separated markets. The coefficients $\beta_i^{'}$ and $\beta_i^{'''}$ measure the degree of transmission of current and lagged short term changes in the second market price (w_t) to the first market price (p_t), and the degree of transmission of current and lagged short-term changes in the first market price (p_t), to the second market price (w_t), respectively. The coefficients β_p and β_w measure the degree of adjustment to the long-term equilibrium relation for price (p_t) and (w_t), respectively. Since the term in parenthesis represents the long-run equilibrium. The transmission of the price change for the predictable portions of price between the two regions is modelled by this VECM model.

On the other hand, the Multivariate Generalized Autoregressive Heteroskedasticity models (MGARCH) are commonly used to model volatility transmission (Assefa et al., 2015;

[30] See Meyer and von Cramon-Taubadel (2004) and Frey and Manera (2007) for a survey of asymmetric price transmission models.

Bauwens et al., 2006). In general, the MGARCH models allow the conditional covariance matrix of the dependent variables to follow a flexible dynamic structure and the conditional mean follows a Vector Autoregressive (VAR) structure. The literature on the MGARCH models[31] is vast and there are different approaches to construct these models depending on the specification of the conditional covariance matrix, as noted by Bauwens et al. (2006): (i) direct generalizations of the univariate Generalized Autoregressive Heteroskedasticity (GARCH) models, (ii) linear combinations of univariate GARCH models, and (iii) non-linear combinations of univariate GARCH models.

In the first category we have the VEC, Diagonal VEC, BEKK and factor models, among others. In these approaches, the conditional covariance matrix is modelled directly. The VEC and Diagonal VEC models were introduced by Bollerslev et al. (1988). The Baba-Engle-Kraft-Kroner (BEKK) model from Engle and Kroner (1995) that has the main attractive property of the positivity of the conditional covariance matrices by construction and appears as a specific case of the VEC model. Factor models introduced by Engle et al. (1990) were motivated by the economic theory. In these models, common unobserved components or factors generate the dependent variables. The process is hypothesised to be generated by a small number of unobserved heteroskedastic factors, as noted by Silvennoinen and Teräsvirta (2009), and these models can be seen as a special case of the BEKK model.

The second category is generally composed by orthogonal and latent factor models. These models appear as linear combinations of GARCH or non-standard GARCH models such as the Nelson (1991)'s exponential GARCH (EGARCH) model, the Ding et al. (1993) 's Asymmetric Power Autoregressive Conditional Heteroskedasticity (APARCH) model, the Baillie et al. (1996)'s fractionally integrated GARCH model and the El Babsiri and Zakoian (2001)'s contemporaneous asymmetric GARCH model, among others. Orthogonal models introduced by Kariya (1998) can be seen as factor models with factors that are one-dimension GARCH processes with zero median. Observed data in orthogonal model are created by orthogonal transformation of many one-dimension GARCH processes. The factor latent models are a special case of factor models discussed above in which the conditional variance matrix is not anymore measurable. Then, according to Shephard (1996), latent factor models are classified as stochastic volatility models.

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[31] For models specifications, details and derivations see Bauwens et al. (2006) and Silvennoinen and Teräsvirta (2009).

In the last category, we have constant and dynamic conditional correlation models, the general dynamic covariance model, and Copula-MGARCH models. These models allow for separated specification of the individual conditional variances, on the one hand, and on the other hand, the conditional correlation matrices or other forms of dependence between individual series, as noted Bauwens et al. (2006). These families of models are easier to estimate, since the number of parameters to be estimated is fewer than in others category of MGARCH models. The Constant Conditional Correlation GARCH (CCC-GARCH) from Bollerslev (1990) assumes the constance of the conditional correlation matrix. By imposing such restriction, the number of parameters to be estimated is reduced and the estimation procedure is simplified. This assumption may be unrealistic, therefore, Tse and Tsui (2002) and Engle (2002) proposed a Dynamic Conditional Correlation GARCH (DCC-GARCH) model that allows the conditional correlation matrix to be time-varying. The General Dynamic Covariance (GDC-GARCH) model proposed by Kroner and Ng (1998) appears to be different from all the previous models, but nests several of them, depending on parameter restrictions. Finally, Copula-MGARCH models introduced by Kearney and Patton (2000) and Jondeau and Rockinger (2001) are specified by three elements: GARCH equations for the conditional variances, marginal distributions for each series, and a conditional copula function[32].

2.1.1.2. Brief literature review on price volatility transmission

Price volatility transmission in financial markets has been well-documented, but has received relatively less attention in agriculture. In general, the literature about the transmission of price volatility can be divided into two groups: transmission of price volatility in food supply chains, and transmission of price volatility in one or between different agricultural markets.

Among the studies that explicitly analysed price volatility transmission in food supply chains, most of them have detected transmission of price volatility. For instance, Khan and Helmers (1997), Buguk et al. (2003), Apergis and Rezitis (2003) and Khiyavi et al. (2012) detected transmission of price volatility from feed to farm, Natcher and Weaver (1999) detected bidirectional volatility transmission across all the chain stages, Zheng et al. (2008) and Uchezuba et al. (2010) identified price volatility transmission from farm to retail, and Rezitis (2012) detected the transmission of price volatility from retail to farm due to retailer concentration, amongst others.

[32] For more details about the copula function, see Nelsen (1999).

For a complete literature review on the transmission of price volatility along a food value chain, see Assefa et al. (2015). Moreover, as mention by these latter authors, there is a lack in the literature about the effect of contextual factors on the degree of transmission of price volatility. Nevertheless, some authors have discussed this issue. Khan and Helmers (1997) in the case of the U.S. livestock-meat industry, Apergis and Rezitis (2003) in the case of Greece, and Khiyavi et al. (2012) in the case of Iran suggested that farm production contract reduced the transmission of volatility from farm input and retail output prices at the farm stage. Market power was identified as another factors having an impact on the transmission of price volatility. For instance, Buguk et al. (2003) in the case of U.S. catfish markets documented that market power helps cooperatively organized farmers to asymmetrically transmit positive input shocks to the next stage in the value chain, while Uchezuba et al. (2010) argued that retailers asymmetrically transmitted unexpected positive farm price shocks in the South African Broiler Market.

The literature about price volatility transmission in agricultural markets is relatively large since the price hike in 2008. For instance, Gardebroek et al. (2015) analysed the dynamics of volatility across major agricultural commodities in the United States. More precisely, these authors focused on the volatility transmission and the time evolution of interdependencies between corn, soybeans, and wheat using a MGARCH approach. Contrary to similar studies, these authors assess whether interdependencies in volatility differ among different data frequencies comparing daily, weekly, and monthly data. Overall, results suggest that there are important volatility spillovers across commodities at the weekly and monthly levels. For instance, shocks in wheat and corn price returns have significant cross-volatility spillovers. Finally, the latter authors concluded that it is necessary to account for data frequency when analysing commodity price volatility; this could explain observed conflicting findings in the literature. Rapsomanikis (2011) focused on the persistence of food price volatility and the volatility spillover between world food markets and the markets of six different developing countries. The author focused on the relationship between the world market, the wheat market in Peru, and the maize market in Mexico. In Africa, this author considered maize in Malawi and sorghum in Niger. In Asia, the author finally investigated price transmission and volatility spillover in rice markets in India and the Philippines. The results suggest that world price changes have been partially and slowly transmitted in the considered developing countries. Moreover, domestic markets exhibit the persistence in price volatility, mainly owing to domestic shocks, rather than international market shocks. In order to reduce food price volatility in developing countries, the focus should be on domestic policies leading to reduce domestic price volatility. Finally, an internal community action to mitigate the negative impact of international price volatility on developing countries is necessary. Similar results in terms of an incomplete world price change adjustment between world market, Ethiopia, and Malawi were found by Rapsomanikis and Mugera (2011). The latter authors also concluded that the volatility problem in domestic markets is due to domestic factors, rather than to world market shocks.

The transmission of price volatility was also analysed in the case of agricultural future markets. For instance, Beckmann and Czudaj (2014) used price data of first nearby future contracts for wheat, cotton, and corn and estimated GARCH-in-mean VAR models following Elder (2003) to analyse the volatility spillover between different future markets. Contrary to the previous studies that focused on separately futures markets or the link between them, Beckmann and Czudaj (2014) adopted a new perspective by focusing on the spillover between various markets. This last question is important since it can help to identify the general causality patterns and the possibility of co-movements of future markets that can be a crucial issue for both policymakers and investors. The authors found a short-run volatility transmission in agricultural futures markets. Additionally, the main question researched by Von Ledebur and Schmitz (2009) was whether and to what extent the volatility of agricultural commodity prices separated market places have been transferred during the drastic price changes of 2008. The latter authors used a daily price data from March 27, 2007 to March 5, 2008, and argued in favour of an operating volatility transmission from a multivariate GARCH models. More simply, the authors documented that the volatility of future prices in different separated market places did impact each other.

2.1.2. Market integration

The definition of market integration is not a subject of consensus in the literature. However, market integration or price transmission generally refers to the fact that, homogeneous commodities share a common long-run trade information even when geographically separated (Amikuzuno, 2011). To present the theoretical framework of market integration, it seems necessary to review some relevant concepts, namely spatial arbitrage, the Law of One Price (LOP), spatial market integration, and spatial market efficiency. After that, we are going to present economic models of price formation.

2.1.2.1. Spatial arbitrage, Law of One Price, spatial market integration, and spatial market efficiency

Spatial arbitrage can be a starting point when analysing market integration. Broadly speaking, the spatial arbitrage property ensures that for homogeneous goods, the price difference between two regions will be at most equivalent to the transaction cost. For instance, people are incited to sell in the region where the price of a given goods is high, and to buy in the region where the price is low. If spatial arbitrage is efficient, this will lead to a fall in prices, which reflects the transaction cost.

Spatial arbitrage can be represented, following Fackler and Goodwin (2001), by this equation:

$$p_j - p_i \leq r_{ij} \tag{2.3}$$

Where p_j, p_i and r_{ij} are the prices of the considered goods in location j, location i and the transaction cost of moving the considered goods from location i to location j respectively. If there is a direct trade between these locations, the condition (2.3) will hold as equality.

The relation (2.3), known as the spatial arbitrage condition, can be viewed as the starting point for any price behaviour analysis. However, this condition is an equilibrium concept and its main drawback is the fact that this relation does not tell us about price definition and formation, as noted by Fackler and Goodwin (2001).

The Law of One Price (LOP) implies that the price for the same goods tends to converge to the same level, abstracting from transaction costs between spatially different markets that are linked by trade and arbitrage as a result of profit incentives and market forces (Fan and Wei, 2005). This Law is very important in the economic literature and authors have developed several versions. About this Law, Marshall (1890) wrote that *"... the more nearly perfect a market is, the stronger is the tendency for the same price to be paid for the same thing at the same time in all parts of the market"*. Many authors as Fackler and Goodwin (2001) stablished two relationships between spatial arbitrage and the LOP. Therefore, the spatial arbitrage condition can be seen as the "weak" LOP, whereas the "stronger" version of the LOP is observed when the arbitrage condition holds with equality. On other hand, when tacking into account the aggregation, the LOP is generally referred to as the Purchasing Power Parity (PPP).

The popular Enke-Samuelson-Takayama-Judge (ESTJ) spatial equilibrium model (Enke, 1951; Samuelson, 1952; Takayama and Judge, 1971) can be seen as an attempt to illustrate the spatial arbitrage and the LOP. The price dispersion in two separated regions i and j, for homogeneous goods is bounded from above by the spatial arbitrage cost between the markets when trade volumes are unrestricted and bounded from below if price volume reaches some price ceiling, as noted by Barrett (2005).

In ESTJ spatial equilibrium model:

$$
p_i \quad \begin{aligned} &= p_j + \tau_{ij} \;\; if \;\; q_{ij} \in (0, q_{ij}^*) \\ &\le p_j + \tau_{ij} \;\; if \;\; q_{ij} = 0 \\ &\ge p_j + \tau_{ij} \;\; if \;\; q_{ij} = q_{ij}^* \end{aligned} \tag{2.4}
$$

Where p_i and p_j are respectively the prices in two separated regions, i and j. τ_{ij} is the cost of moving the commodity from market j to market i. q_{ij} and q_{ij}^* are the physical volumes of trade between the two regions and a maximal permitted trade volume between the two regions[33], respectively.

These equilibrium conditions imply a long-run market competitive equilibrium at the market level, and a firm-level profit maximization. When the LOP holds, the strict equality condition reflects the competitive equilibrium relationship.

The LOP was extensively used and plays an important role when modeling international trade and exchange rate determination as noted by Yang et al. (2000). In some extent, the LOP can define and mesure the market integration. Indeed, if a single price prevails between spatially separated markets, these markets can be said integrated as a single market. According to Ravallion (1986), market integration analysis can help to understand how markets work. This latter author interpreted market integration as connection of spatially separated locations by trade. Moreover, information on market integration is important when designing agricultural price stabilization policies (Fackler and Goodwin, 2001).

At a macro level, well-integrated markets ensure that economic policies change the constraints and incentives faced by decision-makers by distributing risks and raising the incentive to adopt improved production technologies (Barrett, 2005).

[33] Due to trade quota, for example.

On the other hand, Fackler and Goodwin (2001) argued that there is a difference between the absence of arbitrage and market integration. These latter authors suggested that market integration can be defined as the measure of the degree of demand and supply shocks' transmission between two or more separated regions. Then, if there is no transmission of shocks between two markets for example, these markets are said to be separated or non-integrated. In this latter case, an economic policy can be less effective as noted by Cirera and Arndt (2008). Generally, this spatial market integration is distinct to vertical market integration that refers to price links at different points of the supply chain (Rashid and Minot, 2010).

Considering a given shock, ε_A that moves the excess demand for a commodity in region A, but not in region B. The price transmission ratio associated with this shock that can measure market integration as noted by Fackler and Goodwin (2001) is:

$$R_{AB} = \frac{\partial p_B / \partial \varepsilon_A}{\partial p_A / \partial \varepsilon_A} \tag{2.5}$$

When the expected price transmission ratio R_{AB} is 1, market integration is said to be perfect. Note that, perfect integrated markets is opposed to completely separated markets, and the first one should exhibit the strong form of the LOP.

On the other hand, it may be useful to note that it is possible to have this price ratio below 1, even if the LOP holds as notde by Fackler and Goodwin (2001). Therefore:

Perfect Market Integration $\Rightarrow$ "Stronger" form of the LOP $\Rightarrow$ "Weak" form of the LOP.

Finally, it can be important to make a distinction between **spatial market integration** and **spatial market efficiency**. Indeed, some authors have used these notions interchangeably, but they are conceptually different (Rashid and Minot, 2010). Market efficiency, in general measures the degree to which a resource allocation is efficient / optimal / cost minimizing (Buccola, 1989; Fackler and Goodwin, 2001; Rashid and Minot, 2010). Therefore, in efficient market, no aggregate welfare improvement can be made by the reallocation of resources. There is no more profit for spatial arbitrage that can be made by trader in such a situation. The distinction between these two concepts is also important when constructing the empirical test for market integration, since one author's view can suggest the evidence in favour of market integration, when another can show evidence against integration (Fackler and Goodwin, 2001).

2.1.2.2. Economic models of price formation

Theoretical models of price formation can be classified into two categories depending on the nature of the dynamics used in the model (Fackler, 1996; Fackler and Goodwin, 2001). For instance, there are models with exogenous dynamics in which exogenous shifts in model parameters cause price change and lead to a sequence of static equilibria, and models with endogenous dynamics where endogenous dynamic relationships due to storage, temporal delays in sales, and delivery for example are directly introduced in the equilibrium model.

2.1.2.2.1. Models with exogenous dynamics

Discussion on the models with exogenous dynamics generally focuses on three issues in the literature: point-location models, agents-on-links models, and dynamic linkages.

Point-location models:

In the point-location model, network links are treated as routes over which transport occurs (Fackler, 1996). These models can be used in markets in which nodes are major collection, distribution, or processing centres dealing directly with each other (Fackler and Goodwin, 2001). The aforementioned ESTJ model can be seen as the simplest form of a static point-location model.

Following Fackler and Goodwin (2001), we consider the basic m-location model:

$$q = D(p) \tag{2.6}$$

The equation (2.6) above represents the excess demand function $D(p)$ and p is the price vector. Equilibrium is characterized by two conditions: the LOP and an accounting identity.

The LOP here can be written as:

$$p_i - p_j + r_{ij} \geq 0, \quad s_{ij} \geq 0, \quad s_{ij}(p_i - p_j + r_{ij}) = 0 \tag{2.7}$$

Where r_{ij} is the transport cost from location i to location j of one unit of the commodity; s_{ij} corresponds to the amount shipped from location i to location j.

The accounting identity can be written as:

$$q_i = D_i(p) = \sum_{j=1}^{n} s_{ji} - s_{ij} \tag{2.8}$$

Finally, the equilibrium conditions also known as a complementary problem can be written as[34]:

$$f(x) \geq 0, \quad x \geq 0, \quad x^T f(x) = 0 \tag{2.9}$$

Authors have developed several algorithms to solve this complementary problem. For example, Takayama and Judge documented that the equilibrium can be solved by using linear demand functions and treating the problem as a quadratic programming problem. Widely available software can now be used to routinely solve large-scale complementary problems in both linear and non-linear form (Billups et al., 1997; Ferris and Pang, 1997).

Agents-on-links models:

The agents-on-links model is another type of spatial network models in which economic activity occurs at the nodes and along the links (Fackler, 1996). According to Fackler and Goodwin (2001), in agent-on-links model, an individual agent consumes or produces along the links, and market or city centres constitute the network nodes. Then, there are economic agents on nodes that interact (by buying or selling) with other agents on the links[35]. In general, theoretical results in the agents-on-links model remain similar as those in the point-location model. Since, the former appears as a continuous extension of the latter.

Dynamic linkages:

An important issue in both the point-location model and the agents-on-links model is their dynamic linkage. In commodity markets over time, linkages occur as result of storage, seasonality in production and consumption, transport delays, investment, preference shifts, demographic shifts, etc. Generally, these factors are treated as exogenous factors, except for storage, transport delays, and investment (Fackler, 1996). These exogenous factors that generate dynamics are represented by a shift in demand and supply functions. Such models

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[34] For details on derivations and solutions of this model, see Fackler and Goodwin (2001).
[35] For more details about the agents-on-links model, see for example Faminow and Benson (1990) and Dahlgran and Blank (1992).

are generally termed “sequential equilibrium models”, since prices at equilibrium are determined by a sequence of static equilibria[36].

2.1.2.2.2. Models with endogenous dynamics

The models with endogenous dynamics appear to be more general by endogenizing dynamics. These models are quite different from the models with exogenous dynamics by integrating the nature of intertemporal linkages. As noted by Fackler and Goodwin (2001), models with exogenous dynamics are appropriate in the case where the market’s shocks are beyond the market[37].

Let us consider, for example, the effects of delivery lags. Following Fackler and Goodwin (2001), consider a two-period, two-region model, where region 1 is a deficit region and there is a surplus in region 2. Assuming that, it takes one period to deliver commodity from region 2 to region 1, and with first order serial correlation in the excess demand shocks in region 1:

$$a_{1t} = \rho a_{1t-1} + v_{1t} \tag{2.10}$$

Other things being equal, the price shift in the two regions are expected to be in the same amount than in the next period, thus:

$$\frac{\partial p_{2t}}{\partial v_{2t}} = \frac{\partial E\left[p_{1t+1}\right]}{\partial v_{1t}} = \rho < 1 \tag{2.11}$$

The price transmission ratio from region 1 to region 2, arising from region 1 demand shocks, after derivation is:

$$\frac{\partial p_{2t} / \partial v_{1t}}{\partial p_{1t} / \partial v_{1t}} = \rho < 1 \tag{2.12}$$

Therefore, in this simple model, we obtain the usual result that the price transmission ratio is less than one.

Development on the case of excess demands in the two markets can be found in Fackler and Goodwin (2001).

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[36] For illustrations and implications of these models, see Fackler (1996) and Fackler and Goodwin (2001).
[37] For example, weather, fuel price, and macroeconomic shocks.

Finally, two points are essential in this analysis: (i) response time delays may determine the transmission shock speed and (ii) the degree of the response in the shipping region is determined by the interaction between the persistence of the shocks in the receiving regions and shipping delays.

In general, literature about the transmission of price volatility is abundant in the case of developed countries, however, studies are relatively rare for developing countries and there is none study focusing on the Cameroonian case, to the best of our knowledge. Therefore, we have tried to fill this gap by providing to the existing literature a case study on Cameroon.

2.2. EMPIRICAL EVIDENCE ON THE TRANSMISSION OF FOOD PRICE VOLATILITY IN CAMEROON

This section presents an empirical analysis on the transmission of food price volatility in Cameroon.

2.2.1. Methodology

2.2.1.1. Data

Secondary data from two different sources are used in this study. Monthly price data from January 1994 to December 2010 of the main markets in Cameroon where National Institute of Statistics (NIS) collected foodstuff price data. These markets are in Douala, Yaoundé, Bamenda, Bafoussam, and Garoua.

Prices on the international market are from the world commodity prices of the International Monetary Fund (IMF). Recall that the main idea in this chapter is to question the transmission of price volatility between the international market and the Cameroonian markets. All the price series used are real price series deflated by the Cameroonian Consumer Price Index (CPI) in order to capture the time effect of the variation of the cost of life in the analysis.

This study focuses on rice. Indeed, food importation is necessary for Cameroon to feed its population, and rice accounts for a large share on those importations. Rice importations rose from about 143,000 tons in 2000 to over 650,000 tons in 2014 (Horwitz, 2014; Sneyd, 2013).

Despite the implementation of agricultural policies to significantly increase national rice production, the imported rice satisfied about 80% of the national rice demand, which makes the country vulnerable to an high volatile world market (ACDIC, 2006; Goufo, 2008; Horwitz, 2014). The situation was totally different in 1975, when the country almost met 80% of its own rice need (Sneyd, 2013). On the other hand, rice can be seen as a commodity of high importance in Cameroon due to the increased urbanisation and the change in food preferences in the country (Molua, 2010a). Indeed, the urbanization growth rate rose from 17% in 1960 to 52% in 2007 as noted by World Bank (2007). In the same period, the consumption per capita on rice equivalents rose from 2 kg to 23 kg in the country (ACDIC, 2006; Goufo, 2008). Then, as noted by the Citizens Association in Defence of Collective Interests in Cameroon (ACDIC, 2006), three out of four households consume rice at least four time per week, and poor spend around 50% of their total expenditure on food, in which rice accounts for about 75%.

We have to note that, on the one hand, we use the exchange rate (USD/FCFA) available in the IMF database to convert the rice price from the world market price into the domestic price. As discussed in chapter one, we expect that the fluctuation in this price is not caused by the fluctuation on the exchange rate. The hypothesis of no long-run relationship between rice price in local currency and exchange rate is accepted, since we fail to accept the existence of a cointegration relation between the considered price series. On the other hand, all price series are seasonally adjusted by the commonly census *X-12 ARIMA* method of the US Census Bureau, when seasonality is detected as discussed in the chapter one. The results of the seasonality test reveal that for the six price series under consideration (see in the appendix table 2.1), seasonality is present only for the world market rice price series, thus seasonally adjusted data are used for this series.

2.2.1.2. Methodological framework

In this this chapter, we test whether Cameroonian markets can be integrated with world market, and also we look at the market integration between Cameroonian markets by analysing the food price volatility transmission. The following stages guide the analysis of price volatility transmission :

- Deseasonalization (if necessary) and descriptive statistics for each return price series;

- Standard unit root tests with and without change in regime (ADF, PP, KPSS and ZA)[38] for each real price series;
- Test for serial correlations on return price series;
- The ARCH LM test; and
- The MGARCH estimation

2.2.1.3. Models

In this chapter, we use the Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) models to assess the transmission of food price volatility, since this method is appropriate for this purpose as mentioned in the first section. Indeed, we want to know if the volatility in one market affects volatility in other markets, and if the shock in one market increases volatility on another market. In fact, volatility is measured here by the conditional variance of each series computed from a GARCH equation. Then, MGARCH models appear to be an appropriate technique as they allow for relationships between volatility processes of multiple time series (Bauwens et al., 2006). There is a large range of MGARCH models in the literature and this class of models allows both the conditional covariance and the conditional mean to be dynamic.

In addition, as noted by Serra (2013), time-series econometric techniques to model price volatility and volatility interactions have the advantage of requiring a small amount of data compare to structural models. Even if these time series models have a lack of a theoretical structure and can lead to contrasting results with the economic theory.

To analyse the volatility transmission between Cameroonian markets, we estimate successively a Constant Conditional Correlation model (CCC-MGARCH) and a Dynamic Condition Correlation model (DCC-MGARCH). This class of MGARCH models (Conditional Correlation models) represents the conditional covariances by nonlinear combinations of univariate GARCH models (Bauwens et al., 2006). More importantly, in each conditional correlation model, the positiveness of the conditional covariance matrix which is a main condition in the MGARCH modelling is ensured by construction and has a simple structure, that facilitates the estimation of parameters (Tas, 2008). These models have a slower number of estimated parameters, as the number of time series increases.

[38] Dickey-Fuller unit root test (ADF); Phillips-Perron unit root test (PP); Kwiatkowski, Phillips, Schmidt and Shin unit root test (KPSS); Zivot and Andrews unit root test (ZA).

In the CCC-MGARCH model proposed by Bollerslev (1990), the conditional correlations are constant. By imposing such restriction, the number of unknown parameters is greatly reduced and thus, the estimation is simplified (Bauwens et al., 2006). This assumption seems unrealistic in empirical application and is considered as the main limitation of this model. The Engle (2002)'s DCC-MGARCH model, which appeared as a generalisation of CCC-MGARCG model, makes the conditional correlation matrix time-varying. Moreover, the DCC-MGARCH model takes into account the time varying volatility. Time-varying correlation estimated from this model provides more sensitive results than the constant correlation estimated with the CCC-MGARCH model and indicates market integration. This model, among others, is also able to examine the volatility spillover between markets and is useful in presence of a high-dimension data set. Basically, the idea is to apply Tse's (2000)'s Lagrange multiplier (LM) test before estimating the DCC-MGARCH model to test for dynamic conditional correlation in errors of the CCC-Model. The DCC-Model is estimated when the null hypothesis of constant conditional correlation is rejected.

Following Bauwens et al. (2006), the standard multivariate MGARCH framework is defined as:

$$y_t = \mu_t(\theta) + \varepsilon_t \tag{2.13}$$

Where y_t is a vector of a stochastic process of dimension $N \times 1$. $\mu_t(\theta)$ is the conditional mean vector and ε_t is such that:

$$\varepsilon_t = H_t^{\frac{1}{2}}(\theta)\eta_t \tag{2.14}$$

ε_t is conditionally heteroskedastic given the information set I_{t-1}[39]. H_t is the $N \times N$ conditional covariance matrix of y_t and must be a positive definite matrix[40]. η_t is a vector of normal, independent, and identically distributed innovations such that $E\left[\eta_t \eta_t^{'}\right] = I_N$

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[39] I_{t-1} is the information set generated by the observed series $\{y_t\}$ until time $t-1$.

[40] $H_t^{\frac{1}{2}}$ is obtained by the Cholesky factorization of H_t.

The different types of MGARCH models depend on the specification of the process matrix H_t. For instance, in the Bollerslev (1990) CCC-MGARCH model, the conditional covariance matrix is defined as:

$$H_t = D_t^{\frac{1}{2}} R D_t^{\frac{1}{2}} \qquad (2.15)$$

Where D_t is a diagonal matrix of conditional variances, $D_t = diag\left(\sigma_{1t}^2, ..., \sigma_{Nt}^2\right)$,

σ_{it}^2 evolves as any univariate GARCH model, and R is a symmetric positive definite matrix of time-varying unconditional correlations of the standard residuals $D_t^{-1/2}\varepsilon_t$,

$$R = \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1N} \\ \rho_{12} & 1 & \cdots & \rho_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1N} & \rho_{2N} & \cdots & 1 \end{pmatrix} \qquad (2.16)$$

The CCC-MGARCH model has the constant conditional correlation due to the time invariance of R.

The difference between the CCC-MGARCH model and the Engle (2002)'s DCC-MGARCH model is on the specification of the matrix R which is time-varying in this latter case. For instance:

$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2} \qquad (2.17)$$

With $Q_t = (1-\lambda_1-\lambda_2)R + \lambda_1 \hat{\varepsilon}_{t-1} \hat{\varepsilon}'_{t-1} + \lambda_2 Q_{t-1}$.

$\hat{\varepsilon}_t$ is a $N \times 1$ vector of standardize residuals. λ_1 and λ_2 are non-negative parameters that govern the dynamics of the conditional quasicorrelations such that $0 \le \lambda_1 + \lambda_2 < 1$.

In this case R_t, a matrix of conditional quasicorrelations is defined as :

$$R_t = \begin{pmatrix} 1 & \rho_{12,t} & \cdots & \rho_{1N,t} \\ \rho_{12,t} & 1 & \cdots & \rho_{2N,t} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1N,t} & \rho_{2N,t} & \cdots & 1 \end{pmatrix} \text{ which is time variant.} \qquad (2.18)$$

Our MGARCH model focuses on the price return series $r_{i,t}$ for the price series i at time t and is defined as:

$$r_{i,t} = \ln(\frac{p_{i,t}}{p_{i,t-1}}); \qquad i = 1, \ldots, 5$$

The parameters of the CCC-MGARCH and DCC-MGARCH models are estimated by the Maximum Likelihood, via the Stata's '***mgarch***' command in Stata14.

More details regarding these models can be found in Engle (2002), Bollerslev (1990), and Bauwens et al. (2006).

2.2.2. Results and Discussions

2.2.2.1. Variables description

Standard descriptive statistics for return series are reported in the following table 2.1.

The statistics show evidence of an asymmetric distribution (positive skew) and an excess kurtosis (highly leptokurtic). The Jarque-Bera test rejects the null hypothesis of a Gaussian distribution for all return series. We suspect some heteroscedasticity in the data that can explain the non-normality. However, this issue will be explored later in this chapter.

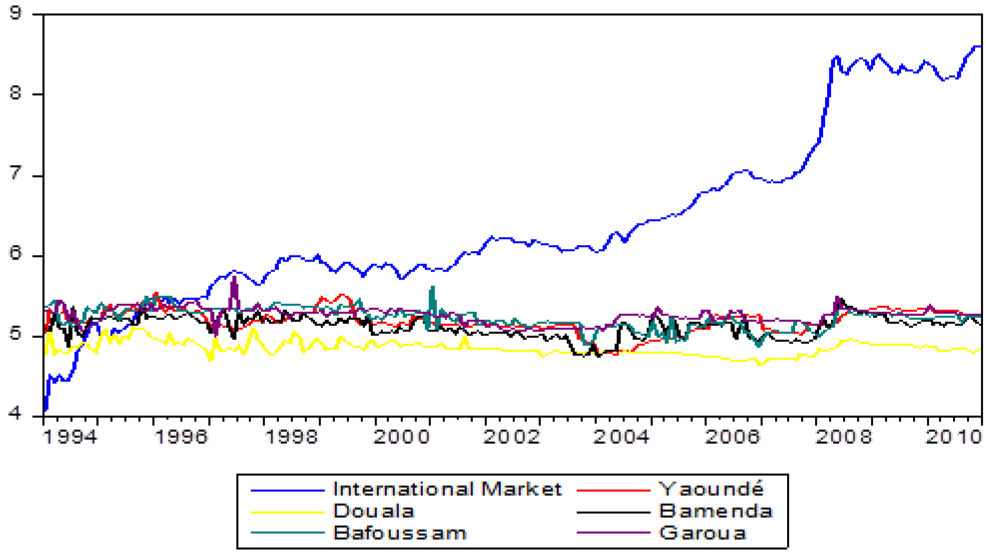
Table 2.1: Descriptive statistics of rice return series

	R_RIRICE_SA	R_RRI__YDE	R_RRI_DLA	R_RRI__BAF	R_RRI___BAM	R_RRI___GAR
Mean	0.022368	0.001065	0.000294	-0.000618	0.000248	-0.000317
Median	0.015339	0.000825	-0.001637	-0.000441	-0.003705	-0.002203
Maximum	0.475494	0.285938	0.297067	0.546940	0.486953	0.431031
Minimum	-0.194318	-0.206998	-0.318075	-0.547879	-0.327879	-0.409844
Std. Dev.	0.080673	0.054520	0.066389	0.094660	0.099624	0.072588
Skewness	1.746943	0.414694	0.328070	0.012855	0.726600	0.040924
Kurtosis	11.00824	9.233416	9.090484	14.19566	7.095213	16.11961
Jarque-Bera	645.7020	334.4709	317.3949	1060.197	159.7150	1455.940
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	4.540666	0.216278	0.059727	-0.125355	0.050426	-0.064376
Sum Sq. Dev.	1.314638	0.600431	0.890323	1.810018	2.004853	1.064327
Observations	203	203	203	203	203	203

R_RIRICE_SA is the return series in international market; R_RRI_YDE is the return series in Yaoundé; R_RRI_DLA is the return series in Douala; R_RRI_BAF is the return series in Bafoussam; R_RRI_BAM is the return series in Bamenda; R_RRI_GAR is the return series in Garoua

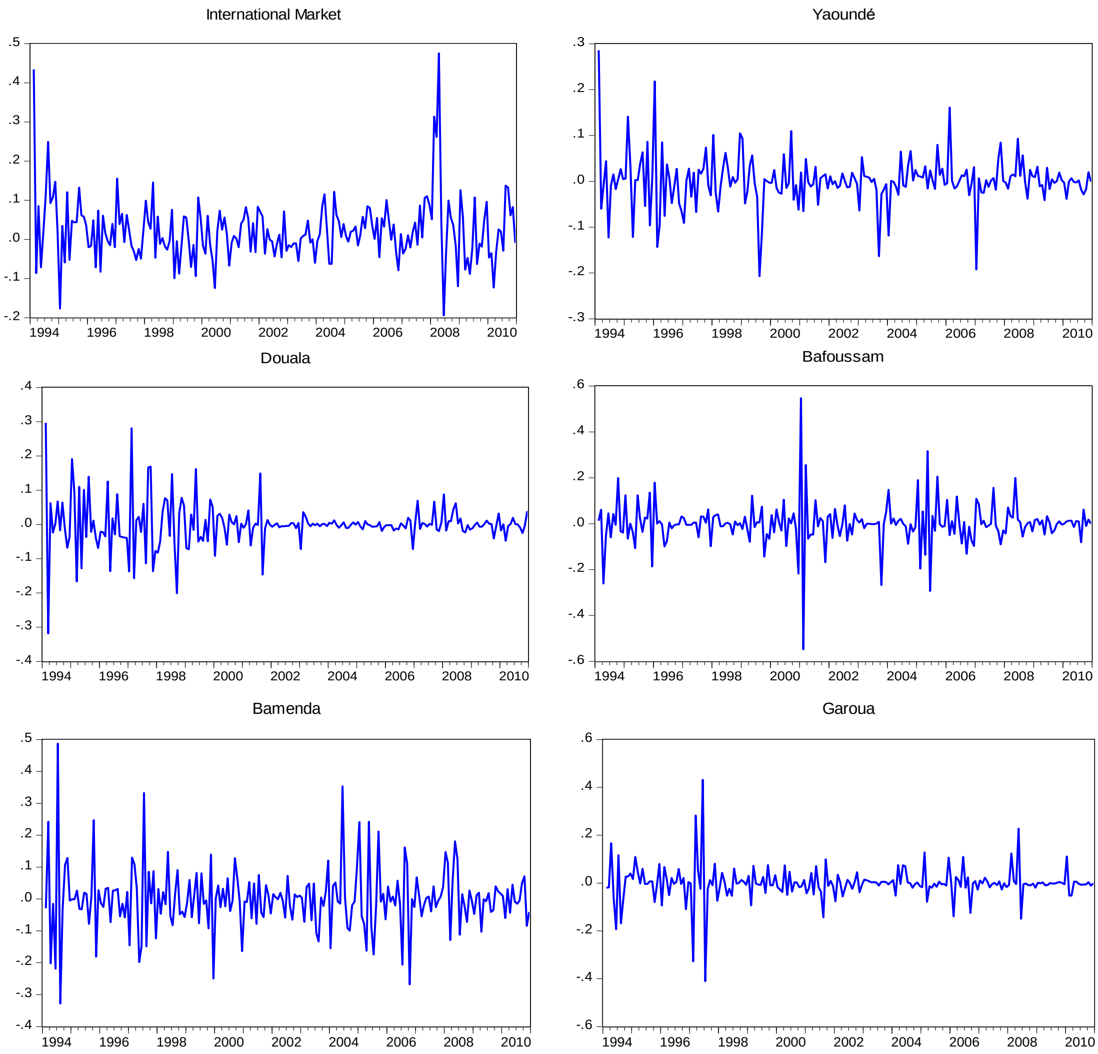
Rice real price and return series are respectively displayed in figures 2.1 and 2.2. The evolution of real price series of rice suggests that there is no co-movement between international price and Cameroonian prices. Moreover, the graphical inspection suggests that the evolution of real price series seems similar between Cameroonian markets, even if the Douala rice price seems to move alone. These real price series behaviours are confirmed by the analysis of correlation between these price series (see in the Appendix table 2.2).

Figure 2.1: Evolution of rice real price series



The evolution of returns series (figure 2.2) suggests that international market was more risky this last decade than Cameroonian markets, since high return is generally associated with high risk. At the national level, such behaviour was not observed, and it seems that all national markets were more risky during the Structural Adjustment Program (SAP) period. In figure 2.2, we can also observe that large changes seem to follow by large changes of either sign and small changes tend to be followed by small changes that exhibit volatility clustering. This can legitimate the application of ARCH-type processes.

Figure 2.2: Evolution of rice return price series



Furthermore, the graphical inspection of the evolution of the rice returns suggests that returns are stationary, while real prices seem to be non-stationary. These results are confirmed by the standard unit root tests in table 2.2. In all cases, the return series are stationary.

Table 2.2: Unit root test for rice real price series

	No Break			One Break	
Return series	**ADF**	**PP**	**KPSS**	**ZA**	**Break date**
R_RIRICE_SA	-4.785558***[1]	-12.39761***[2]	0.144411[2]	-8.833***	2007m10
R_RRI_YDE	-7.831300***[1]	-16.19777***[1]	0.059040[2]	-8.073***	2004m6
R_RRI_DLA	-4.645336***[1]	-51.16857***[1]	0.160412[2]	-12.139***	1997m2
R_RRI_BAF	-24.81336***[1]	-31.68503***[1]	0.065335**[2]**	-24.801***	2007m1
R_RRI_BAM	-13.51766***[1]	-22.70768***[1]	0.027362[2]	-13.743***	2003m12
R_RRI_GAR	-9.916107***[1]	-41.43964***[1]	0.137678**[2]**	-10.071 ***	1996m11

Akaike information criterion was used to determine the optimal lag for ADF test. [1] none; [2] model with intercept; [3] model with trend and intercept. ***/**/* denote statistical significance at 1%, 5% and 10% respectively indicating that the null hypothesis can be rejected. For ZA test, the critical value in the case of model Care: -5.57 for 1% significance level and -5.08 for 5% significance level.

In this chapter, we use a GARCH type process to model price volatility and then, we first test for an ARCH effect. Table 2.3 reports values for the Ljung-Box test on return (JB) and the squared return (JB^2), together with the ARCH LM-statistics for each return series. Overall, there are significant serial correlations in both residual and their squares since the p-values of the JB and JB^2 tests are all less than 1%, with the exception of Yaoundé return series. Additionally, the ARCH effect is found to be significant, with the exception of the Yaoundé return series. Thus, a GARCH parametrization could be appropriate for the conditional variance processes.

Table 2.3: Test for serial correlation and heteroscedasticity

Return series	I(d)	ARMA process	JB	JB^2	ARCH LM test
R_RIRICE_SA	I(0)	ARMA(2,2)	17.94*	35.43***	9.915076***
R_RRI_YDE	I(0)	ARMA(2,1)	13.46	7.29	1.387572
R_RRI_DLA	I(0)	ARMA(3,4)	43.99***	69.94***	70.95627***
R_RRI_BAF	I(0)	ARMA(2,1)	16.610*	35.421***	40.24401***
R_RRI_BAM	I(0)	ARMA(4,2)	30.112***	37.381***	28.02747***
R_RRI_GAR	I(0)	ARMA(1,4)	33.371***	84.897***	32.05829***

2.2.2.2. Empirical results from the MGARCH model

We have to note that our primary interest is not the estimated parameters, but lies on the sign and the significance of the conditional correlation parameters that indicate the relationship between price volatilities. The empirical results are presented in two sub-sections: the link between price volatility on the international market and Cameroonian markets, and the relationship between rice price volatility on Cameroonian markets.

2.2.2.2.1. Volatility transmission between the international market and Cameroonian markets

Turning first to the connection between international market and Cameroonian markets, we use different model specifications. First, we assume that only Douala (the economic capital), the main big and strategic town in terms of imports (with the presence of the port authority of Douala), and Yaoundé (the second Cameroonian big town and the political capital) markets can be linked to the international market. Therefore, we estimate a trivariate model, and we fail to establish significant linkages between Cameroonian markets and the international market (table 2.4); meaning that Cameroonian markets are not integrated to the world market in terms of rice price volatility transmission. This result is consistent with those obtained when estimating the entire system, taking into account all Cameroonian markets (excluding Yaoundé which does not exhibit heteroscedasticity as noted in table 2.3).

Table 2.4 : Constant conditional correlation MGARCH model for the world, Douala and Yaoundé markets

		Coef	Std. Err.	P>|z|
r_ririce_sa				
	r_ririce_sa L1.	.0900491	.0803879	0.263
	r_rri__yde L1.	-.0025207	.0821781	0.976
	r_rri_dla L1.	.066663	.0768328	0.386
ARCH_r_ririce_sa				
	arch L1.	.2525328	.1019224	0.013
	garch L1.	.6345477	.1231194	0.000
	_cons	.0006475	.000345	0.061
r_rri__yde				
	r_ririce_sa L1.	.0210431	.0411546	0.609
	r_rri__yde L1.	-.0636136	.0735561	0.387
	r_rri_dla L1.	.1140695	.0587153	0.052
ARCH_r_rri__yde				
	arch L1.	.0378701	.0293593	0.197
	garch L1.	.8641079	.1376576	0.000
	_cons	.000237	.0003047	0.437
r_rri_dla				
	r_ririce_sa L1.	.0150152	.0277776	0.589
	r_rri__yde L1.	.0083672	.0440709	0.849
	r_rri_dla L1.	-.3689575	.0746157	0.000
ARCH_r_rri_dla				
	arch L1.	.1588162	.0532835	0.003
	garch L1.	.8452754	.0326405	0.000
	_cons	.0000147	.0000103	0.153
corr(r_ririce_sa,r_rri__yde)		-.0046309	.0705588	0.948
corr(r_ririce_sa,r_rri_dla)		.0011776	.0699559	0.987
corr(r_rri__yde,r_rri_dla)		.12458	.0684545	0.069

Additionally, when looking at pairwise (international and Douala markets) results (table 2.5), the conditional correlation parameters is relatively small (0.0005), but significantly positive at 5%. This indicates that rice price volatilities between the international market and the Douala market move together. However, when releasing the time invariant assumption of the conditional correlation by estimating the DCC-MGARCH model, the results suggest that there is no relationship between price volatility on the international market and the Douala market (see table 2.5). The Wald tests for the assumption of the time-invariance on the DCC-MGARCH parameters reveal that we have to reject the null hypothesis that conditional correlations are time invariant.

Table 2.5 : Constant conditional correlation MGARCH model between world and Douala markets

		Coef.	Std. Err.	P>|z|
r_ririce_sa				
	r_ririce_sa L1.	.0895512	.0789028	0.256
	r_rri_dla L1.	.0664354	.0762197	0.383
ARCH_r_ririce_sa				
	arch L1.	.2524742	.1019435	0.013
	garch L1.	.6344539	.1228212	0.000
	_cons	.0006481	.0003427	0.059
r_rri_dla				
	r_ririce_sa L1.	.0143886	.0271837	0.597
	r_rri_dla L1.	-.368525	.0734129	0.000
ARCH_r_rri_dla				
	arch L1.	.1629558	.050917	0.001
	garch L1.	.8447574	.0299747	0.000
	_cons	.0000127	9.57e-06	0.184
corr(r_ririce_sa,r_rri_dla)		.0005182	.069291	0.994

The non-market integration between the international and Douala markets was confirmed even when imposing conditions in both bivariate CCC-MGARCH and DCC-MGARCH that the return series in these markets follow the same process, so we impose the constraints that the ARCH and the GARCH coefficients are the same for the two markets, respectively.

The empirical results point out the fact that there is no co-movement between international market and Cameroonian markets in term of rice price volatility. This suggests that, if the rice price becomes volatile in Cameroonian markets, the causes have to be found elsewhere, not on the international market volatility. Similar results was found by Rapsomanikis and Mugera (2011) between the world market and Ethiopian and Malawians agricultural markets. Moreover, this result can be explained by the implementation of government subsidies and support to rice importation since the 2008 food crisis. This policy seems to be effective, at least by disconnecting Cameroonian market to the more volatile world market, in some instance.

The rice price volatility on Cameroonian markets can be caused by the markets' structure, the retailer market power, and the lack of infrastructure, among others. However, due to data limitations, we cannot specifically focus on these issues. For policy makers, such information can be important to fight against price volatility in national markets that can hurt consumers and cause urban riots, as those observed in Cameroon in 2008.

2.2.2.2.2. Volatility transmission among Cameroonian markets

To assess the linkages between rice price volatility in Cameroon, we use two approaches: the global approach by modelling the entire system with the return series from Douala, Bafoussam, Bamenda and Garoua; and the pairwise approach considering six pairs of markets, namely Douala – Bamenda, Douala - Garoua, Douala – Bafoussam, Bamenda – Bafoussam, Garoua – Bamenda, and Garoua – Bafoussam[41]. The idea is to see if there is a link between the aforementioned markets. The question is: can the shortage in one market can be compensate rapidly with the excess of supply in another market? Since, we consider a case of imported cereal (rice) that is not perishable, one can expect a positive response to this question.

The results from the constant conditional correlation MGARCH model, in the global approach, suggest that there is a transmission of price volatility only between Douala and Garoua, and Bamenda and Bafoussam markets, among the six pairs of markets. The estimated parameters are respectively -0.1391 significant at 5% and 0.2973 significant at 1% (table 2.6), meaning that the rice price volatility in the Douala market move in the opposite direction of the Garoua price volatility. But, we have to note that the estimated parameters are relatively low, thus the link between price volatility between Douala and Garoua market is not expected to be strong. However, this link can be explained by the fact that Douala is the main entry zone for imported rice, while Garoua is close to the main national rice producers. Therefore, when the rice price became highly volatile in the main supplier market in Cameroon (Douala), as a response, local rice is preferred in the North part of the country (Garoua). This can lead to a reduction in rice price volatility in Garoua, as a result of substitution between imported rice and local rice. Conversely, Bamenda and Bafoussam markets seem to move together in terms of rice price volatility. These results are consistent even when considering the time variance of the conditional correlation. However, the Wald test is in favour of CCC-MGARCH specification.

[41] Note that there is a symmetry in this analysis. Therefore, the pairwise analysis of Douala – Bamenda markets for example, is equivalent to the pairwise analysis of Bamenda – Douala markets. This is why we have six pairs of markets in our analysis.

Table 2.6: Constant conditional correlation MGARCH model in global approach for Cameroonian markets

		Coef.	Std. Err.	P>|z|
ARCH_r_rri_dla				
	arch L1.	.1741328	.054825	0.001
	garch L1.	.8292606	.0325921	0.000
	_cons	.0000208	.000011	0.058
ARCH_r_rri___bam				
	arch L1.	.3953236	.124164	0.001
	garch L1.	.3031016	.1564747	0.053
	_cons	.0032815	.0011105	0.003
ARCH_r_rri__baf				
	arch L1.	.4754082	.1399191	0.001
	garch L1.	-.0988908	.0412726	0.017
	_cons	.00474	.0007131	0.000
ARCH_r_rri___gar				
	arch L1.	.3114814	.1068345	0.004
	garch L1.	.5892596	.0621751	0.000
	_cons	.0006365	.0001751	0.000
corr(r_rri_dla,r_rri___bam		.0321727	.0675455	0.634
corr(r_rri_dla,r_rri__baf		.0565857	.0673827	0.401
corr(r_rri_dla,r_rri___gar		-.1390698	.0662742	0.036
corr(r_rri___bam,r_rri__baf		.2973159	.0643197	0.000
corr(r_rri___bam,r_rri___gar		-.0066976	.0706358	0.924
corr(r_rri__baf,r_rri___gar		-.0253684	.0703896	0.719

On the other hand, the pairwise approach produces similar results as the global approach. Then, significant links between return series was found only for the pairs Douala – Garoua and Bamenda – Bafoussam, even when allowing for time variance, and imposing constraints as previously. For the remaining pairs of markets, there is no evidence of linkages in terms of volatility transmission. This reinforces the suggested idea that rice price volatility in Cameroonian markets can be due to structural parameters and markets' problems such as speculation of wholesalers, retailer market power, transport infrastructure, etc. However, due to the data constraint, it is relatively difficult to empirically justify such assumption in the case of Cameroon.

We have to note that, for all the considered models (CCC-MGARCH and DCC-MGARCH), the Wald test against the null hypothesis that all the estimated coefficients for the independent variables in the mean equations are zero leads to the rejection of the null hypothesis at 1% level of significance.

Conclusion

This chapter examines the price volatility transmission in Cameroon using the case study of rice, which is the most imported and consumed food in the country. A multivariate GARCH model, namely CCC-MGARCH and DCC-MGARCH, is used in order to provide conditional covariance matrix.

The empirical results suggest that there is no price volatility transmission between the world market and Cameroonian markets. However, at national level, significant links between return price series were only found for two pairs of markets out of six, namely the pairs Douala-Garoua and Bamenda-Bafoussam. For the remaining pairs of markets, there is no evidence of linkages in terms of volatility transmission.

This study can lead to three main lessons in terms of economic policy. First, the non-linkages of Cameroonian markets in term of price volatility suggest that the observed volatility in Cameroonian markets can be caused by structural parameters such as markets structure, retailer market power, and lack of infrastructure, amongst others. Therefore, to fight against price volatility, a special attention must be given to improve the aforementioned structural parameters. Second, the analysis reveals that, when imported rice has local substitute, the volatility in the price of imported rice can lead to a substitution in favour of local rice. Thus, government should encourage the local production and improve transport infrastructure in order to supply other markets with local rice. Third, it seems necessary to improve the data collection system with high frequency time series data (daily, weekly,… data), up to date data, and data about infrastructure, retailer market power in order to appropriately address similar issues as in this study and provide more specific policy recommendations.

For future research, it may be interesting to use different data frequencies (if available), for robustness check and comparison of results. After dealing with price volatility transmission in this chapter, the next chapters of this thesis will focused on the consequences of food price volatility for both producers and consumers.

CONCLUSION TO THE FIRST PART

The aim of this first part was to answer to two questions: what are the determinants of food price volatility in Cameroon? Is there a transmission of food price volatility in Cameroon? Firstly, using data from IMF and NIS, and ARMA, GARCH and GARCH-X models, we can conclude that food price volatility in Cameroon is determined mostly by internal factors such as the volatility of other products, and not by external factors such as the volatility of crude oil and the volatility of imported cereals. This result can be explained by the low transmission of food price volatility between Cameroonian and international markets. Secondly, using the case study of rice that is the most imported and consumed food in Cameroon, the estimation of a CCC-MGARCH and DCC-MGARCH models has confirmed that there is no price volatility transmission between the world market and Cameroonian markets. Indeed, significant links between return price series were only found for two pairs of markets out of six at the national level, namely the pairs of Douala-Garoua and Bamenda-Bafoussam.

In term of policy recommendations, three main suggestions can be drawn: first, it can be important to implement more specific development projects based on other commodities than exportable goods in Cameroon and to improve the efficiency of existing agricultural development programs. Second, to fight against price volatility, a special attention must be given to improve structural parameters such as markets structure, retailer market power, and infrastructure. Third, it seems necessary to update and improve the existing data collection system on commodity prices in order to implement analysis that is more specific.

PART II: CONSEQUENCES OF FOOD PRICE VOLATILITY IN CAMEROON

INTRODUCTION TO THE SECOND PART

Cameroon as other Sub-Saharan African countries is dependent to the world food market to feed its population. However, this market is highly volatile and this can have negative consequences in Cameroon. On the other hand, since 2000's Cameroon has implemented many development programs and projects in order to boost the agricultural production and to fight against poverty and food insecurity. Information on the agricultural supply response to price incentive and price volatility is necessary for policymakers. Therefore, it seems timely to analyze both supply response and welfare impact of food price volatility as a means to assess the consequences of food price volatility for both producers and consumers.

The second part of this thesis analyzes the consequences of food price volatility for both producers and consumers in Cameroon. First, from the producer point of view, the supply response of food price volatility is analyzed using the Pesaran et al. (2001) Autoregressive Distributed Lag (ARDL) approach to deliver short-run and long-run elasticities of supply (chapter 3). Secondly, from the consumer point of view, the welfare impact of food price volatility is assessed within the compensating variation framework, after estimating price elasticities from a Quadratic Almost Ideal Demand System (QUAIDS) model (chapter 4).

CHAPTER 3: *AGRICULTURAL SUPPLY RESPONSE TO FOOD PRICE VOLATILITY IN CAMEROON*[42]

Introduction

To increase agricultural production in Cameroon, the Ministry of Agriculture and Rural Development has implemented several programs and projects since the 2000's. However, it remains unclear whether these policies effectively stimulate food supply. It appears urgent to increase food production and reduce the country dependence on imports in order to deal with food insecurity and poverty by increasing farmers' income. For this purpose, information on the agricultural supply response to price incentive and price volatility is necessary for policymakers. Moreover, the literature on supply response in the case of Cameroon is relatively rare. To the best of our knowledge, there are just two studies from Molua (2010a, 2010b) on the estimation of supply response. Even if these studies confirm the responsiveness of farmers to price incentive, they focus only on rice, which is not amongst the major crops grown by farmers. The present study is an attempt to fill this gap. Therefore, this study aims to analyses the supply response for the major staple crops grown by agricultural households in Cameroon, namely maize, groundnut, and cassava. Using annual time series data over the period 1966 to 2012, the Autoregressive Distributed Lag (ARDL) bounds testing procedure is used to deliver short-run and long-run elasticities of supply.

The remainder of this chapter presents the theoretical framework allowing us to analyse agricultural supply response to price volatility (I), followed by the methodology, results from the estimation and discussion, and their implications for policy-makers (II).

[42] Publish as Kane, G.Q. and Piot-Lepetit, I. 2017. Agricultural supply response to food price volatility in Cameroon, in: Piot-Lepetit, I. (Ed.), *Cameroon in the 21st Century: Prospects and Challenges. vol. 2. Environment and People*, New York: Nova Science Publishers, Inc.

3.1. THEORETICAL FRAMEWORK FOR ANALYSZING AGRICULTURAL SUPPLY RESPONSE TO PRICE VOLATILITY

Broadly, we have two ways to derive supply response to price incentives in the economic literature. The mostly used Nerlovian supply model, and the supply function derived from the profit-maximizing framework.

3.1.1. Nerlove supply response model

3.1.1.1. Original Nerlove supply response model

The Nerlove supply response model[43] consists of the following three equations:

$$A_t^* = \alpha_1 + \alpha_2 P_t^* + \alpha_3 Z_t + u_t \tag{3.1}$$

$$P_t^* = P_{t-1}^* + \gamma\left(P_{t-1} - P_{t-1}^*\right), \quad 0 \le \gamma \le 1 \tag{3.2}$$

$$A_t = A_{t-1} + \delta\left(A_t^* - A_{t-1}\right), \quad 0 \le \delta \le 1 \tag{3.3}$$

Where A_t^* and A_t are desired (or equilibrium) and actual areas under cultivation at time t (or sometimes outputs or yields). P_t^* and P_t are expected and actual prices at time t. Z_t is a set of other exogenous factors affecting supply at time t. γ is the *adaptive–expectations coefficient* measuring the responsiveness of expectations to the observed price. δ is the *partial-adjustment coefficients* measuring the responsiveness of observed areas under cultivation to a change in desired areas. u_t accounts for unobserved random factors affecting the area under cultivation. The reduced form obtained after eliminating the unobservable variables (P_t^* and A_t^*) from equations (3.1), (3.2) and (3.3) is:

$$A_t = b_1 + b_2 P_{t-1} + b_3 A_{t-1} + b_4 A_{t-2} + b_5 Z_t + b_6 Z_{t-1} + e_t \tag{3.4}$$

With

$b_1 = \alpha_1 \delta \gamma$,

[43] for more details on the Nerlove supply model, see Askari and Cummings (1976), Nerlove and Addison (1958), Nerlove (1956, 1958).

$b_2 = \alpha_2 \delta\gamma$ (the short-run elasticity of the supply response),

$b_3 = (1-\delta) + (1-\gamma)$,

$b_4 = -(1-\delta)(1-\gamma)$,

$b_5 = \alpha_3 \delta$,

$b_6 = -\alpha_3 \delta(1-\gamma)$,

$e_t = \delta(u_t - (1-\gamma)u_{t-1})$

The estimable form of the nerlovian supply response model is the equation (3.4). A nonlinear constraint must be imposed to this reduced form (which is overidentified) in order to obtain an unique solution:

$$b_6^2 - b_4 b_5^2 + b_3 b_5 b_6 = 0 \qquad (3.5)$$

The following equations help to solve the structural coefficients as noted by Sadoulet and De Janvry (1995):

$$\delta^2 + (b_3 - 2)\delta + 1 - b_3 - b_4 = 0 \qquad (3.6)$$

$$\gamma = 1 + b_4 / (1-\delta) \qquad (3.6)$$

$$\alpha_1 = b_1 / \delta\gamma \qquad (3.7)$$

$\alpha_2 = b_2 / \delta\gamma$ (3.6) the long-run elasticity of the supply response,

$$\alpha_5 = b_5 / \delta \qquad (3.8)$$

Since both δ and $\gamma \leq 1$, the long-run elasticity of supply exceeds the short-run elasticity of supply, as expected.

We have to note that $\gamma = 1$ and $\delta = 1$ in the cases where there are either no expectation formation or no partial adjustment, respectively.

The model has been extentively used in empirical studies in differents ways. These differences can be grouped mainly in three categories as noted by Askari and Cummings (1976): modification affecting Nerlove initial variables, modification affecting exogenous supply shifters (Z_t in equation 3.1), and finally, situations not considered initially by Nerlove.

Exploring the first type of modification, *what price variable should be used in the model* was the main question faced by researchers. Initially, Nerlove idea was based on the normal or expected prices function of past market price realisation. Authors have improved the orignal model by the use of more realistic price formulations, amongs others: the price of the crop actually reveive by farmers, the ratio of the price of the crop received by farmers to some comsumer price index, the ratio of the price of the crops reveive by farmers to some index prices of the farmer's inputs, and the ratio of the crop received by farmers to some index of the competitive crops (Askari and Cummings, 1976). However, the choice of the adequate price formulation may depend on the the reason of increasing particular crop production by farmers. Lastly, it has been argued that planted acreage is the best way of gauging how producer actions reflect their price expectation, instead of other output measures (crop weight, volume produced, volume marketed…).

About the second type of modification, the main source of difficulties were the choices of which non-market factors to exclude. In the literature, the most common exogenous factors introduced in the model was a measurement of weather, with a wide variety of variables: rainfall, humidity, and so on. Moreover, it is usual in the literature to capture the time-related effects on output by introducing a trend variable in the model. But, the use of this variable largelly depends on the availability of reliable time series data.

The third type of modification is about the use in the Nerlovian model of non- annual crops (as perennials, and those with more than one year cycle) and livestock.

Since there is a time lag between planting decisions and harvest time, taking into account the formation of expectations is thus important when analysing agricultural supply response (Sadoulet and De Janvry, 1995). Therefore, the mechanisms of expectations formation is discussed in the next section.

3.1.1.2. Expectation formation

In general, five principal approaches are used to model expectation formation (Nerlove and Bessler, 2001): extrapolative expectations, adaptive expectations, implicit expectations, rational and quasi-rational expectations, and futures markets.

3.1.1.2.1. Extrapolative expectations

The extrapolative expectation is due to Goodwin (1947) and basically assume that the expected price in period t is equal to a fraction of the lattest change in the observed price plus (or minus) the lattest observed price. More simply, the expected price in period t is equal to actual price in $t-1$ plus (or minus) a part of a price change between period $t-2$ and $t-1$ (Nerlove and Bessler, 2001).

Formally, the extrapolative expectation is represented by the following equation:

$$p_t^* = p_{t-1} + \eta(p_{t-1} - p_{t-2}) \tag{3.9}$$

Where p_t^* is the price expected in period t. As noted by Muth (1961), depending on the sign of η, which is within a range between -1 and +1, there is a great variety of behaviours.

The expectation generated by the equation (3.9) is called "extrapolative" by Muth (1961).

3.1.1.2.2. Adaptive expectations

The adaptive expectations was formally introduced by Phillip Cagan, Milton Friedman, and Marc Nerlove in the 1950s. The main idea of the adaptive expectation hypothesis is that economic agents form their expectation exclusively based on the past observed price behavior.

Formally, the adaptive expectation can be represented by the following equation:

$$p_t^* = p_{t-1}^* + \beta\left(p_{t-1} - p_{t-1}^*\right) \tag{3.10}$$

Where p_t^* is the price expected in period t. β is a *coefficient for expectation* that ranges between zero and one. If β is equal to one, the expected "*normal*" price is the same as the last year's actual price. Conversely, if β is equal to zero, actual price will have no effect on expected "*normal*" price. As noted by Nerlove and Bessler (2001), economic agents revise their notion of "*normal*" price in each period in a fraction of the difference between the current price and their previous ideas of the "*normal*" price.

Nerlove (1958) shows that, in the adaptive expectation hypothesis, the expected normal price can be represented as a geometrically weighted moving average of past prices:

$$p_t^* = H(1-\beta)^t + \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda}\, p_{\lambda-1} \qquad (3.11)$$

Where H is a constant taking into account initial conditions. Assuming that H equals to zero implies that:

$$p_t^* = \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda}\, p_{\lambda-1} \qquad (3.12)$$

Since β is between zero and unity, the weights of past prices decline as one goes back in time.

3.1.1.2.3. Implicit expectations

The notion of "*implicit expectations*" was introduced by Mills (1962) in the early 1960's. The idea is that future values can served as proxies for anticipations assuming that economic agents forecast successfully and errors are small (Nerlove, 1983).

As noted by Nerlove and Bessler (2001), the expectation error is:

$$x = x^* + u \qquad (3.13)$$

Where u is the error in predicting x. Introducing x^* in $Y(x^*)$ [the relation to be inferred]:

$$y = Y(x^*) = Y(x-u) = \alpha + \gamma x^* \qquad (3.14)$$ (when the decision rule is linear in x^*).

Then:

$$y = \alpha + \gamma x - \gamma u = \alpha + \gamma x - \varepsilon \qquad (3.15)$$

This is the regression equation. Assuming that the standard statistical properties for least squares estimation hold, we can thus estimate α and γ. If a and c are ordinary last squared estimates from a sample of observations of x and y, then:

$$\hat{y} = a + cx \quad (3.16)$$

And the regression error e is defined by: $e = y - \hat{y}$ (3.17)

$$e = y - \hat{y} = est(e) + est(-\gamma u) \quad (3.18)$$

Therefore

$$e/c = est(-u) = -\hat{u} \quad (3.19)$$

The estimate of x^* is then: $\hat{x}^* = x - e/c = x - \hat{u} = (y - a)/c$ (3.20)

$\hat{x}^*$ is the implicit expectation. In this approach, there is no need to first obtain an estimate of x^* before the estimation of the behavior equation. From this behavior equation, the use of inverse function provides an estimate of the expectation related to the observed decision (Nerlove and Bessler, 2001). What is innovative in this approach is that we can estimate both the behavior relation and the expectation in an indirect (or implicit) way, under certain assumptions about the statistical properties of the estimate (Mills, 1962).

3.1.1.2.4. Rational expectations and quasi-rational expectations

Originally formulated by Muth (1961), the rational expectations hypothesis (RE) assumes that information is a scarce resource, thus economic agents make an efficient use of available information when optimizing their decisions. However, rational expectation, approaches used by researchers suffer at least for the inconsistencies between the model of the market and the model of expectations, as noted by Irwin and Thrae (1994). The more important advantage of the rational expectation is its theoretical consistency. According to Nerlove and Fornari (1998), the rejection of the rational expectation hypothesis can be explained, amongst others, by: a non-quadratic objective function, the agent learning process, and the incorrect behavioral model specification by the econometrician[44]…

[44] See, Pesaran (1987) for a general discussion about the limits of the rational expectation hypothesis.

Quasi-rational expectations (QRE)[45] appear as a general form of the rational expectation hypothesis. Folowing Nerlove and Bessler (2001), considering a model with one endogenous variable (y_t) and one exogenous variables (z^*_{t+1}):

$$y_t = a + bz^*_{t+1} + \vartheta_t \tag{3.21}$$

Where ϑ_t is a random white noise disturbance ($\vartheta_t \sim i.i.d.\ WN(0,\sigma^2_\vartheta)$).

For simplicity purposes, suppose that z_t follows a AR(1):

$$z_t = \alpha z_{t-1} + v_t \tag{3.22}$$

Where v_t is a random white noise disturbance ($v_t \sim i.i.d.\ WN(0,\sigma^2_v)$) independently of ϑ_t

The RE are: $z^*_{t+1} = E(z_t|\Omega_t) = \alpha z_t$ (3.23)

Ω_t is a set of the relevant information. $a, b, \alpha, \sigma^2_\vartheta$ and σ^2_v should be estimated jointly:

$$\begin{aligned} y_t &= a + b\alpha z_t + \vartheta_t \\ z_t &= \alpha z_{t-1} + v_t \end{aligned} \tag{3.24}$$

The estimate of $\hat{\alpha}$ helps to calculate the RE z^*_{t+1} from $\hat{\alpha} z_t$. The estimation of the second equation in (3.24) gives the QRE. Moreover, there is no need to restrict z_t to be a AR(1) in a general QRE, and this would not lead to both loss of efficiency and inconsistent estimates. Also, in absence of structural change, QRE satisfies the minimal requirement of RE (Nerlove, 1983).

The RE approach was intensively used in the literature. However, there is no consensus about the falsification or the verification of the rational expectation hypothesis. Despite the lack of consensus, RE has improved knowledge of the process of agricultural market equilibrium and price determination, and expectation formation in agricultural market (Irwin and Thrae, 1994).

[45] For more discussion on quasi-rational expectations, see Nerlove (1972, 1979).

3.1.1.2.5. Futures markets

Futures prices when available can be seen as an observation of expectations. According to Gardner (1976), futures prices can be used for all expectations in agricultural markets. Gardner (1976) writes:

"*…an alternative approach to estimating supply elasticity… is to exploit the theoretically well-grounded hypothesis that the price of a futures contract for next year's crop reflects the market's estimate of next year's cash price. Since the appropriate price for supply analysis is the price expected by producers at the time when production decisions are being made, a futures price at this time is a good candidate for a directly observable measure of product price in supply analysis*".

The use of futures price raises several issues: futures price reflects the expectations of both nonfarm speculators and crop producers; the choice of appropriate futures price to use; the observed date for futures price; and finally the exogeneity of the futures price.

John Muth's rational expectations can justified the use of futures price with respect to the first issue (Gardner, 1976). Indeed, there is no reason of having different expectations behavior between farmers who make no futures transactions and are not futures speculators. In fact, if the price expectation between farmers is different, then there will be an incentive for those out of the market to enter.

Gardner (1976) suggested the use of the first futures price after the crop, regarding the second issue. The rationale for this is to determine when the production decision was made. In the literature, numerous studies have used the price of a harvest-time contract traded at planting-time (Choi and Helmberger, 1993; Gardner, 1976; Hausman, 2012), while the price of a harvest-time contract traded prior to planting was used by some other authors (Holt, 1999; Orazem and Miranowski, 1994; Wu et al., 2004).

Gardner (1976) also suggested the use of the futures price in the period immediately preceding the planting season as the expected price concerning the third issue. Indeed, before harvest time, there is not any irrevocably date for planned output. Basically, the main idea is that, the choice of acreage and planting techniques are the main production decisions taken by farmers.

The fourth issue is more relevant for an econometric analysis. Indeed, as noted by Hendricks et al. (2013), it is important to use a price with fewer endogeneity concerns. Indeed, futures price are endogenous to supply, since producer expectation affects the futures price (Roberts and Schlenker, 2013).

3.1.2. Supply function approach

3.1.2.1. Profit function and the derived supply function

Generally, production is the process of transforming inputs into outputs. The ways inputs are transformed into output is described by a production function (Jehle and Reny, 2011). Following Sadoulet and De Janvry (1995)'s presentation, the production function can be formalized as:

$$h(q,x,z)=0 \tag{3.25}$$

Where q, x, and z are, respectively, a vector of output quantities, a vector of variable input quantities (e.g., labor, fertilizer, water, pesticides, seeds…), and a vector of fixed factor quantities (land, equipment, infrastructure, weather, distance to market…).

As noted by Jehle and Reny (2011), production functions have several properties such as continuity, strictly quasiconcave, and strictly increasing. Continuity ensures that small changes in the input vector lead to small changse in the output vector. Strict quasiconcavity is assumed for simplicity and the strictly increasing property ensure that using strictly more of all inputs lead to strictly more of outputs.

If the price of inputs and ouputs are respectivelly w and p, then the producer's profit is $p'q - w'x$ (the symbol ' refers to the transposition of a vector). This is basically *the profit*, which can be defined as the difference between the producer's revenues and the cost of production.

The profit maximization problem facing producer's subject to the technology constraint can be written as:

$$\begin{cases} \underset{x,q}{Max} \quad p'q - w'x \\ s.t. \ h(q,x,z)=0 \end{cases} \tag{3.26}$$

The solution of this maximization problem is:

$$x = x(p,w,z) \text{ and } q = q(p,w,z) \tag{3.27}$$

The *profit function* (π) results in the substitution of x and q in the profit. Broadly, the profit function can be seen as the maximum profit that a famer could obtain, given w, p, z and $h(.)$ (the production technology).

$$\pi = p^{'}q(p,w,z) - w^{'}x(p,w,z) = \pi(p,w,z) \tag{3.28}$$

Note: there is a one-to-one correspondence between profit function and production function (Sadoulet and De Janvry, 1995). If, for example, the production function is translog, the profit function will also takes a translog from.

The profit function[46] defined above with $p \geq 0$ and $w \geq 0$, is, amongst others, continuous, increasing in p, decreasing in w, homogeneous of degree one in (p,w), convex in $(p,w)\ldots$ Moreover, the most interesting property of profit function is given by the *Shephard duality Lemma*. Indeed, $\pi(p,w,z)$ is differentiable in (p,w) and assuming that $h(.)$ is strictly concave:

$$\frac{\partial \pi}{\partial p}(p,w,z) = q(p,w) \quad \text{and} \quad -\frac{\partial \pi}{\partial w_i}(p,w,z) = x_i(p,w) \qquad i = 1,2,\ldots,n \tag{3.29}$$

Where $q(p,w)$ is the supply function of product and $x(p,w)$ is the input demand function. These supply and demand functions have the following properties, assuming that $\pi(p,w,z)$ is twice continuously differentiable:

Homogeneity of degree zero: $q(kp,kw) = q(p,w)$ and $x_i(kp,kw) = x_i(p,w)$ for all $k > 0$

Own-price effects: $\dfrac{\partial q(p,w)}{\partial p} \geq 0$ and $\dfrac{\partial x_i(p,w)}{\partial w_i} \leq 0$ for all $i = 1,2,\ldots,n$

The substitution matrix :

[46] See Jehle and Reny (2011) for all the properties of the profit function and the proofs.

$$\begin{pmatrix} \frac{\partial q(p,w)}{\partial p} & \frac{\partial q(p,w)}{\partial w_1} & \cdots & \frac{\partial q(p,w)}{\partial w_n} \\ \frac{-\partial x_1(p,w)}{\partial p} & \frac{-\partial x_1(p,w)}{\partial w_1} & \cdots & \frac{-\partial x_1(p,w)}{\partial w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{-\partial x_n(p,w)}{\partial p} & \frac{-\partial x_n(p,w)}{\partial w_1} & \cdots & \frac{-\partial x_n(p,w)}{\partial w_n} \end{pmatrix}$$ is ***symmetric and positive semidefinite.***

3.1.2.2. Examples of Profit Functions and Derived Systems of Output Supply

In this subsection, we present the most common types of output supply function derived from the maximization of profit functions, namely: Normalized Cobb-Douglas, Generalized Leontief, Normalized Quadratic, and Translog.

Note: for simplicity, we will use the symmetry between inputs and outputs, knowing that inputs can be seen as negative outputs. Therefore, $\mathbf{p}$ will be either an output or a input price, and $\mathbf{q}$ represents the quantity of outputs (when positive), and the quantity of inputs (when negative).

3.1.2.2.1. Normalized Cobb-Douglas

This approach was pioneered by Yotopoulos and Lau (1979). The normalized profit function (in a log-linear form) from a single output Cobb-Douglas production function is:

$$\ln \pi^* = a + \sum_i \alpha_i \ln w_i^* + \sum_m \beta_m \ln z_m \qquad (3.30)$$

This function is homogenous of degree one in the fixed factors if $\sum_m \beta_m = 1$, and homogenous of degree zero in all prices.

The outputs supply functions are:

$$\begin{cases} q = \pi^* + \sum_i w_i^* x_i = \left(1 - \sum_i \alpha_i\right)\pi^* \\ or \;\; \ln q = \ln\left(1 - \sum_i \alpha_i\right) + \alpha + \sum_i \alpha_i \ln w_i^* + \sum_m \beta_m \ln z_m \end{cases} \qquad (3.31)$$

The the input demand functions are:

$$\begin{cases} x_i = -\dfrac{\partial \pi^*}{\partial w_i^*} = -\alpha_i \pi^* / w_i^* \\ or \ \ \ln x_i = \left[a + \ln(-\alpha_i) \right] + \sum_j (\alpha_j - \delta_{ij}) \ln w_j^* + \sum_m \beta_m \ln z_m \end{cases} \quad (3.32)$$

With δ_{ij} the Kronecker index $(=1 \ if \ i = j \ and \ 0 \ if \ i \neq j)$

3.1.2.2.2. Generalized Leontief

In this case, the profit function is: $\pi = \sum_{i,j} b_{ij} \sqrt{\mathbf{p_j}/\mathbf{q_i}} + \sum_m b_{im} z_m$ with $b_{ij} = b_{ji}$ (3.33)

This profit function is homogenous of degree one in all prices, and the equations of the output supply function and the input demand function are:

$$\mathbf{q_i} = b_{ij} + \sum_{i \neq j} b_{ij} \sqrt{\mathbf{p_j}/\mathbf{q_i}} + \sum_m b_{im} z_m \quad (3.34)$$

3.1.2.2.3. Normalized Quadratic

When normalizing profit and prices by the price of the *n*th commodity, the profit function is:

$$\pi^* = \pi / p_n = a_0 + \sum_i a_i p_i^* + \frac{1}{2} \sum_{i,j} b_{ij} p_i^* p_j^* + \sum_{i,m} b_{im} p_i^* z_m, \quad i, j = 1, ..., n-1 \text{ with } b_{ij} = b_{ji} \quad (3.35)$$

$\mathbf{p_i^*} = \mathbf{p_i} / \mathbf{p}_n$ is the vector of normalized prices.

The equations of the output supply function and the input demand function are:

$$\mathbf{q_i} = a_i + \sum_j b_{ij} \mathbf{p_j^*} + \sum_m b_{im} z_m \quad (3.36)$$

3.1.2.2.4. Translog

The translog profit function can be considered as the second order approximation of a function, and does not suffer from the restrictions of the Cobb-Douglas function. The profit function in this case is:

$$\ln \pi = a_0 + \sum_i a_i \ln \mathbf{p_i} + \sum_m \beta_m \ln z_m + \frac{1}{2}\sum_{i,j} b_{ij}\mathbf{p_i} \ln \mathbf{p_j} + \frac{1}{2}\sum_{m,n} c_{mn} \ln z_m \ln z_n + \sum_{i,m} d_{im} \ln \mathbf{p_i} \ln z_m \tag{3.37}$$

For homogeneity: $b_{ij} = b_{ji}, c_{mn} = c_{nm}, \sum_i a_i = 1, \sum_m b_m = 1, \sum_i b_{ij} = \sum_m c_{mn} = \sum_i d_{im} = \sum_m d_{im} = 0$

The equations of the output supply function and the input demand function are:

$$\mathbf{q_i} = \frac{\pi}{\mathbf{p_i}}\left[a_i + \sum_j b_{ij}\mathbf{p_j} + \sum_m d_{im} \ln z_m \right] \tag{3.38}$$

In the estimation of supply response, the supply function derived from profit function maximization is more theoretically rigorous, however this approach is more demanding in terms of data (Sadoulet and De Janvry, 1995). Since, it is necessary to estimate both output supply and input demand functions.

3.2. EMPIRICAL ANALYSIS OF AGRICULTURAL SUPPLY RESPONSE TO PRICE VOLATILITY IN CAMEROON

3.2.1. Methodology

3.2.1.1. Data

This study used national level data for the period of 1966 to 2012 to estimate the agricultural supply response to food price volatility in Cameroon. These data were obtained from two sources: FAO (2015) and Jones (2014).

The key interesting variables for the estimation of supply response are acreage, yield, prices, and climate variables. These variables are derived from the economic literature on agricultural supply response. While data on acreage, yield, and producer price were obtained from the FAO (2015), climate data (mean annual rainfall) was obtained from Jones (2014). We have to stress that due to missing data, we cannot use fertilizer price as usual in the literature.

There is a problem when using commodity price data relating to deflation. Indeed, it is advised that before using price data, nominal price data should be cleared of any trend that may be present in data due to inflation. To solve this problem, nominal price are usually divided by some price index. However, the key question is what deflator to use? (Bowman and Husain, 2006). In this study, we use nominal price data for the following reasons: firstly, there is no consensus on the best nominal price deflator and the choice of the deflator is mainly based on the data availability (Huchet-Bourdon, 2011). Secondly, data can be transformed by deflation, since deflation can change the properties of time series, leading to biased estimations (Hikaru Hanawa and Tomek, 2000).

This study focuses on the major staple crops grown by agricultural households in Cameroon (maize, groundnut, and cassava). Indeed, the most planted food crops by households, among others, are: maize (42.7%), groundnut (29.9%), and cassava (28.3%) according to the 2007 Cameroonian Household Survey (ECAM III). These food crops can be seen as competing crops for scarce resources.

3.2.1.2. Empirical framework

In this study, the Nerlovian framework is used. Basically this approach overcomes at least two important issues. The first relates to the dynamics in the quantity produced. Indeed, there may be a time lag in the reaction of famers due to change in output price (adjustment lag). The second relates to the price variable. Since there is a time lag between planting decision and harvest time, taking into consideration the formation of expectations is then important when analyzing agricultural supply response (Sadoulet and De Janvry, 1995). However, this approach is considered weak for the following reasons: no adequate distinction between long-run and short-run elasticity (McKay et al., 1999), danger of spurious regressions due to the use of non-stationary time series data (Granger and Newbold, 1974; Nelson and Plosser, 1982; Townsend, 1997; Tripathi, 2008), the unrealistic assumption that production adjusts to fixed targets of supply, towards which supply adjusts under dynamic condition (Nerlove, 1979). Based on this latter assumption, Thiele (2000) argued that the elasticities estimated by the Nerlovian model are biased downwards, since this model is unlike to capture the full dynamics of supply. In this study, a cointegration analysis is used. It is assumed to correct major weaknesses aforementioned as usual in the literature (Abdulai and Rieder, 1995; Abou-Talb and Begawy, 2008; Anwarul Huq et al., 2013; Boansi, 2014; Hallam and Zanoli, 1993; Muchapondwa, 2009; Thiele, 2000; Townsend and Thirtle, 1995; Tripathi, 2008).

Cointegration analysis was extensively used in the literature to overcome the major weaknesses of the Nerlove partial adjustment model in supply response studies. Indeed, the application of Error Correction Model (ECM) in cointegration analysis helps to capture the forward-looking behaviour of famers optimizing their production in dynamic environment (Abdulai and Rieder, 1995; Abou-Talb and Begawy, 2008; Olubode-Awosola et al., 2006). Amongst others advantages, the ECM allows the examination of the existence of both long-run and short-run relationships among variables, as noted by Tripathi (2008). This latter author also showed that the ECM is a more general framework than the partial adjustment model and considers the formation of expectation which is fundamental in the agricultural supply response analysis. ECM is employed in the analysis of non-stationary time series that are known to be cointegrated (Abou-Talb and Begawy, 2008; Anwarul Huq et al., 2013; Olubode-Awosola et al., 2006). Variables are said to be cointegrated[47] if they tend to move together in long-run, even if they exhibit their own dynamic in short-run.

This procedure has some weaknesses: it has been argued that the standard unit root tests (Dickey-Fuller, Phillips-Perron,…) usually used to determine the order of integration of variables have a low power and are not appropriate in the case of small sample (Blough, 1992; Cochrane, 1991); Both Engle-Granger and Johansen cointegration test procedures have some limitations, as noted by Muchapondwa (2009)[48]. Moreover, this approach when estimating the cointegration vector ignores the short-run dynamics and this can lead to biased results. When dealing with some of the aforementioned limitations, the Johansen estimation procedure like the Engle-Granger approach presupposes that all the variables are integrated in the same order; The Engle-Granger and Johansen cointegration approach is not appropriated when the sample size has less than 80 observations, and produces bias results (Pesaran et al., 2001).

This study uses the relatively recent approach to cointegration proposed by Pesaran et al. (2001): the Autoregressive Distributed Lag (ARDL) approach[49], to empirically analyse the dynamic interactions and the long-run relationships among the variables of interest. The following reasons justify the adoption of this procedure, as noted by Muchapondwa (2009). First, this procedure is simple, since it allows the estimation of cointegration relationships by Ordinary Least Squares (OLS) in contrary to other multivariate techniques such as Johansen

[47] Two conditions must be satisfied for cointegration: the considered variables have to be integrated in the same order, and the linear combination of those variables in level must be stationary.
48 The Engle-Grander approach assumes that only one cointegration relation exists, and this can lead to inefficiency in estimation when there is more than one cointegration vector.
49 Also known as the Bounds test procedure. See Pesaran et al. (2001) for a detailed explanation of this approach.

and Julselius (Johansen and Juselius, 1990). Second, the bounds testing procedure testing for cointegration captures both long-run and short-run dynamics. Third, this approach, unlike other methods, does not require the unit root pre-tests for variables included in the model. It is applicable whether variables are integrated of order 0 (I(0)), I(1) or mixture of the two. Fourth, this approach accounts for the possibility of reverse causality. Finally, this procedure is relatively more efficient in the case of small sample data size as it is the case in this study.

3.2.1.3. ARDL Model

Our ARDL model consists of the following steps:

In the first step, we used the following Error Correction Model (ECM) representation of the ARDL framework[50]:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i} \Delta y_{t-i} + \sum_{i=1}^{n_2} \beta_{2i} \Delta p_{t-i} + \sum_{i=1}^{n_3} \beta_{3i} \Delta p_{1t-i} + \sum_{i=1}^{n_4} \beta_{4i} \Delta p_{2t-i} + \sum_{i=1}^{n_5} \beta_{5i} \Delta wh_{t-i} \tag{3.39}$$
$$+ \sum_{i=1}^{n_6} \beta_{6i} \Delta vol_{t-i} + \lambda_1 y_{t-1} + \lambda_2 p_{t-1} + \lambda_3 p_{1t-1} + \lambda_4 p_{2t-1} + \lambda_5 wh_{t-1} + \lambda_6 vol_{t-1} + \alpha T + \varepsilon_t$$

Where Δ is the difference operator; y_t is the area harvested or yield; p is the price of the crops under consideration; $p2$, $p3$ are the prices of competing crops; vol is the producer price volatility; wh_t is the weather variable (rainfall); β_0 is the drift components; λ_i is a long-run coefficient; β_{ij} is a short-run coefficient (with $j = 1,..,6$); ε_t is a white noise; n_1 to n_6 represents number of lags; and T is the trend variable. Note that all the variables used are in their natural logarithm form.

The first step of the bounds test is the estimation of equation (3.39) by OLS to test the existence of a long-run relationship between the variables. From equation (3.39), the null hypothesis of no cointegration among the variables is:

$H_0: \ \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$ against the alternative

$H_1: \ \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \neq 0$

[50] Also known as Unrestricted Error Correction Model (UECM).

Pesaran et al. (2001) have constructed a table bottom and upper critical levels for comparison with the calculated F-statistics. Then, if the computed F-statistics falls outside the upper and the lower bounds, a decision can be done. The null hypothesis cannot be rejected if the value of the F-statistics is lower than the bottom bounds, whereas this hypothesis is rejected if the value of the F-statistics is greater than the upper bounds. The test is undetermined if the value of the F-statistics falls between the bottom and the upper bounds.

We need to stress that the F-statistics used in the bounds test has a non-standard distribution and the critical value bounds have been tabulated by Pesaran et al. (2001). Secondly, when cointegration is established, the appropriate ARDL model is estimated using the Akaike Information Criterion (AIC) to select the optimal lag lengths of variables.

The following $ARDL\ (n_1,\ n_2,\ n_3,\ n_4,\ n_5,\ n_6)$ long-run model for y_t is estimated:

$$y_t = \pi_0 + \sum_{i=1}^{n_1} \pi_{1i} y_{t-i} + \sum_{i=1}^{n_2} \pi_{2i} p_{t-i} + \sum_{i=1}^{n_3} \pi_{3i} p_{1t-i} + \sum_{i=1}^{n_4} \pi_{4i} p_{2t-i} + \sum_{i=1}^{n_5} \pi_{5i} wh_{t-i} + \sum_{i=1}^{n_6} \pi_{6i} vol_{t-i} + \alpha T + \mu_t \quad (3.40)$$

In the third step, the estimation of an ECM associated with long-run model leads to short-run parameters. The specification is as follows:

$$\Delta y_t = \omega_0 + \sum_{i=1}^{n_1} \omega_{1i} \Delta y_{t-i} + \sum_{i=1}^{n_2} \omega_{2i} \Delta p_{t-i} + \sum_{i=1}^{n_3} \omega_{3i} \Delta p_{1t-i} + \sum_{i=1}^{n_4} \omega_{4i} \Delta p_{2t-i} + \sum_{i=1}^{n_5} \omega_{5i} \Delta wh_{t-i} \quad (3.41)$$
$$+ \sum_{i=1}^{n_6} \omega_{6i} \Delta vol_{t-i} + \varphi ECT_{t-1} + \alpha T + \upsilon_t$$

where ω_{ij} are the short-run dynamics coefficients, and φ is the speed of the adjustment parameter [51].

Due to the frequency of our data (annual), we compute volatility over five years[52] as in Huchet-Bourdon (2011).

3.2.1.4. Definition of variable

The variables used for the estimation are described in table 3.1.

[51] This coefficient indicates the speed of adjustment back to equilibrium after a short-run shock and should be significant whit negative sign.
[52] For example, the volatility in 2010 correspond to the changes over the period 2006-2010. we use a moving average/window, since this approach is not dependant to the observation frequency (monthly or annual) as noted by Huchet-Bourdon (2011).

Detailed descriptive statistics of the series used in the analysis are presented in the appendix in table 3.1.

Table 3.1: Description of variables

Variables	Comments
Area harvested/Yield (y_t)	Output, area and yield can be chosen as dependent variables in the supply response analysis. In this study we estimate both area equation and yield equation. Indeed, the harvested area serves as a proxy for cultivated area since the latter is not available as usual (Haile et al., 2014a, 2014b). Generally the preference of cultivated area to output in supply analysis is justified by the fact that the latter does not reflect planned production decisions and farmers have more control on the area than on the production (Abou-Talb and Begawy, 2008; Anwarul Huq et al., 2013; Molua, 2010b; Vitale et al., 2009). On the other hand, as mentioned in the literature, in the case of developing countries, the hypothesis that farmers respond to price incentives partly by intensive use of other inputs given the same area is admitted, and this can be captured by yield (Mythili, 2008).
Output own price (p)	The output price of crops is expected to largely impact agricultural supply. Basically, an increase in output prices provides greater profit and high profit level provides incentives to production (Tripathi, 2008).
Price of competing crops ($p_{j,}\ j=1,2,3$)	As mentioned in the literature, the prices of competing crops can have a large impact on the supply response. Competing crops can be defined as those competing for resources.
Weather (wh)	This will be captured by annual mean rainfall in order to take into account the impact of irregular rainfall on supply response.
Price volatility (vol)	Price volatility is expected to capture output price-risk as usual in the literature.

3.2.2. Result and discussion

3.2.2.1. Unit root test for stationarity

Although the ARDL procedure does not require the unit root pre-tests as mentioned earlier, this model is based on the hypothesis that all the variables in the model are at most I(1), since the F-statistics computed by Pesaran et al. (2001) and Narayan (2005) assumed that variables are I(0) or I(1). The regression will be spurious in the presence of I(2) variables. Therefore, it is usual before running ARDL model to ensure that all variables are not I(2). For this purpose, we use two types of unit root tests: the Augmented Dickey-Fuller test (ADF) and the Phillips-Perron test (PP) as suggested by Enders (1995), since the choice of the most appropriate test for unit root is difficult in practice. The main idea is that, we can trust the results if they reinforce each other. The results of unit root tesst (ADF and PP) are presented in the following tables 3.2 and 3.3:

Table 3.2: Results of augmented dickey fuller (ADF) unit root tests

Variables	Levels		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
LAREA_CAS	-0.7951(0)	-1.8064(0)	-6.8852(0)***	-7.0008(0)***
LAREA_GNT	-2.9097(0)*	-2.9043(0)	-7.7862(0)***	-7.6946(0)***
LAREA_MZE	-0.6813(0)	-0.8808(0)	-5.5114(0)***	-5.6360(0)***
LYIELD_CAS	-1.6735(0)	-1.8271(0)	-5.8398(0)***	-5.7939(0)***
LYIELD_GNT	-1.4324(0)	-1.7386(0)	-8.0113(0)***	-8.1609(0)***
LYIELD_MZE	-1.7604(0)	-2.2525(0)	-7.0174(0)***	-7.0197(0)***
LPRICE_CAS	-1.8024(0)	-2.1644(1)	-4.8283(0)***	-4.8544(0)***
LPRICE_GNT	-1.8881(0)	-1.5411(0)	-8.1383(0)***	-8.4029(0)***
LPRICE_MZE	-1.4760(0)	-2.0692(0)	-6.9471(0)***	-6.9486(0)***
LVOL_CAS	-3.3679(1)**	-3.3608(1)*	-4.3259(0)***	-4.8431(0)***
LVOL_GNT	-2.6740(0)*	-3.1676(0)	-5.7983(0)***	-5.7842(0)***
LVOL_MZE	-3.2271(1)**	-3.3910(1)*	-5.0563(0)***	-5.0104(0)***
LRAINFALL	-6.1807(0)***	-6.1645(0)***		

*Notes: (i) L=log, VOL=volatility, CAS=cassava, GNT=groundnuts, MZE=maize; (ii) Unit root test is performed by using EViews 9.0 and the optimal lag length is chosen on the basis of the Schwarz Bayesian Criterion; (iv) Critical values for ADF at level with intercept at 1%, 5%, and 10% are: -3.5811, -2.9266, -2.6014 respectively; (v) Critical values for ADF at level with intercept and trend at 1%, 5%, and 10% are: -4.1705, -3.5107, -3.1855 respectively; (vi)Critical values at first difference for ADF with intercept at 1%, 5%, and 10% are: -3.5847, -2.9281, -2.6022 respectively; (vii) Critical values at first difference for ADF with intercept and trend at 1%, 5%, and 10% are: -4.1756, -3.5130, -3.1868 respectively; (viii) *** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

The results of the ADF unit root test (table 3.2) indicate that most of the variables are non-stationary in level. However, they are stationary in difference, meaning that they are I(1). Only rainfall series is stationary in level. These results are confirmed by the PP unit root test (table 3.3). Therefore, the variable are a mixture of I(1) and I(0) variables. The use of ARDL bounds testing procedures is justified since none of the variable is I(2). We have to note that there is a contradiction in results of ADF and PP unit root tests for two volatility price series (cassava and maize). When ADF suggests that these series are I(0), the PP results claim that these series are I(1). These results suggest that none of these price volatility series is I(2), thus, the ARDL procedure can be applied.

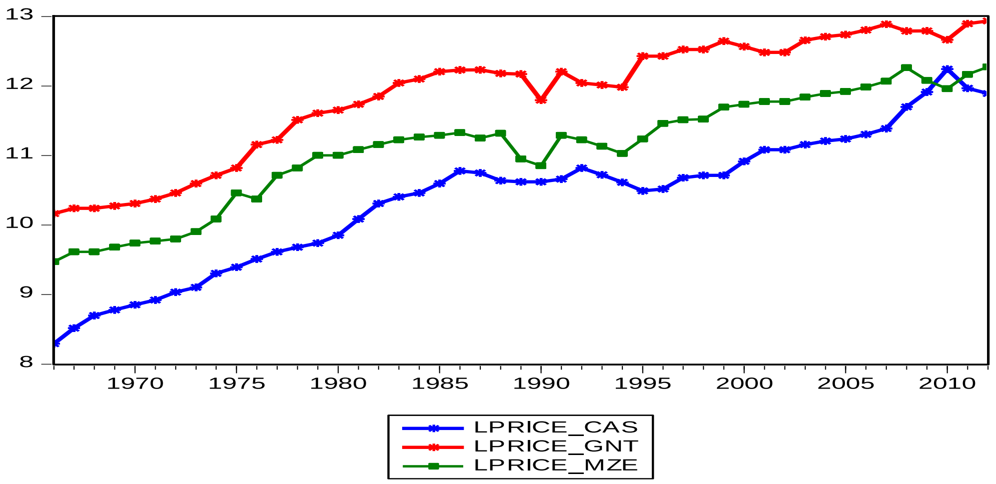
Table 3.3: Results of Phillips-Perron (PP) unit root tests

Variables	Levels		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
LAREA_CAS	-0.7951(0)	-1.8064(0)	-6.8870(2)***	-7.0233(3)***
LAREA_GNT	-2.8390(5)*	-2.8609(5)	-8.3223(14)***	-8.2008(14)***
LAREA_MZE	-0.9225(2)	-1.0252(1)	-5.5114(0)***	-5.6152(2)***
LYIELD_CAS	-1.6735(0)	-1.9559(1)	-5.8257(2)***	-5.7783(2)***
LYIELD_GNT	-1.1788(2)	-1.3755(4)	-8.2191(7)***	-10.825(19)***
LYIELD_MZE	-1.7402(1)	-2.2835(1)	-7.0146(2)***	-7.0192(3)***
LPRICE_CAS	-1.6707(2)	-2.1549(1)	-4.6545(7)***	-4.6737(7)***
LPRICE_GNT	-1.7563(4)	-1.3944(1)	-8.0354(2)***	-8.3756(1)***
LPRICE_MZE	-1.5173(6)	-2.0112(2)	-6.9982(3)***	-6.9919(4)***
LVOL_CAS	-2.5864(2)	-2.5186(2)	-3.9623(7)***	-3.7118(7)**
LVOL_GNT	-2.7927(1)*	-3.0643(5)	-5.8153(6)***	-5.8046(6)***
LVOL_MZE	-2.5252(1)	-2.5704(1)	-4.9799(4)***	-4.9289(4)***
LRAINFALL	-6.1804(1)***	-6.1654(1)***		

*Notes: (i) Unit root test is performed by using EViews 9.0 with Newey-West using Bartlett Kernel; (ii) Critical values for PP at level with intercept at 1%, 5%, and 10% are: -3.5811, -2.9266, -2.6014 respectively; (iii) Critical values for PP at level with intercept and trend at 1%, 5%, and 10% are: -4.1705, -3.5107, -3.1855 respectively; (iv)Critical values at first difference for PP with intercept at 1%, 5%, and 10% are: -3.5847, -2.9281, -2.6022 respectively; (v) Critical values at first difference for PP with intercept and trend at 1%, 5%, and 10% are: -4.1756, -3.5130, -3.1868 respectively; (vi) *** significant at 1% level, ** significant at 5% level,*
** significant at 10% level.*

3.2.2.2. "Bounds test" results

Figure 3.1: Evolution of producer price from 1966 to 2012



We have to note that producer prices tend to move together over time for cassava, groundnuts, and maize (figure 3.1). Therefore, a long-run cointegration relationship between these series is suggested. In this study, the ARDL approach for cointegration is used to investigate this relationship.

The results of the bounds F-test statistics are reported in the table 3.4 below for cointegration for both the area and yield equations. The results of the ARDL bounds tests show that the computed F-statistics in all the cases exceeds the upper bound at 5% level of significance. Therefore, we reject the null hypothesis of no cointegration and we can conclude that there is a long-run relationship among variables.

Table 3.4: Bounds test results for cointegration

	$F(larea_t/lprice_t, lvol_t, lrainfall_t, T)$	$F(lyield_t/lprice_t, lvol_t, lrainfall_t, T)$	Critical values at 5%	
			I(0)	**I(1)**
Cassava	11.14	8.38	3.12	4.25
Groundnuts	4.42	4.32	3.12	4.25
Maize	4.96	5.87	3.12	4.25

Notes: Bounds tests performed using EViews 9.0 that automatically reports the critical upper and lower bounds. $F(.)$ is the F-statistics.

Next, the results of the supply response estimation using area or yield as dependent variable are discussed.

3.2.2.3. Supply response for each crop using the area equation

In general, results (see table 3.5 below and tables 3.2 to 3.4 in the appendix) suggest that long-run elasticities are higher than short-run elasticities; confirming similar findings in the literature (Binswanger, 1989; Kul, 1998; Kuwornu et al., 2011; Mamingi, 1997; Rahji and Adewumi, 2008). Therefore, supply is most responsive to price and other factors in long-run. Indeed, farmers in Cameroon as in other developing countries cannot rapidly react to incentives due to resource constraints and the fact that it takes time to increase the quantity of production factors. The short-run own price elasticities are very small and inelastic (i.e., less than one). This result can be explained by the fact that farmers operate at a small scale and subsistence farming is a common practice. Moreover, the short-run elasticities appear significant only for maize price and price volatility in the case of cassava, and rainfall in the case of groundnuts. For instance, a 1% increase in maize price and cassava price volatility increases cassava area by 0.97% and 0.31%, respectively. A 1% increase in rainfall increases groundnuts area by 1.02% (table 3.5). The own price elasticity for groundnuts and maize in short-run is positive; consistently with the standard production theory; even if those elasticities are not significant.

The negative sign of own price elasticity for cassava, and the long-run own price elasticity for groundnuts are contrary to the expected signs. Similar results was found by McKay et al. (1999) and Muchapondwa (2009) in the case of Tanzania. McKay et al. (1999) explained this surprising results by the fact that price is endogenous. Meaning that, price is determined after supply has been observed. Thus, the price is low during bumper harvests and high when supply is low. However, we have to note that ARDL estimates remain consistent even if regressors are endogenous as mentioned earlier.

Table 3.5: Estimated long-run and short-run elasticities using area equation

		Short-Run coefficients	Long-Run coefficients
Cassava	Cassava	-0.4085	-0.7455***
	Groundnuts	-0.3407	-1.4787***
	Maize	0.9689***	1.9748***
	Volatility	0.310797*	0.2549**
	Rainfall	0.4902	-1.6471
Groundnuts	Cassava	-0.0306	1.2757***
	Groundnuts	0.1350	-0.9755**
	Maize	0.0603	0.0893
	Volatility	0.0024	0.0036
	Rainfall	1.0197**	1.5098*
Maize	Cassava	0.0222	0.0449
	Groundnuts	-0.1221	-2.2786***
	Maize	0.0958	1.4594***
	Volatility	0.0674	0.1359
	Rainfall	-0.2908	-0.6396

*Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

Additionally, the results suggest that cassava and groundnuts compete for land in short-run since their cross-price elasticity is negative. Therefore, a 1% increase in groundnuts price leads to a reduction in cassava area under cultivation of 0.31%. A 1% increase cassava price reduces groundnuts area under cultivation of 0.03%.

In general, long-run elasticities are significant. These elasticities suggest that farmers respond to price incentive in an elastic manner only for Maize. For instance a 1% increase in maize price increases supply by 1.45%, implying that maize producers respond to a price incentive by increasing area. However, for cassava and groundnuts, the supply remains non-responsive to price incentives as in short-run.

The results show that farmers seem non-responsive to price volatility as the elasticities are non-significant in general when using area as dependent variable. This effect is negligible and only fairly significant for cassava. The positive sign of the volatility coefficient suggests that farmers react to price volatility by increasing area under cultivation. This can be explained by the fact that, price volatility generally leads to output price increases, then to some extent, volatility can be seen as an opportunity for producers since it can increase their profit. Similar results were found by De Menezes and Piketty (2012) for soybean acreage supply in Brasil.

Table 3.6 : ECM representation results using the area equation

Crops	Cassava		Groundnuts		Maize	
Selected model	ARDL(4, 4, 2, 3, 3, 4)		ARDL(4, 3, 4, 0, 0, 0)		ARDL(2, 0, 2, 1, 0, 2)	
	coefficients	**t-statistics**	**coefficients**	**t-statistics**	**coefficients**	**t-statistics**
D(Y(-1))	1.0821**	2.9022	0.0603	0.3270	0.2300	1.4971
D(Y(-2))	0.9232***	3.2598	0.1024	0.5824	---------	---------
D(Y(-3))	0.8361***	4.0325	-0.2074	-1.2918	---------	---------
D(LPRIC_CAS)	-0.4085	-1.4608	-0.0306	-0.1491	0.0222	0.1137
D(LPRICE_CAS(-1))	1.4478***	3.0254	0.9945***	2.8488	---------	---------
D(LPRICE_CAS(-2))	0.8985	1.5174	-0.8164***	-3.1476	---------	---------
D(LPRICE_CAS(-3))	-1.4944***	-3.2569	---------	---------	---------	---------
D(LPRICE_GNT)	-0.3407	-1.3602	0.1350	0.6082	-0.1221	-0.4576
D(LPRICE_GNT(-1))	1.3348***	3.3595	0.3284	1.5209	0.5748**	2.6544
D(LPRICE_GNT(-2))	---------	---------	-0.1682	-0.8319	---------	---------
D(LPRICE_GNT(-3))	---------	---------	0.4230**	2.4471	---------	---------
D(LPRICE_MZE)	0.9689***	3.8056	0.0603	0.3199	0.0958	0.4258
D(LPRICE_MZE(-1))	-1.5030***	-3.7555	---------	---------	---------	---------
D(LPRICE_MZE(-2))	-0.5494*	-1.7828	---------	---------	---------	---------
D(LVOL_Y)	0.3107*	2.0231	0.0024	0.0480	0.0674	1.3880
D(LVOL_Y(-1))	-0.4142**	-2.4262	---------	---------	---------	---------
D(LVOL_Y(-2))	-0.0660	-0.5265	---------	---------	---------	---------
D(LVOL_Y(-3))	---------	---------	---------	---------	---------	---------
D(LRAINFALL)	0.4902	0.6695	1.0197**	2.1395	-0.2908	-0.5269
D(LRAINFALL(-1))	1.3901	1.3894	---------	---------	0.6893	1.4247
D(LRAINFALL(-2))	1.3162	1.6001	---------	---------	---------	---------
D(LRAINFALL(-3))	-0.2361	-0.4669	---------	---------	---------	---------
T	0.0984**	2.9923	-0.0179**	-2.3569	0.0325***	3.2665
ECT(-1)	-2.0258***	-4.5329	-0.6753***	-3.3115	-0.4960***	-4.2674

Cassava: ECT = LAREA_CAS - (0.5979*LPRICE_CAS + 1.4370*LPRICE_GNT - 2.0077*LPRICE_MZE - 0.1514*LVOL_CAS - 1.6503*LRAINFALL + 6.3602 - 0.0102*T)

Groundnuts: ECT = LAREA_GNT - (1.2758*LPRICE_CAS - 0.9756*LPRICE_GNT + 0.0894*LPRICE_MZE + 0.0037*LVOL_GNT + 1.5098*LRAINFALL + 3.2249 - 0.0266*T)

Maize: ECT = LAREA_MZE - (0.0449*LPRICE_CAS - 2.2787*LPRICE_GNT + 1.4594* LPRICE_MZE + 0.1360*LVOL_MZE -0.6397*LRAINFALL + 25.1481 + 0.0657*T)

*Note: (i) Y is the log of the dependent variable; (ii) ECT: Error Correction Term. (iii) *** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

The error correction coefficients (ECT) are highly significant for all crops (table 3.6) and have a negative sign and imply a high speed of adjustment to equilibrium after a shock.

Approximatively 202.58%, 67.33%, 49.60% of previous year's shock disequilibrium converges back to long-run equilibrium in the current year for cassava, groundnuts and maize, respectively (table 3.6).

3.2.2.4. Supply response for each crop using yield equation

Recall that we are using both area and yield as dependent variables to estimate supply response, since the literature is not conclusive about the best choice for a supply response proxy variable.

The results in table 3.7 confirm the fact that producers are not responsive to price incentive in short-run, since long-run elasticities are almost higher than short-run elasticities as observed for the area supply model. Moreover, the short-run elasticities are relatively small and inelastic. The negative sign of own price elasticities for groundnuts and maize can be explained by the aforementioned endogeneity problem.

Table 3.7 : Estimated long-run and short-run elasticities using yield equation

		Short-Run coefficients	Long-Run coefficients
Cassava	Cassava	0.7028*	0.5979***
	Groundnuts	0.1032	1.4370***
	Maize	-0.7744**	-1.7949***
	Volatility	-0.3340*	-0.3641**
	Rainfall	-0.8609	-1.6502
Groundnuts	Cassava	0.2301	-2.0413***
	Groundnuts	-0.0966	-2.1188***
	Maize	0.9023*	2.1932***
	Volatility	-0.3085**	-0.4724***
	Rainfall	-1.5581	-11.4771***
Maize	Cassava	-0.0169	-0.0290
	Groundnuts	0.0104	0.9770**
	Maize	0.4242**	-0.6108*
	Volatility	0.0781	-0.1818**
	Rainfall	0.0437	1.3886

*Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

There are two main differences between the two equations: the sign of coefficients and the impact of price volatility on supply. There is no need to have the same sign in the estimated coefficients since the two equations capture supply response in a different manner. While the area equation helps to analyse the producer's reaction to economic incentives in terms of land allocation, the yield equation tries to capture producers response to economic incentives in term of investment to improve yield. Therefore, for agricultural policy design, it seems important to first investigate how farmers respond to price incentive (which hypothesis should be considered) as the outcomes are strongly related to the supply proxy variable chosen. Indeed, producers can have area response, yield response, or both.

Contrariwise to the area equation, yield equation results reveal a significant negative impact of price volatility on production, implying that farmers are risk adverse and reduce investment in yield improvement in presence of volatility. This is consistent with finding in the literature that price volatility has a negative impact on supply (Ajetomobi, 2010; Behrman, 1968; Guillaumont and Bonjean, 1991; Haile et al., 2013, 2014a, 2014b; Moschini and Hennessy, 2001; Subervie, 2006).

Table 3.8 : ECM representation results using yield equation

Crops	**Cassava**		**Groundnuts**		**Maize**	
Selected model	ARDL(4, 4, 2, 2, 4, 4)		ARDL(2, 3, 2, 2, 1, 4)		ARDL(3, 0, 2, 1, 1, 2)	
	coefficients	**t-statistics**	**coefficients**	**t-statistics**	**coefficients**	**t-statistics**
D(Y(-1))	0.8089**	3.0112	0.2820	1.4417	0.3071*	2.0155
D(Y(-2))	0.6217**	2.8726	---------	---------	0.2360*	1.7186
D(Y(-3))	0.6098**	2.8596	---------	---------	---------	---------
D(LPRIC_CAS)	0.7028*	1.7863	0.2301	0.5132	-0.0169	-0.1036
D(LPRICE_CAS(-1))	-1.4087**	-2.1942	0.2539	0.2996	---------	---------
D(LPRICE_CAS(-2))	-0.1960	-0.2718	1.2224*	1.9442	---------	---------
D(LPRICE_CAS(-3))	1.1057*	2.0496	---------	---------	---------	---------
D(LPRICE_GNT)	0.1032	0.3247	-0.0966	-0.1716	0.0104	0.0448
D(LPRICE_GNT(-1))	-0.9588**	-2.6513	1.5110**	2.2335	-0.4704**	-2.5275
D(LPRICE_MZE)	-0.9588**	-2.6513	0.9023*	1.8175	0.4242**	2.2796
D(LPRICE_MZE(-1))	-0.7744**	-2.7550	-1.4566**	-2.7298	---------	---------
D(LPRICE_MZE(-2))	1.2085**	2.9154	---------	---------	---------	---------
D(LVOL_Y)	-0.3340*	-1.9729	-0.3085**	-2.2645	---------	---------
D(LVOL_Y(-1))	0.4219*	1.8203	---------	---------	---------	---------
D(LVOL_Y(-2))	-0.0896	-0.3341	---------	---------	---------	---------
D(LVOL_Y(-3))	0.2658	1.4652	---------	---------	---------	---------
D(LRAINFALL)	-0.8609	-1.1713	-1.5581	-1.3259	0.0437	0.0926
D(LRAINFALL(-1))	0.4339	0.6352	3.2832**	2.6428	-1.1696***	-2.8253
D(LRAINFALL(-2))	0.2245	0.3070	2.6502**	2.4176	---------	---------
D(LRAINFALL(-3))	1.1641*	1.9289	2.2666**	2.5331	---------	---------
T	-0.0159	-0.9584	0.1727***	4.9110	0.0003	0.0525
ECT(-1)	-1.5702***	-5.3936	-1.1251***	-4.3300	-0.5836***	-4.4425

Cassava: ECT = LYIELD_CAS - (0.5979*LPRICE_CAS + 1.4370*LPRICE_GNT - 1.7950*LPRICE_MZE - 0.3641*LVOL_CAS - 1.6503*LRAINFALL + 6.3602 - 0.0102*T)

Groundnuts: ECT = LYIELD_GNT - (-2.0414*LPRICE_CAS - 2.1188*LPRICE_GNT + 2.1932*LPRICE_MZE - 0.4725*LVOL_GNT - 1 1.4772*LRAINFALL + 72.7376 + 0.1535*T)

Maize: ECT = LYIELD_MZE - (-0.0290*LPRICE_CAS + 0.9770*LPRICE_GNT - 0.6109*LPRICE_MZE - 0.1818*LVOL_MZE + 1.3887*LRAINFALL - 11.3572 - 0.0007*T)

*Note: (i) Y is the log of the dependent variable (area or yield); (ii) ECT: Error Correction Term. (iii) *** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

We find that the estimated ECT coefficients are negative and strongly significant (table 3.8). For instance, the coefficients of the ECT are equal to -1.5702, -1.1251 and -0.5836 for cassava, groundnuts and maize, respectively; meaning that the deviation from the long-term path of yield is corrected by 157.02% for cassava, 112.51% for groundnuts and 58.36% for maize (table 3.8).

In addition, the results suggest that the trend is significant. This could be explained by the fact that structural variables such as infrastructural development, governance, expenditure on agricultural research and extension, application of modern techniques, and other uncontrollable factors affect supply response to economic incentives and volatility in Cameroon.

We have to note that our regression of the ARDL equations fits well and passes the diagnostic tests against serial correlation and hetoeroscedasticity (see tables 3.2 to 3.4 in the appendix).

Conclusion

This chapter has analysed the supply response for the major staple crops grown by agricultural households in Cameroon (maize, groundnut and cassava). The chapter has attempted to answer one fundamental question: do producers respond to price incentives and price volatility? Using the ARDL bounds testing procedure that is the most appropriate to examine long-run relationships in small sample, this study tends to support the argument that farmers in developing countries are not responsive to economic incentives such as prices in short-run.

Furthermore, it seems that producers respond to price volatility by increasing the area under cultivation, and reducing investments in improving yield in Cameroon. Such information can be of importance when designing agricultural policies. Indeed, to boost food production, improvement in yield is a necessary condition. Therefore, there is a need to control for output price volatility in order to boost agricultural production. Reduced agricultural output price volatility not only increases production by affecting investment in yield improvement, but also reduces food insecurity, stabilizes producers' income, and may increase growth. Moreover, to improve producer responsiveness to economic incentives and reduce the effect of price risk, some structural measures in terms of improvement in infrastructural development, governance, expenditure on agricultural research and extension, etc. should not be ignored. For future research, it could be interesting to analyse at regional level how producers respond to economic incentives and risk.

CHAPTER 4: IMPACT OF FOOD PRICE VOLATILITY ON HOUSEHOLD WELFARE IN CAMEROON[53]

Introduction

The literature is abundant about the welfare impact of recent price changes in developing countries, however, little is known about how households in Cameroon have responded to food price changes and the welfare effects of such situation. Previous studies used statistical methods to measure the effect of food price volatility on the purchasing power of households (MINEPAT, 2008). They showed that food price volatility adversely affected the purchasing power of households and subsequently, their nutritional status. This chapter goes further and analyses the impact of food price volatility on household welfare in Cameroon using data from the third Cameroonian household consumption survey. Since socio-economic and demographic characteristics of households play an important role in determining their demand patterns, the demand model is estimated taking into account heterogeneity across households. We then estimate price elasticities using a Quadratic Almost Ideal Demand System (QUAIDS) model and, following the compensating variation framework, we used those elasticities to estimate the welfare effects of price volatility.

The rest of the chapter is laid out as follows: the theoretical framework underlying the analysis of the welfare impact of food price volatility is briefly reviewed in the first section. The empirical analysis of the impact of food price volatility on consumers' welfare in the case of Cameroon is presented in the second section.

[53] Publish as Kane, G.Q., Mabah Tene, G.L., Ambagna, J.J., Piot-Lepetit, I. and Fondo Sikod. 2015. The impact of food price volatility on consumer welfare in Cameroon. WIDER Working Paper 2015/013, United Nations University (UNU-WIDER), Helsinki.

4.1. THEORETICAL FRAMEWORK FOR ANALYSING THE HOUSEHOLD WELFARE IMPACT OF FOOD PRICE VOLATILITY

An important issue about food price volatility is its welfare impact, since households in developing countries spend a large proportion of their total expenditure on food provision (Budd, 1993). Moreover, such information is crucial for policy makers, since it is necessary to know who are the most affected, in which area. This section discusses the theoretical framework for analysing the welfare impact of food price volatility. Additionally, the aim of this section is to provide the basic idea underlining the effect of changes in price on both demand behavior and consumer welfare.

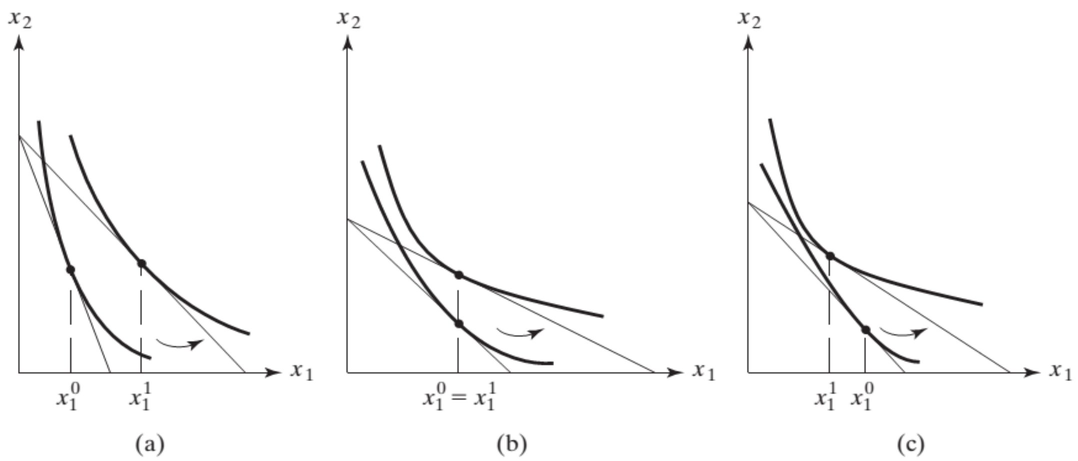
4.1.1. Effect of change in price on demand

The effect of price changes on demand can be seen in two conceptual frameworks: the income and the substitution effect, and the Slutsky equation.

4.1.1.1. The income and substitution effect

Intuitively, we tend to think that when the price of a good declines, other things being equal, the consumption of this good will increase (Jehle and Reny, 2011). However, this is not always the case as illustrated in the figure 4.1 below.

Figure 4.1: Response of quantity demanded to a change in price



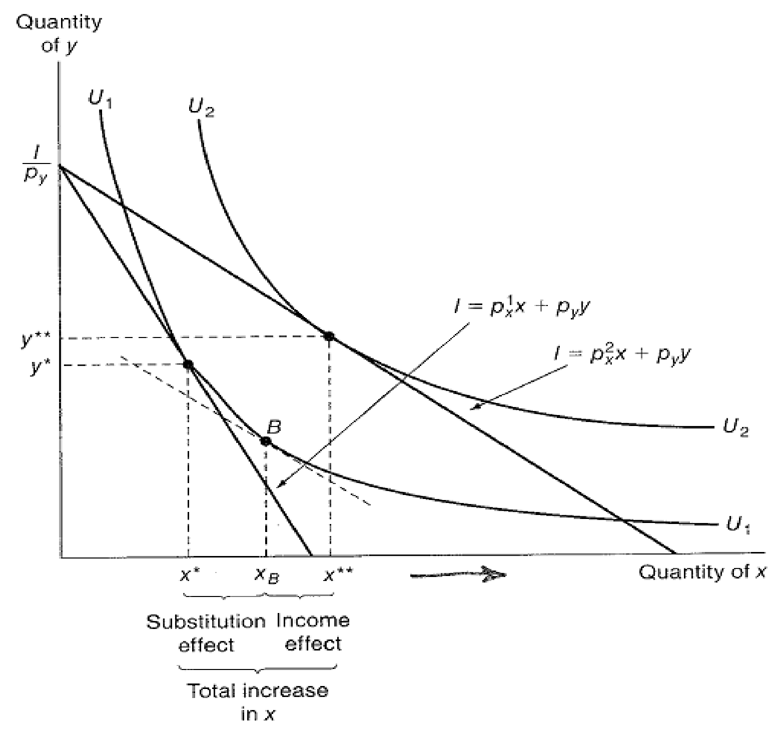
Source : Jehle and Reny (2011)

In figure 4.1, we suppose a decrease in the price of good 1. Its effect on the demand is different in the different panels. Indeed, in panel (a) the quantity demanded of good 1 increases, in panel (b) the quantity demanded of good 1 is constant, while in panel (c) the quantity demanded of good 1 decreases.

In general, a change in price not only cause a change in the intercepts but also a change in the slope of a budget constraint (Snyder and Nicholson, 2008). Thus, when the price of a good change, there are at least two different effects: the *substitution effect (SE)* and the *income effect (IE)*.

As noted by Jehle and Reny (2011), when the price of a good declines for exemple, the substitution effect can be explained by the substitution of the relative cheaper good to the relative more expensive ones, since the good for which the price has been reduced becomes relatively cheaper compared to others. The income effect in this situation, is the result of the generalised increase in the consumer's purchasing power. Graphically, the substitution and income effects in this case are expressed as in figure 4.2 below. Originally, the indivdual consumes a combination of x* and y*, subject to total expenditure I.

<u>Figure 4.2 : Income and substitution effects of a fall in the price of x</u>

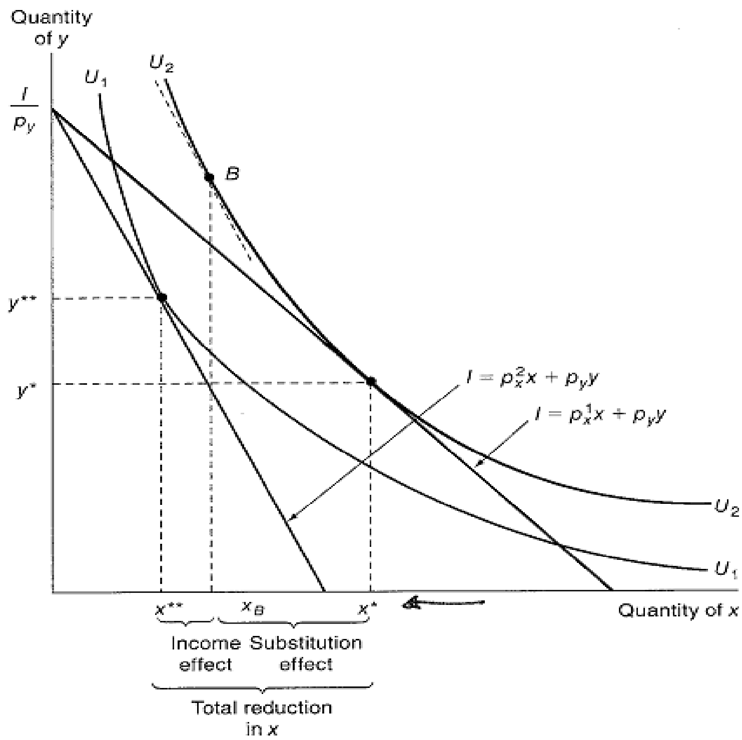


Source : Snyder and Nicholson (2008)

Initiatlly, the utility-maximizing choice is (x*,y*), this optimal choice shifts to (x**,y**) due to the fall in the price. However, this movement is not direct. First, the SE involve a movement from (x*,y*) to point B where the marginal rate of substitution (MRS) is equal to the new price ratio. second the IE entails a movement from the point B to (x**,y**). It is important to note that, both the income and the substitution effects increase the quantity of the good x consumed when its price falls. Additionally, the point B is not observed, just the two optimal choices (x*,y*) and (x**,y**) are observed.

Contrary to the case of a price decline, when the price of a good increases, the substitution effect can be explained by the substitution of the relatively new more expensive good for the cheaper ones, as the good for which the price has increased becomes relatively expensive compared to others. In such a situation, the income effect is the result of the generalised reduction in the consumer's purchasing power. The graphical analysis of an increase in price is presented in figure 4.3 below.

Figure 4.3 : Income and Substitution effects of a fall in the price of x



Source : Snyder and Nicholson (2008)

In the figure 4.3, the effect of the rise in price of good x[54] can be decomposed in two effects. First, the SE involve a movement from the initial optimal choice (x*,y*) to point B, since

[54] From (x*,y*) to (x**,y**).

consumer has an incentive to substitute y to x (which becomes relatively more expensive). Second, the IE entail a movement from the point B to the final optimal choice (x**,y**) since there is a reduction in the consumer purschassing power. Moreover, in a situationof a rise in the price of a good, income and substitution effects work in the same direction and implies a reduction in the quantity demanded.

It should be noted that, the situation depicted before is appropriate in the case of "normal good", a good for which the demand and income moves in the same direction. The story is more complicated when looking at an "*inferior good*". Recall that, a good is called inferior if an increase in income leads to a reduction in the consumption (Varian, 2010), as it is the case for low quality goods, for example. Therefore, in the case of inferior goods, the effect of price change is indeterminate since income and substitution effects work in opposite directions (Snyder and Nicholson, 2008). In the case of a fall in price for example, when the substitution effect contributes to an increase in the quantity demanded of the inferior good, the income effect leads to a reduction in the quantity, and the resultant total effect (sum of substitution and income effects) is indeterminate.

Another exception have to be noted, what is known in microeconomics as the *Giffen paradox*. This paradox is explained by the possibility of an increase in the quantity bought in response to an rise in the price of the good considered. Then, a giffen good is one for which the demand and the price move in the same direction, contrary to ordinary goods, for which the demand and the price move in the opposite direction.

4.1.1.2. Slutsky equation

The Slutsky equation can be seen as the derivative of the Mashallian demand with respect to price and income (Varian, 1992). More precisely, the Slutsky equation allows a decompositision of the total effect induced by a change in price for both the income and substitution effects. This equation also helps to more precisely analyse the size and the direction of the income and substitution effects than with the graphical analysis.

As noted by Jehle and Reny (2011), the Slutsky equation is:

$$\frac{\partial x_i(\mathbf{p}, y)}{\partial p_j} = \frac{\partial x_i^h(\mathbf{p}, u^*)}{\partial p_j} - x_j(\mathbf{p}, y)\frac{\partial x_i^h(\mathbf{p}, u^*)}{\partial y}, \qquad i, j = 1, ..., n. \tag{4.1}$$

Where $x(\mathbf{p}, y)$ is the consumer's Marshallian demand system; x_i^h is the Hicksian demand for good i; u^* is the level of utility achieved by the consumer at prices $\mathbf{p}$ with income y.

The Slutsky equation represents the decomposition of the total effect due to a change in a price:

Total effect = Substitution effect + Income effect

With **Total effect =** $\dfrac{\partial x_i(\mathbf{p}, y)}{\partial p_j}$;

Substitution effect = $\dfrac{\partial x_i^h(\mathbf{p}, u^*)}{\partial p_j}$;

Income effect = $-x_j(\mathbf{p}, y)\dfrac{\partial x_i^h(\mathbf{p}, u^*)}{\partial y}$ [55]

Note that as long as the MRS is diminishing, the substitution effect is always negative, since price and quantity generally move in opposite directions. On the other hand, the sign of the income effect is a function of the sign of $\dfrac{\partial x_i^h(\mathbf{p}, u^*)}{\partial y}$. Thus, for a normal good for example, both income and substitution effect are negative since $\dfrac{\partial x_i^h(\mathbf{p}, u^*)}{\partial y}$ is positive. However, in the case of inferior good, $\dfrac{\partial x_i^h(\mathbf{p}, u^*)}{\partial y}$ is negative and then, income and substitution effects work in opposite directions.

4.1.2. Effect of change in price on consumer welfare

In this subsection, we discuss and characterize the two mostly used tools in order to evaluate the welfare impact of price change in literature, namely: consumer surplus, equivalent variation and compensating variation.

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[55] The proof of this theorem is relatively easy and developed in any microeconomic text books as Varian (1992); Snyder and Nicholson (2008); Jehle and Reny (2011)…

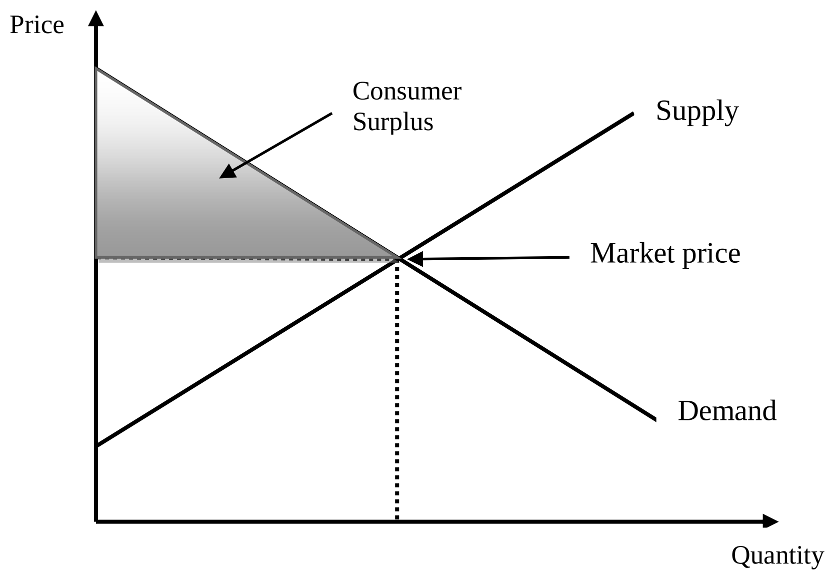
4.1.2.1. Consumer surplus framework

The consumer surplus (CS) is the classical tool for measuring the welfare impact of a change in price (Varian, 1992). As noted by Varian (1992), the consumer's surplus associated with price change from p^0 to p^1, where $x(t)$ is the demand for some goods (function of its price), is:

$$CS = \int_{p^0}^{p^1} x(t)dt \qquad (4.2)$$

On the other hand, as noted by Snyder and Nicholson (2008), CS is the area below the Marshallian demand curve and above market price. It simply represents the extra benefit of making transaction on the prevailing market price. Graphically, CS can be represented as in figure 4.4 below.

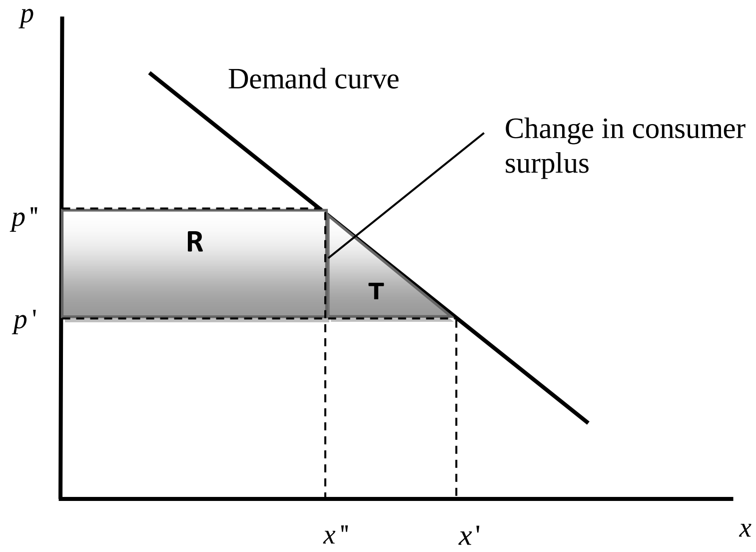
<u>Figure 4.4 : Consumer surplus</u>



Generally, the absolute value of CS is not interesting for researchers, but the value of a change in CS as a result of price change. Indeed, it is admitted that a change in CS can be used as a measure of the welfare effect of a change in price (Snyder and Nicholson, 2008; Varian, 2010). Basically, the idea is that, the change in consumer utility due to welfare loss from price change can be captured by a change in the consumer surplus.

Graphically (figure 4.5), the change in the consumer surplus as noted by Varian (2010) is the sum of two sub-regions: the rectangle **R** and the triangle **T**. Indeed, when price of the x-good rose from p' to p'' for example, there are two resulting effects: the reduction in the consumption of the x-good as a result of the increase in the price (captured by the **T** area) and the loss from paying more the units of x-good than before (measured by the **R** area). Therefore, the sum of these two effects is the total loss to the consumer.

<u>Figure 4.5 : Change in consumer surplus</u>



Source: Varian (2010)

The concept of the consumer surplus was mostly used in the empirical studies to measure consumer welfare, however as noted by Just et al. (2004), this concept is at the center of a controversy surrounding consumer welfare measurement. Therefore, except under the restrictive assumption, the Marshallian consumer surplus is not an exact measure of the individual welfare change (Blackorby et al., 2008). According to Paul Samuelson[56]: "*the Consumer's surplus is a worse than useless concept*". Indeed, Samuelson (1942) demonstrated nonuniqueness of a consumer surplus as a money measure of utility, and this can lead to a contradiction depending upon the use of empirical data. Moreover, one critique of the consumer surplus by Pfouts (1953) states: "*Probably no single concept in the annals of economic theory has aroused so many emphatic expressions of opinion as has consumer's surplus. Indeed, even today the biting winds of scholarly sarcasm howl around this venerable storm centre*." Indeed, issues caused by the use of consumer surplus as a welfare measure is

[56] Cited by Willig (1976).

complex and requires advanced mathematical techniques for a proper resolution (Just et al., 2004).

4.1.2.2. Equivalent and Compensating variation

The compensating variation and equivalent variation, introduced by Hicks (1943; 1956) are the two most widely used money measures of the welfare effect of price change in applied microeconomic studies. Indeed, as noted by Varian (1992), it is important to measure the welfare effect of a change in the consumer economic environment. Since this change can make consumer better-off or worse-off. Ideally, the change in utility levels between two[57] situations is the best measure of the welfare change. However, utility is not directly observable, and there is no unambiguous way to measure utility changes. Therefore, it appeared convenient to have a money measure of a change in consumer welfare.

The compensating variation (CV) and equivalent variation (EV), also known as Hicksian willingness-to-pay measures of a price change is defined by Just et al. (2004) as: "*the amount of income that must be taken away from a consumer after a price and/or income change to restore the consumer's original welfare level; and the amount of income that must be given to a consumer in lieu of price and income changes to leave the consumer as well off as with the change respectively"*. Therefore, CV uses the initial level of welfare (using the initial price change) as a base, while the EV focuses on the final level of welfare (using after the price change).

Formaly, as noted by Varian (1992):

$$\begin{aligned} EV &= \mu(p^0; p^{'}; m^{'}) - \mu(p^0; p^0; m^0) = \mu(p^0; p^{'}; m^{'}) - m^0 \\ CV &= \mu(p^{'}; p^{'}; m^{'}) - \mu(p^{'}; p^0; m^0) = m^{'} - \mu(p^{'}; p^0; m^0) \end{aligned} \tag{4.3}$$

Where $\mu(p;q;m)$ is the money metric indirect utility function, and measures how much money is needed at prices **p** to be as well-off as facing price **q** (which can be $p^{'}$ or p^0 in this case) with income **m**.

$\left(p^0, m^0\right)$ and $\left(p^{'}, m^{'}\right)$ are two budgets, that measure the price and income in the initial and the final situation, respectively.

[57] Suppose two situations, where the only difference is the change in price.

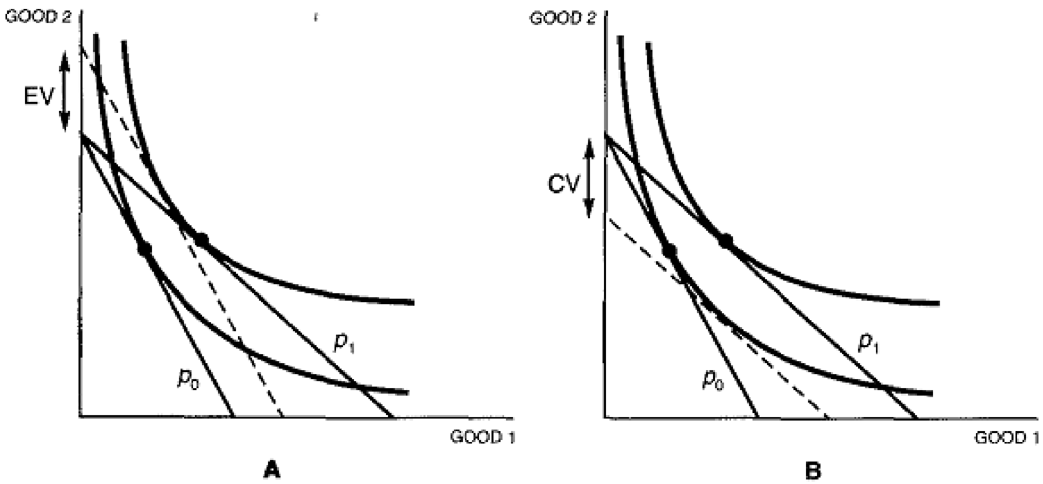
On the other hand, for example, suppose an increase in the price of a good x (from p_x^0 to p_x^1), using expenditure function, the CV as noted by Snyder and Nicholson (2008) is:

$$CV = E(p_x^1, p_y, U_0) - E(p_x^0, p_y, U_0) \tag{4.4}$$

Where $E(p_x^0, p_y, U_0)$ is the expenditure required to reach the utility level U_0 with initial price p_x^0 and p_y and, $E(p_x^1, p_y, U_0)$ is the expenditure required to achieve the same utility level U_0 at the final price p_x^1 and p_y.

Graphically, suppose that we have two goods (good 1 and good 2), EV and CV can be represented as follows:

Figure 4.6 : Equivalent variation and compensating variation



Source : Varian (1992)

In figure 4.6 above, there is a decrease in the price of good 1 from p_0 to p_1 and the price of good 1 is normalized to 1. In panel A, the equivalent variation corresponds to the additional amount of money needed at p_0 by a consumer to be as well-off as with price p_1. Moreover, as defined by Just et al. (2004): "*the EV is the minimum amount of money the consumer is willing to accept to forgo the lower price, for a fall in prices*". In panel B, the compensating variation corresponds to the amount of money which should be taken away from the consumer, in order to be as well-off as with price p_0. additionally, as defined by Just et al. (2004): "*the CV is the maximum amount of money the consumer is willing to pay rather than relinquish the price reduction*".

It is important to note that in the case of quasilinear utility function, the egality below is verified:

Compensation variation = Equivalent variation = Consumer surplus

Therefore, quasilinear utility appear to be an exception, while for more general forms of utility function, these three measures are different.

On the other hand, the choice between the compensation variation and the equivalent variation as a welfare measure of a price change is not definite. Indeed, as noted by Hause (1975), some authors argued that unlike the compensating variation, the equivalent variation is consistent with utility ranking and then, appears to be the only acceptable welfare measure. For example, when measuring EV and CV for a change income and price from the same initial situation and the same final utility level, the EV measures of the change in income and price are identical, but the CV measures are different. However, Just et al. (2004) noted that this criteria is unstable and can be reversed. Therefore, it can be better to consider both the compensating and equivalent variations if they are anticipated to differ substantially.

4.2. EMPIRICAL EVIDENCE OF THE IMPACT OF FOOD PRICE VOLATILITY ON HOUSEHOLDS WELFARE IN CAMEROON

This section presents empirical analysis of the welfare impact of food price volatility on Cameroonian consumers[58].

4.2.1. Methodology

4.2.1.1. Data type and sources

4.2.1.1.1. ECAM3 Survey

The data used in this study are from the 2007 Cameroonian household consumption survey called ECAM III, carried out by the National Institute of Statistics (NIS) of Cameroon. This survey was conducted from May to July 2007 when 11,391 households were surveyed from 32 strata (12 urban, 10 semi-urban and 10 rural), and four agro-ecological zones, namely

[58] Our analysis in this chapter is restricted to consumers due to data limitation.

Rural Forests, Rural Savannah, Other Towns and Rural High Plateaus. Following the first round of the ECAM in 1996, and the second in 2001, the principal objectives of ECAM III was to upgrade the poverty profile and to provide living standard indicators, which are useful in evaluating the realization of the Millennium Development Goals' objectives through the implementation of the Poverty Reduction Strategy Paper (DSRP) in Cameroon.

As noted by the (NIS, 2008), this survey specifically aimed to: study all dimensions of poverty at both national and regional levels; establish correlations between different poverty aspects; analyse the effect of the macroeconomic policies of the last five years through the study of the change in poverty between 2001 and 2007; evaluate the demand for education and identify its determinants; and provide a useful database in order to updating official statistics.

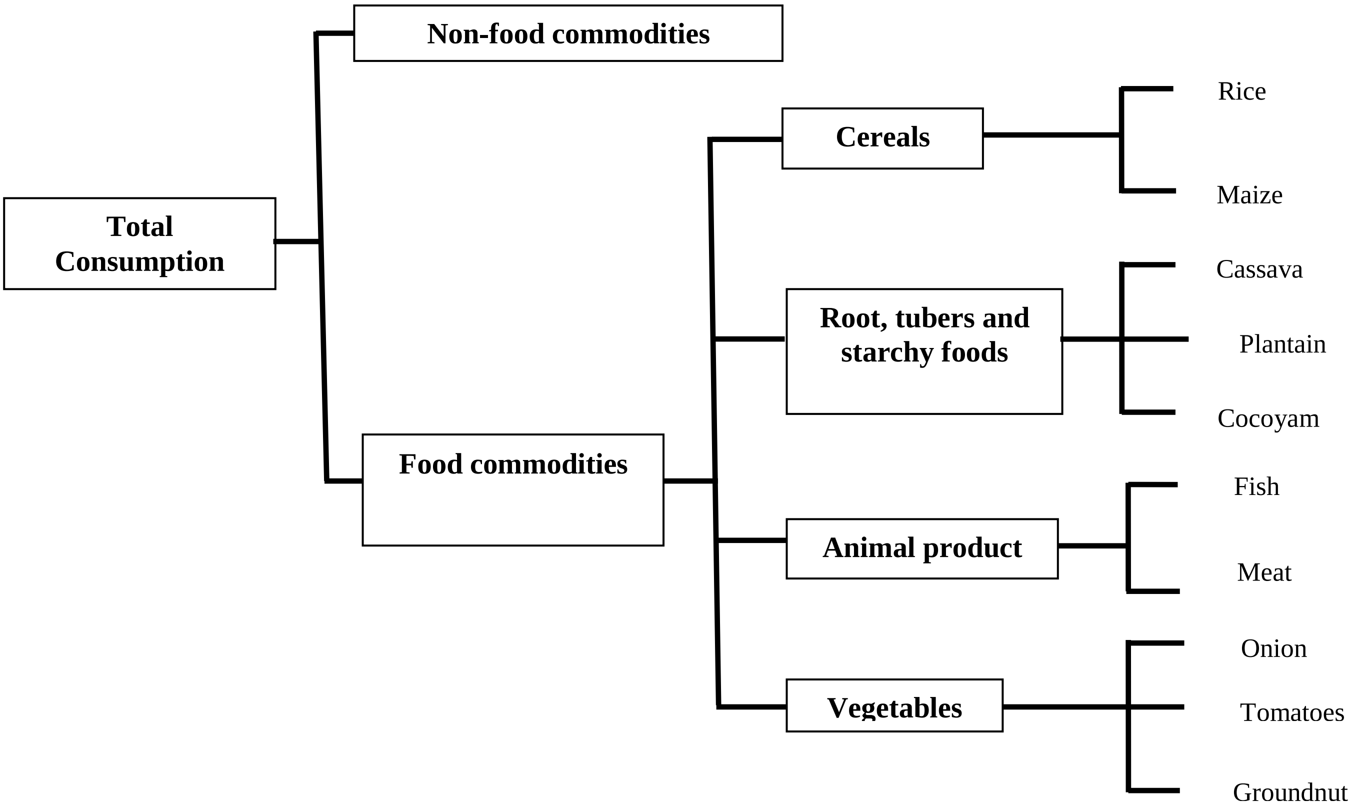
The survey was nationally representative and recorded data with variables on: household expenditure, consumption and income; household demographics; economic activities; and other useful variables for welfare analysis. The sampling design for household interviews was carried out in two stages. First, the primary sampling units (PSU) or clusters either in urban or rural area was selected all over the country. Second, a sample of households was randomly selected from each of the selected PSUs.

Due to data limitation, and excluding households who do not consume the commodities retained in this study, we use a sample of 2,665 households from ECAM III. Unfortunately, it was not possible to find data on food production for this sample since ECAM mainly focused on consumption information, thus this study only focuses on consumers.

4.2.1.1.2. food groups

To deal with the large number of goods involved and to facilitate the empirical analysis, we aggregated the major components of food consumption into four groups: cereals, roots and tubers, animal products, and vegetables. The grouping of the food products was carried out according to the nomenclature adopted by the NIS. Although it can be important to consider simultaneously both food and non-food items such as education, housing, health and durable ownership to estimate the entire demand system, due to data limitation, we adopt a separability assumption in this study as usual in practice (Ackah and Appleton, 2007; Attanasio et al., 2013; Béké, 2013). Under this assumption, the preference is independence between the choice of foodstuffs and non-food items. In addition, this assumption implies that the choice within a given food group is independent of the choice in the other groups. Then, the allocation of total expenditure is sequential in three stages as presented in Figure 4.7:

Figure 4.7 : Utility tree for three- stage budgeting for food demand in Cameroon



Source: Adapted from Béké (2013)

4.2.1.2. Welfare impact of changing price

The effect of food price volatility on consumer welfare is evaluated using the compensating variation (CV) concept as is usual in the literature (Badolo and Traore, 2012; Leyaro, 2009; Minot and Goletti, 2000; Tafere et al., 2010). Price volatility is taken into account by the induced change in price.

As stated earlier, the compensating variation can be defined as the amount of money required to compensate a household for a change in prices and to restore the pre-change utility level (Badolo and Traore, 2012; Tafere et al., 2010).

The CV can be expressed using the expenditure function as follows:

$$CV = e(p_1, u_0) - e(p_0, u_0) \tag{4.5}$$

Where $e(.)$ is the expenditure/cost function, p is the price vector, p_1 and p_0 are respectively prices after and before the price change, and u is the utility.

Using second-order Taylor-series expansion and Shephard's lemma on equation (4.5), the effect of price changes on consumers is obtained as follows (Badolo and Traore, 2012):

$$\frac{CV}{x_0} \cong CR_i \frac{\Delta p_i}{p_{0i}} + \frac{1}{2}\varepsilon_d CR_i \left(\frac{\Delta p_i}{p_{0i}}\right)^2 \tag{4.6}$$

Where $CR_i = \frac{p_{0i} q_i(p_0, x_0)}{x_0}$ is the consumption ratio defined as the proportion of the budget affected to the product consumption relative to the household income or total expenditure.

p_i, q_i, x_0 and ε_d are respectively the price, the quantity demanded, the original income, and the own-price elasticity for a given product.

On the other hand, it is possible to derive the short-run (immediate) impact of a changing price by assuming a zero elasticity as follows:

$$\frac{\Delta w^1}{x_0} \cong -\frac{\Delta p_i^c}{p_{0i}^c} CR_i \tag{4.7}$$

Where Δw^1 is the first-order approximation of the net welfare effect of a changing price.

There is one major issue in such an analysis; notably the use of appropriate price elasticities, since price elasticities are needed to calculate the compensating variation after demand adjustments (Ackah and Appleton, 2007; Attanasio et al., 2013; Pons, 2011). To overcome this point, we estimated an entire demand system for all commodity groups under consideration as discussed in the following sub-section.

4.2.1.3. Welfare measure

We have to deal at least with two important issues when analysing household welfare: the choice between income or consumption measure and the choice of variables used to capture household welfare. First, they are both theoretical and practical considerations that affect the choice between income and consumption. Indeed, income and consumption are not just different ways of measuring the same concept, but different concepts (Deaton and Grosh, 1999). According to these last authors, income can be considered as a measure of a household potential claims on the economy, while consumption can be seen as the measure of what a household actually requires. For others, random irregularities and seasonal patterns can be more important in income than in consumption. Then, the seasonal pattern in income requires many visits to the households and the capacity of the respondents to remember their income from many months earlier is not guaranteed. Also, consumption data tell us who consumes how much of what, such information is useful in the analysis of the distributional consequences of price changes (Deaton, 1997). For these reasons, we use the consumption approach in this study to measure household welfare by assuming that consumption is smoothed over the seasons which ensure that the seasonal variation in consumption will be less than in income as suggested in the literature.

Second, three variables were widely used in the literature to capture welfare using consumption approach: the total consumption of household, per capita consumption, and per adult equivalent consumption. The superiority of the per equivalent consumption variable is the fact that this variable takes into account both the household size and the household composition by age and gender (Badolo & Traore, 2012). Thus, we will use this variable when defining the welfare measure.

4.2.1.4. The model of demand

Price elasticities are needed to calculate the compensating variation after demand adjustments as usual in the literature (Ackah & Appleton, 2007; Pons, 2011; Attanasio *et al.*, 2013). Thus elasticities in this study are derived from the QUAIDS model.

4.2.1.4.1. The QUAIDS model

In the literature, the most commonly used method in demand analysis over the last two decades is the Deaton and Muellbauer (1980) AIDS model. Indeed the AIDS model has a number of desirable demand properties such as allowing testing for symmetry and homogeneity through linear restrictions. However, more recently (Banks et al., 1997) generalized the AIDS model by demonstrating that the appropriate form for some consumer preferences is of a quadratic nature contrary to the linear form in the basic AIDS. In addition, the QUAIDS model maintains the theory consistency and the desirable demand properties of the AIDS model.

Formally, the share equations in the (Banks et al., 1997) QUAIDS model are:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{m}{a(p)}\right] + \frac{\lambda_i}{b(p)}\left\{\ln\left[\frac{m}{a(p)}\right]\right\}^2 + \varepsilon_i \qquad (4.8)$$

Where w_i is a household's expenditure share for commodity i, defined as $w_i \equiv \frac{p_i q_i}{m}$ and $\sum_{i=1}^{n} w_i = 1$

On the other hand, the demand theory requires the following restrictions:

Adding-up: $\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \beta_i = 0, \quad \sum_{i=1}^{n} \gamma_{ij} = 0, \quad \sum_{i=1}^{n} \lambda_i = 0$ (4.9)

Homogeneity: $\sum_{i=1}^{n} \gamma_{ji} = 0$ (4.10)

Slutsky symmetry: $\gamma_{ji} = \gamma_{ij}$ (4.11)

The QUAIDS model in this study was carried out accounting for socio-demographic effects. Indeed, demographic factors can affect household behaviour in terms of demand and allocation of expenditure among goods (Olorunfemi, 2013; Pollak and Wales, 1981; Pollak and Wales, 1992; Tafere et al., 2010). The Ray (1983)'s 'demographic scalling' method has been used to take into account demographics in this study as in Poi (2012). In this approach, the effects of a change on the demographics are closed to the effects of a change in prices (Pollak and Wales, 1992).

Considering z as a vector of s household characteristics z is a scalar representing the household size in the simplest case. Let $e^R(p,u)$ represents the expenditure function of a reference household with just a single adult.

For each household, the Ray's method uses an expenditure function of the following form:

$$e(p,z,u) = m_0(p,z,u) * e^R(p,u) \qquad (4.12)$$

Further, Ray decomposes the scaling function as $m_0(p,z,u) = \overline{m}_0(z) * \phi(p,z,u)$

Where the first term measures the increase in a household expenditure as a function of household characteristics, without controlling for any changes in consumption patterns. The second term controls for a change in relative prices and actual goods consumed.

Following Ray (1983), QUAIDS parameterizes $\overline{m}_0(z)$ as $\overline{m}_0(z) = 1 + \rho' z$

Where ρ is a vector of parameters to be estimated.

The expenditure share expenditure equation takes the following form:

$$w_i = \alpha_i + \sum_{j=1}^{k} \gamma_{ij} \ln p_j + (\beta_i + \eta_i' z) \ln \left\{ \frac{m}{\overline{m}_0(z) a(p)} \right\} + \frac{\lambda_i}{b(p) c(p,z)} \left[\ln \left\{ \frac{m}{\overline{m}_0(z) a(p)} \right\} \right]^2 \qquad (4.13)$$

Where $c(p,z) = \prod_{j=1}^{k} p_j^{\eta_j' z}$

The adding-up condition requires that $\sum_{j=1}^{k} \eta_{rj} = 0$ for $r = 1, \ldots, s$.

The uncompensated price elasticity for the commodity group i with respect to changes in the price of commodity good j is:

$$\varepsilon_{ij} = -\delta_{ij} + \frac{1}{w_i} \left(\gamma_{ij} - \left[\beta i + \eta_i' z + \frac{2\lambda_i}{b(p) c(p,z)} \ln \left\{ \frac{m}{\overline{m}_0(z) a(p)} \right\} \right] * \left(\alpha_j + \sum_l \gamma_{jl} \ln pt \right) - \frac{(\beta_j + \eta_j' z) \lambda_i}{b(c) c(p,z)} \left[\ln \left\{ \frac{m}{\overline{m}_0(z) a(p)} \right\} \right]^2 \right)$$

(4.13)

The expenditure (income) elasticity for the good or commodity group i is :

$$\mu_i = 1 + \frac{1}{w_i} \left[\beta_i + \eta_i' z + \frac{2\lambda_i}{b(p) c(p,z)} \ln \left\{ \frac{m}{\overline{m}_0(z) a(p)} \right\} \right] \qquad (4.14)$$

The compensated price elasticities are derived from the Slutsky equation:

$$\varepsilon_{ij}^c = \varepsilon_{ij} + \mu_i w_j$$

All the lowercase Greek letters other than α_0 are the parameters to be estimated. Two demographic variables were finally used in this study, namely area (urban and rural), and household size.

The parameters are estimated by Iterated Feasible Generalized Nonlinear Least-Squares (IFGNLS) which is equivalent to the multivariate normal maximum-likelihood estimator for this class of problem via Stata's '***nlsur***' command as suggested by Poi (2012).

After the presentation of the demand model, it is worth discussing at least two major data issues, namely the price measure, and the treatment of outliers and missing values.

4.2.1.4.2. Data problems

Price measure: unit value

In demand analysis using microeconomic data, when the survey process is not accompanied by a questionnaire on prices as it is usual for developing countries, there are two main sources of price data collection for cross-section analysis: regional price data and household price data (Deaton, 1997). Regional data, when available from the statistical office, can be used for constructing consumer price indexes. However, the main problem with such an approach is that there are few sites where price data can be collected. This can cause inaccurate estimates of prices for some households.

On the other hand, household responses usually provide useful information on price data. Then, the ratio of the household total expenditure divided by the total quantity purchased for each good gives a measurement of price or, more accurately, of unit value. The unit value for a commodity can be seen as the highest acceptable price and thus, a 'subjective price' (Pons, 2011). However, this may be problematic, since unit values are not the same as prices, since unit values reflect both quality and price variations[59] (Cox and Wohlgenant, 1986; Deaton, 1988, 1997). Therefore, a correction was needed, in order to take into account both quality effects and measurement errors when using unit values as proxy of prices. The Deaton (1988) method was widely used in the literature for the linear demand system. However, this method cannot be used in the case of QUAIDS due to its non-linearity (Attanasio et al., 2013). In addition, the assumptions on which this approach is based are strongly rejected by McKelvey (2011). For these reasons, this chapter uses the same method as in Attanasio et al. (2013), for lack of better alternatives. The median unit value of each cluster was used as a measure of the price of a given good for each locality.

[59] For example, in the presence of a change in price or income, a household not only responds by a change in quantity, but also by a change in quality of food expenditure. Also, since quantities can be subject to measurement errors, these errors can be transmitted to the derived unit value.

The treatment of outliers and missing values

When outliers were detected, they have been replaced by the cluster median (obtained in the presence of these values) or the regional median, when the cluster median was null for the product group under consideration, since it can be too costly to drop such observations. In the case where data on expenditure, quantity, or both were missing for some households, the cluster median value or regional median has replaced the missing unit value when the cluster median was null for the product group considered.

4.2.1.5. Definition of variable

Dependent variable: in the analysis of demand, the dependent variables are the budget shares of the 5 food groups as usual in the literature (Ackah and Appleton, 2007; Béké, 2013). The budget shares are the shares of consumption expenditure of each food commodity in total food consumption expenditure under consideration.

Explanatory variables: in this study, we consider two sets of explanatory variables, namely, the price variable and a set of household characteristics and demographics (household size and area dummy[60]).

4.2.2. Results and discussion

4.2.2.1. Description of the variables

An understanding of the differences in household food expenditure patterns across regions and income groups is important to design effective food price policies. In order to look at expenditure patterns for food demand in Cameroon, this sub-section describes statistics for food expenditure, prices, and expenditure shares by area and poverty status.

Table 4.1 shows that, on average, the highest food expenditure is for roots and tubers. Table 4.1 also reports that in rural areas, expenditure on cereals is higher than in urban areas. This can be explained by the fact that cereals are more consumed in rural areas. In the same line, animal products expenditure is higher for non-poor households than for poor households.[61]

[60] The area variable is a dummy variable which takes 1 for urban and 0 otherwise.
[61] A poor household is defined by the NIS (2008) as a household in which the average per adult equivalent consumption does not exceed 269,443 F CFA per year at Yaoundé prices (about 738 F CFA per day equivalent

Table 4.1: Summary statistics for expenditure by area and living standard (in FCFA)

	Area		Poverty status		Entire sample
	urban	rural	poor	non-poor	
Cereals	4919.201	5712.848	5546.770	5233.599	5523.054
Animal products	6357.015	5486.209	4693.121	6218.543	6066.899
Roots and tubers	6601.493	7773.826	7015.113	7174.600	7135.325
Vegetables	2687.294	2720.729	2454.918	2755.335	2757.457

Source: Author's computation from ECAM III.

On average, food prices are higher in urban regions than in rural ones (Table 4.2). This can be explained by the fact that agricultural production mostly takes place in rural areas that provide urban areas with food products.

Table 4.2: Average food prices in urban and rural areas (in FCFA)

	Area		Entire sample
	urban	rural	
Cereals	281.1529	219.3193	252.3947
Animal products	1195.896	1056.202	1056.202
Roots and tubers	197.5873	171.6362	171.6362
Vegetables	459.0365	457.1031	457.1031

Source: Author's computation from ECAM III.

Table 4.3 shows that on average, roots and tubers constitute the largest share of households' total food budget. Poor households spend their food budget more on cereals than on animal products while non-poor households spend rather more on animal products than on cereals. This reflects the fact that maize and rice are staples for most poor households, while fish and meat are considered as luxury goods.

to US$1.5082). This poverty threshold is obtained using adult equivalent consumption as a measure of welfare. Indeed, this measure compared to the total consumption of households and the per capita consumption has the advantage of taking into account both the size and the composition of the household.

<u>Table 4.3 : Average expenditure shares of food commodities by area and poverty status</u>

	Area		Poverty status		Entire sample
	urban	rural	poor	non-poor	
Cereals	.2438614	.2653359	.2823012	.2478251	.253849
Animal products	.298809	.2529891	.2448695	.2844068	.2774986
Roots and tubers	.3232621	.3570203	.3484115	.3369622	.3389627
Vegetables	.1340675	.1246547	.1244177	.1308059	.1296897

Source: Author's computation from ECAM III

4.2.2.2. Demand Results

The expenditure elasticities (Table 4.4) show that, cereals, roots and tubers, and vegetables are normal goods, with elasticities between 0 and 1. Only animal products are luxury goods, with an expenditure elasticity higher than 1. Similar results were found by Béké (2013) for Cote d'Ivoire.

<u>Table 4.4 : Expenditure elasticities</u>

Commodity groups	Expenditure elasticities
Cereals	.9230848
Animal products	1.192594
Roots and tubers	.9961353
Vegetables	.7164125

Source: Author's computation from ECAM III

An increase of 1 per cent in income leads to an increase of 1.19 per cent in the demand for animal products, 0.99 per cent for roots and tubers, 0.71 per cent for fruits and vegetables, and of 0.92 per cent for cereals. Animal products seem therefore to have a more important place in the diet of Cameroonian households. However, the demand for fruits and vegetables is less sensitive to income changes.

Table 4.5 gives estimates by area of the Hicksian elasticities which contain only price effects, contrary to the Mashallian elasticities which contain both income and price effects (see table 4.2 in the appendix). All own-price elasticities (see the diagonal of the matrix in bold) for each commodity group considered satisfied the negativity property. This is consistent with the demand theory and suggests that the relationship between changes in own-price indexes and quantities demanded is in opposite directions. The own-price elasticities suggest inelastic demand for all commodity groups analysed (elasticity absolutely < 1). Except for vegetable and animal products in rural areas, the remaining commodity groups carry positive signs for cross-price elasticity as expected for substitutable products. Cereals, and roots and tubers are identified as substitutes by households.

Table 4.5 : Price elasticity from the QUAIDS model

Compensated/Hicksian elasticity								
Urban					**Rural**			
	CER	ANP	ROT	VEG	CER	ANP	ROT	VEG
CER	**-.9137663**	.4277656	.3293677	.1566330	**-.8922705**	.3821418	.357859	.1522688
ANP	.3739183	**-.7231574**	.3217032	.0275358	.4160866	**-.7931145**	.3787809	-.001753
ROT	.2639336	.2965729	**-.6407257**	.0802191	.2728092	.2653477	**-.6189327**	.0807757
VEG	.3042376	.0582732	.1952205	**-.5577314**	.3242906	-.0040114	.2259223	**-.5462015**

Where CER=Cereal; ANP=Animal product; ROT=Root and tuber; VEG=Vegetable
Source: Author's computation from ECAM III

4.2.2.3. Estimated Impact of Rising Food Prices on Welfare

Empirically, the CV can be seen here as a measure of the total transfer required for compensating households for a change in prices, as a percentage of their initial total food expenditure. The CV is disaggregating by area and poverty status in order to illustrate which groups of households are the most vulnerable to a price change. We utilized the estimated Hicksian elasticities to implement the CV as usual in the literature (Ackah and Appleton, 2007).

Following the CV framework, equations 4.6 and 4.7 are used to estimate the impact of changing food prices on consumer welfare. We simulate the welfare impact of the increase in each commodity group by 10 per cent and 40 per cent in both the short and long run. Indeed, the analysis of food prices variation shows that on average in 2008, food prices have increased the range of 10 per cent for fruits and vegetables and 40 per cent for cereals including imported ones such rice and maize (Medou, 2008).

Tables 4.6 to 4.9 present long-run and short-run welfare effects of food price increases. One should note that in the short run, households cannot respond to price changes and thus, price elasticities are equal to zero.

Table 4.6 : Compensating variation for change in cereals prices

Percentage increase in price	10%		40%	
	Short run	Long run	Short run	Long run
Area				
Urban	2.44%	2.55%	9.75%	11.54%
Rural	2.65%	2.77%	10.61%	12.51%
Poverty status				
Non-poor	2.48%	2.59%	9.91%	11.71%
Poor	2.82%	2.95%	11.29%	13.32%
Poverty status	*Rural*	*Rural*	*Rural*	*Rural*
Non-poor	2.60%	2.72%	10.40%	12.26%
Poor	2.79%	2.91%	11.16%	13.15%
Poverty status	*Urban*	*Urban*	*Urban*	*Urban*
Non-poor	2.40%	2.50%	9.58%	11.33%
Poor	2.92%	3.06%	11.69%	13.82%
Entire sample	*2.61%*	*2.73%*	*10.43%*	*12.32%*

Source: Author's computation from ECAM III

Table 4.7 : Compensating variation for change in animal product prices

Percentage increase in price	10%		40%	
	Short run	Long run	Short run	Long run
Area				
Urban	2.99%	3.10%	11.95%	13.68%
Rural	2.53%	2.63%	10.12%	11.72%
Poverty status				
Non-poor	2.84%	2.95%	11.38%	13.08%
Poor	2.45%	2.54%	9.79%	11.31%
Poverty status	*Rural*	*Rural*	*Rural*	*Rural*
Non-poor	2.58%	2.68%	10.33%	11.97%
Poor	2.39%	2.49%	9.58%	11.10%
Poverty status	*Urban*	*Urban*	*Urban*	*Urban*
Non-poor	3.02%	3.13%	12.09%	13.84%
Poor	2.61%	2.70%	10.43%	11.94%
Entire sample	*2.78%*	*2.89%*	*11.10%*	*12.77%*

Source: Author's computation from ECAM

Table 4.8 : Compensating variation for change in root and tuber prices

Percentage increase in price	10%		40%	
	Short run	Long run	Short run	Long run
Area				
Urban	3.23%	3.34%	12.93%	14.59%
Rural	3.57%	3.68%	14.28%	16.05%
Poverty status				
Non-poor	3.37%	3.48%	13.48%	15.18%
Poor	3.48%	3.59%	13.94%	15.68%
Poverty status	*Rural*	*Rural*	*Rural*	*Rural*
Non-poor	3.55%	3.66%	14.20%	15.96%
Poor	3.62%	3.73%	14.48%	16.28%
Poverty status	*Urban*	*Urban*	*Urban*	*Urban*
Non-poor	3.25%	3.35%	12.99%	14.65%
Poor	3.08%	3.18%	12.32%	13.90%
Entire sample	*3.31%*	*3.41%*	*13.56%*	*15.27%*

Source: Author's computation from ECAMIII

Table 4.9: Compensating variation for change in vegetable prices

Percentage increase in price	10%		40%	
	Short run	Long run	Short run	Long run
Area				
Urban	1.34%	1.38%	5.36%	5.96%
Rural	1.25%	1.28%	4.99%	5.53%
Poverty status				
Non-poor	1.31%	1.34%	5.23%	5.81%
Poor	1.24%	1.28%	4.98%	5.52%
Poverty status	*Rural*	*Rural*	*Rural*	*Rural*
Non-poor	1.27%	1.30%	5.07%	5.62%
Poor	1.19%	1.23%	4.78%	5.30%
Poverty status	*Urban*	*Urban*	*Urban*	*Urban*
Non-poor	1.34%	1.37%	5.35%	5.94%
Poor	1.39%	1.43%	5.56%	6.18%
Entire sample	*1.30%*	*1.34%*	*5.19%*	*5.76%*

Source: Author's computation from ECAM III

Results show that, on average, for each group of households there is a welfare loss due to the increase in food prices. However, results reveal some heterogeneity in the welfare impact of food price volatility. Poor households in both urban and rural areas are the most affected as suggested in the literature (Ackah and Appleton, 2007; Attanasio et al., 2013; Badolo and Traore, 2012). For example, on average poor households need to be reimbursed by about 15.68 per cent of their expenditure as the result of a 40 per cent change in the price of roots and tubers. We observed also that the highest welfare losses are due to increases in the price of roots and tubers. This is as expected since households spend more of their food budget on those commodities.

Poor urban households were more affected by an increase in cereal and vegetable prices than poor rural ones. This can be explained by the fact that in rural areas, poor households can produce some of the agricultural products they consume, while poor urban households may not. On the other hand, it is the welfare of poor rural households that is the most reduced due to an increase in the price of roots and tubers. Similar results were found by Leyaro (2009) and Ackah and Appleton (2007). An increase in the price of animal products mostly affects the non-poor households in urban areas. This is in line with the fact that those households spend more of their total food budget on animal products.

The tables in this chapter also show that the welfare effect of food price increases depends on the extent of the increases. Thus, there is an expected positive relationship between price increases and household welfare losses. They also show that the welfare effect in the long run was greater than in the short run.

Conclusion

This chapter aimed at studying the impact on Cameroonian consumer welfare of food price rises. Using the QUAIDS model, we estimated expenditure, own-price, and cross-price elasticities for four main components of most household food consumption baskets, namely, cereals, roots and tubers, animal products, and vegetables. Results showed that demand for food commodities in Cameroon is price sensitive. In addition, poor households whatever their location (urban or rural) are, on average, the most affected by a hike in prices; even though, welfare losses resulting from food price rises are heterogeneous among consumers. Indeed, while an increase in the price of roots and tubers has an impact on all categories of households, an increase in the price of cereals affects more the poor in general, and more especially the urban poor. An increase in the price of animal products has a higher impact on the urban non-poor. Finally, the effect of an increase in the price of vegetables is relatively small in comparison with the impact of other groups of commodities. Based on our results, specific recommendations can be suggested to policy-makers. The main one is to support programs aiming at developing local production of roots and tubers as well as cereals in order to provide food for all the population, and especially the poor. Thus, in the specific case of Cameroon, a product-oriented policy for roots and tubers as well as a population–oriented policy towards the poor for cereals are the best options for reducing the effects of food price rises on consumer welfare.

The approach developed in this chapter is really important for supporting policy-makers in the design of food policies aiming at fighting against hunger and poverty in developing countries. Indeed, without a comprehensive understanding of which category of households based on their location (urban or rural) and their poverty status (the poor and the non-poor) is affected by changes in food prices and how sensitive they are to such changes, it will be difficult for policy makers to implement specific and efficient policies. Similar studies for other developing countries are of importance, even though data collection remains a major issue. For future research, it could be interesting to extent our study by differentiating between households that are only consumers from those that are both producers and consumers of food commodities. Indeed, it can be expected that the impact of food price rises on the welfare of these households will be different.

CONCLUSION TO THE SECOND PART

The aim of this second part was to analyse the consequences of food price volatility in Cameroon, for both producers and consumers. On the one hand, the supply response for the major staple crops grown by agricultural households, namely maize, groundnut, and cassava has been analysed using the ARDL bounds testing procedure. The results reveal that farmers in Cameroon respond to food price volatility by increasing the area under cultivation, and reducing investments in improving yield. On the other hand, using the price elasticities provided by the QUAIDS model within the compensating variation framework, the welfare effect of food price volatility has been analysed. Demand for food commodities has been found to be price sensitive and the poor are the most affected, on average by the price volatility.

In term of policy making, information provided by the elasticities of supply are important to boost agricultural production. Therefore, there is a need to control for food price volatility in order to improve yield and this can lead to reduce food insecurity, stabilize producers' income, and increase growth. Also, information provided by the analysis of the welfare impact of food price volatility is important for the efficiency of policies that aims at reducing poverty and fight against hunger.

GENERAL CONCLUSION

The question of the volatility of food price has been at the heart of debate since the world food crisis of 2007-2008 that led to urban riots in about forty developing countries including Cameroon. Since the world food market is characterized by high volatility, in such a situation developing countries which largely depend on food importations to feed their population will dramatically be affected. Indeed, the food price volatility deteriorates the balance of payments for the government, for both net importers and net exporters of agricultural commodities and thus, affects their investment capacity and ultimately growth. In addition, poor farmers are exposed to the poverty trap, they cannot make optimal decisions about production and the incentive to invest in production is reduced.

Food price volatility refers to the situation where price fluctuations are high, rapid and sudden over time. To manage the problem of food price volatility at both the macro and micro levels, policy makers have to address the issue of its causes, since the solutions for this problem depends largely on the nature and type of causes. Additionally, the main problem of food price volatility is the variability and then, instability of incomes of both producers and consumers at the micro level. Therefore, the main objective of this thesis was to analyze food price volatility in Cameroon. Specifically, the determinants, the transmission and the consequences of food price volatility for both producers and consumers in Cameroon were analyzed. The thesis was based on four distinct chapters: (i) Determinants of food price volatility in Cameroon; (ii) Transmission of food price volatility in Cameroon; (iii) Supply response for food price volatility in Cameroon; and (iv) Impact of food price volatility on household welfare in Cameroon. The first two chapters use monthly time series data from the world commodity prices of the IMF and the National Institute of Statistics in Cameroon. The third chapter uses data from FAOSTAT database, and the last chapter used cross-sectional data from the third Cameroonian Household Consumption Surveys carried out in 2007 by the National Institute of Statistics in Cameroon.

Results show that food price volatile in Cameroon is determined mostly by local factors such as the volatility of other agricultural products, and not imported from international markets. This suggests that, the linkages between the international and Cameroonian markets are low for cereals. This last result is confirmed in the case of rice, which is the most imported food crop in Cameroon, in term of price volatility transmission. Moreover, at the national level, significant links in term of volatility transmission were found only for two pairs of markets out of six, namely the pairs Douala-Garoua and Bamenda-Bafoussam. For the remaining pairs of markets, there is no evidence of linkages in terms of volatility transmission. The results from the supply response analysis tends to support the argument that farmers in developing countries are not responsive to economic incentives such as prices in short-run. Further, it seems that producers respond to price volatility by increasing the area under cultivation, and reducing investments in improving yield. Finally, it appears that demand for food commodities in Cameroon is price sensitive. Poor households are the most affected by food price volatility and the welfare losses from food price volatility depend on the extent of any price hike.

In term of policy recommendations, it may be interesting to implement more specific development projects based on subsistence crops such as local cereals, roots and tubers, than traditional cash crops (e.g. cocoa and coffee) in Cameroon and find out ways to improve the efficiency of existing development programs on the agricultural sector. Moreover, there is a need to update existing data on commodity prices and collect more detailed price series on consumer and producer prices, which can be really useful for a more detailed analysis and information regarding price transmission among stakeholders. To deal with food price volatility transmission, government should encourage the local production and improve transport infrastructure in order to supply other markets with local rice. Furthermore, it seems necessary to collect high frequency time series data (daily, weekly,… data), and data about infrastructure, retailer market power in order to appropriately address similar issues as in this study and provide more specific policy recommendations. To improve producer responsiveness to economic incentive and fight against price volatility special attention must be given to improve the local structural parameters such as markets structure, retailer market power, infrastructure, agricultural research and extension, etc. Finally, to design policies that aim to fight against food insecurity, poverty and hunger, understanding of how different types of households in different areas are affected by changes in food prices and how sensitive they may be useful. It is worth noting that the aforementioned recommendations are based on the observation of past price volatility behaviour and identification of statistical significant relationship, and not on the forecasting of the future.

The main limitation of this study was the data. Therefore, it may be interesting to collect high frequencies time series data (daily, weekly), up to date data and data about infrastructure, retailer market, and so on, in order to compared results and provide more specific policy recommendations. For future research, it would be interesting to analyse at regional level how producers respond to economic incentives and risk, and investigate how households are affected by changes in food prices using information on both producers and consumers.

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APPENDICES:

Appendix figure 1.1: Sample markets

Appendix Table 1.1: Variables notation

Commodity indication		Market indication	
Notation	**Explanation**	**Notation**	**Explanation**
RMA	real price of maize	YDE	Yaoundé market
RPLA	real price of plantain	DLA	Douala market
RCOCO	real price of cocoyam	BAF	Bafoussam market
RCA	real price of cassava	BAM	Bamenda market
RBR	real price of bread	GAR	Garoua market
RRI	real price of rice		
RMIL	real price of millet		

Appendix Table 1.2 : Seasonality tests for monthly real price series

	F-tests	Q2 parameter	Conclusion
RMA__YDE	14.541***	0.86	Seasonality present at the 0.1 per cent level
RCOCO__YDE	7.924***	0.86	Seasonality present at the 0.1 per cent level
RCA_YDE	1.023	1.46	No evidence of stable seasonality
RBR_YDE	3.755***	1.25	Contradiction in the results
RPLA_YDE	10.157***	0.74	Seasonality present at the 0.1 per cent level
RRI__YDE	0.576	1.67	No evidence of stable seasonality
RBR_DLA	2.555***	1.59	Contradiction in the results
RCA_DLA	4.617***	1.11	Contradiction in the results
RMA_DLA	15.529***	0.67	Seasonality present at the 0.1 per cent level
RCOCO__DLA	3.025***	1.15	Contradiction in the results
RPLA_DLA	9.542***	0.83	Seasonality present at the 0.1 per cent level
RRI__DLA	1.437	1.52	No evidence of stable seasonality
RBR_BAF	3.925***	1.18	Contradiction in the results
RCA_BAF	1.287	1.287	Contradiction in the results
RMA_ BAF	4.533 ***	0.91	Seasonality present at the 0.1 per cent level
RCOCO__ BAF	6.278 ***	1.05	Seasonality present at the 0.1 per cent level
RPLA_ BAF	5.902 ***	0.99	Seasonality present at the 0.1 per cent level
RRI__ BAF	2.723	1.27	No evidence of stable seasonality
RBR_BAM	0.827	1.67	No evidence of stable seasonality
RCAwf_BAM	1.840	1.88	No evidence of stable seasonality
RMA_ BAM	8.057***	0.89	Seasonality present at the 0.1 per cent level
RCOCO__ BAM	7.192***	1.18	Contradiction in the results
RPLA_ BAM	7.443***	1.12	Contradiction in the results
RRI__ BAM	0.606	1.68	No evidence of stable seasonality
RBR_GAR	0.694	1.55	No evidence of stable seasonality
RMIL_ GAR	0.956	1.50	No evidence of stable seasonality
RMA_ GAR	8.638 ***	0.89	Seasonality present at the 0.1 per cent level
RCA__ GAR	5.954 ***	1.07	Contradiction in the results
RRI__ GAR	1.722	1.40	No evidence of stable seasonality

Appendix Table 1.3 : Properties of real price series

Commodity	Market	Integration order
Bread	Yaoundé	I(1)
	Douala	I(1)
	Bafoussam	I(0)
	Garoua	I(0)
	Bamenda	I(0)
Cassava	Yaoundé	I(0)
	Douala	I(0)
	Bafoussam	I(0)
	Garoua	I(0)
	Bamenda	I(0)
Maize	Yaoundé	I(1)
	Douala	I(0)
	Bafoussam	I(0)
	Garoua	I(0)
	Bamenda	I(0)
Cocoyam	Yaoundé	I(0)
	Douala	I(0)
	Bafoussam	I(0)
	Bamenda	I(0)
Plantain	Yaoundé	I(0)
	Douala	I(0)
	Bafoussam	I(0)
	Bamenda	I(0)
Rice	Yaoundé	I(1)
	Douala	I(1)
	Bafoussam	I(0)
	Garoua	I(0)
	Bamenda	I(0)
Millet	Garoua	I(0)

Appendix Table 1.4 : Unit root test for real price series in Douala market

	No Break			One Break	
	ADF	**PP**	**KPSS**	**ZA**	**Break date**
RBR_DLA **D(RBR_DLA)**	-2.978879 [3] -17.91423 ***[1]	-3.130537 [3] -21.72637***[1]	0.303620***[3] 0.234863 [1]	-5.239 -9.849***	n.a 1997m4
RCA_DLA	-4.843796***[2]	-7.108110***[2]	0.103872[3]	-5.122**	2007m3
RMA_DLA_SA	-4.676574***[2]	-4.676574***[2]	0.053632[3]	-4.557	n.a
RCOCO_DLA	-7.018376***[3]	-12.10757***[3]	0.110489[3]	-5.207**	2007m12
RPLA__DLA_SA	-4.806266***[2]	-5.241852***[2]	0.178192[3]	-5.869***	2004m12
RRI__DLA	-2.830844*[2] -4.656443***[1]	-6.543580***[3]	0.146000**[3] 0.160412[2]	-12.139***	1997m2

Appendix Table 1.5 : Unit root tests for real price series in Bafoussam

	No Break			One Break	
	ADF	**PP**	**KPSS**	**ZA**	**Break date**
RBR_BAF	-4.193014***[2]	-3.985201***[2]	0.230171[2]	-4.258	n.a
RCA_BAF	-4.394379***[2]	-5.672395***[2]	0.243574[2]	-6.008***	2001m4
RCOCO__BAF	-7.301372***[3]	-7.398286***[3]	-7.398286[3]	-6.568***	2000m5
RMA__BAF_SA	-3.998820***[2]	-5.154665***[2]	0.166069[3]	-5.862***	1996m9
RPLA_BAF_SA	-5.403172***[3]	-5.403172***[3]	0.086277[3]	-5.643***	2001m3
RRI__BAF	-3.257350**[2]	-6.773265***[3]	**0.254261***[3]**	-5.273**	2008m5

Appendix Table 1.6 : Unit root tests for real price series in Bamenda market

	No Break			One Break	
	ADF	**PP**	**KPSS**	**ZA**	**Break date**
RBR_BAM	-7.226384***[2]	-7.560513***[2]	0.215867[3]	-4.079	n.a
RCAWF_BAM	-10.93895***[2]	-11.49388***[2]	0.081629[3]	-7.262***	2000m12
RCOCO_BAM	-8.847158***[3]	-9.050104***[3]	0.149528[3]	-7.445***	2000m8
RMA__BAM_SA	-4.065877***[2]	-5.741284***[2]	0.116375[2]	-4.039	n.a
RPLA__BAM	-5.542077***[3]	-8.288546***[3]	0.064013[3]	-6.307***	2005m1
RRI___BAM	-4.219632***[2]	-6.040958***[2]	0.248664[3]	-4.116	n.a

Appendix Table 1.7 : Unit root tests for real price series in Garoua

	No Break			One Break	
	ADF	**PP**	**KPSS**	**ZA**	**Break date**
RBR_GAR	-4.265289***[2]	-3.972963***[2]	**0.243462***[3]**	-5.776**	1996m11
RCA__GAR	-6.535994***[2]	-6.395753***[2]	-6.395753[2]	5.632**	2001m2
RMA__GAR_SA	-2.939043**[2]	-4.812406***[3]	0.116521[2]	-3.918	n.a
RMIL_GAR	-4.012718***[2]	-4.911293***[2]	0.075320[2]	-4.540	n.a
RRI___GAR	-3.011943**[2]	-5.250088***[2]	**0.232072***[3]**	-6.087***	2001m8

Appendix Table 1.8 : Unit root tests for return price series

	No Break			One Break	
	ADF	**PP**	**KPSS**	**ZA**	**Break date**
R_LN_E	-9.750514***	-10.25360***	0.395555	-10.359***	2000m11
R_RCRU	-11.38486***	-11.36879***	0.053437	-11.725***	2008m6
R_RWH	-11.53782***	-11.40390***	0.178871	-10.763***	2008m4
R_RRI	-10.40171***	-9.337870***	0.226639	-9.501***	2008m2
R_RBR_BAF	-12.40620***	-17.23752***	0.427189	-10.735***	2007m9
R_RBR_BAM	-7.581843***	-33.54415***	0.373010	-11.544***	2008m6
R_RBR_DLA	-9.230766***	-21.72637***	0.234863	-9.849***	1997m4
R_RBR_GAR	-12.14258***	-20.51016***	0.143909	-12.678***	1997m3
R_RBR_YDE	-17.35091***	-17.58758***	0.157986	-18.183***	1996m9
R_RCA__GAR	-11.60646***	-36.50427***	0.154445	-11.668***	2002m6
R_RCA_BAF	-21.54772***	-26.70142***	0.105377	-8.817***	2008m3
R_RCA_DLA	-13.83882***	-30.33306***	0.142863	-11.092***	1997m3
R_RCA_YDE	-15.63808***	-15.83694***	0.043416	-12.433***	1997m9
R_RCATW_BAM	-11.60139***	-37.11065***	0.177496	-13.867***	1998m2
R_RCOCO__BAF	-15.27772***	-26.67386***	0.070022	-15.234***	1999m9
R_RCOCO__BAM	-13.95038***	-32.62845***	0.099415	-11.428***	1997m7
R_RCOCO__DLA	-15.49369***	-51.11109***	0.105823	-13.864***	2007m10
R_RCOCO__YDE_SA	-15.05370***	-15.02969***	0.035807	-7.273***	1999m7
R_RMA__BAF_SA	-19.67934***	-20.60423***	0.039595	-19.793***	1997m8
R_RMA__BAM_SA	-11.87839***	-21.13188***	0.068685	-12.032***	1997m10
R_RMA__DLA_SA	-16.93859***	-17.59512***	0.036450	-16.915***	1997m6
R_RMA__GAR_SA	-14.00641***	-21.14939***	0.030166	-14.153***	2004m8
R_RMA__YDE_SA	-22.07073***	-22.07073***	0.080549	-22.124***	1996m8
R_RPLA__BAM	-21.83768***	-36.67342***	0.309845	-9.389***	1997m9
R_RPLA__DLA_SA	-13.68822***	-24.55653***	0.087104	-9.380***	1996m11
R_RPLA_BAF_SA	-13.33480***	-21.00482***	0.093661	-10.762***	2002m3
R_RPLA_YDE_SA	-15.81675***	-15.78668***	0.031688	-6.377***	1999m6
R_RRI___BAM	-13.51766***	-22.70768***	0.027362	-13.743***	2003m12
R_RRI___GAR	-9.916107***	-41.43964***	0.137678	-10.071***	1996m11
R_RRI__BAF	-24.81336***	-31.68503***	0.065335	-24.801***	2007m1
R_RRI__YDE	-11.66512***	-16.19777***	0.059040	-8.073***	2004m6
R_RRI_DLA	-11.58343***	-51.16857***	0.160412	-12.139***	1997m2
R_RMIL_GAR	-18.10878***	-18.52272***	0.027287	-12.765***	2000m4

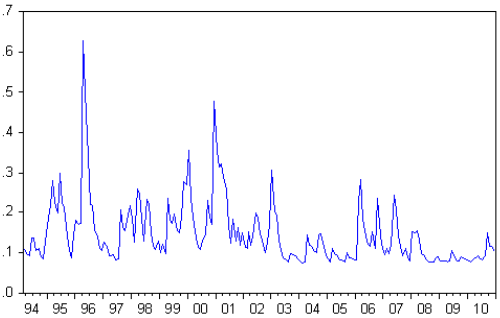
Akaike information criterion was used to determine the optimal lag for ADF test. For ADF, PP and KPSS tests results suggest that only the model [1] none is accepted for all return series. ***denote statistical significance at 1% indicating that the null hypothesis can be rejected. For ZA test, the critical value in the case of model Care: -5.57 for 1% significance level and -5.08 for 5% significance level.

Appendix Table 1.9 : Properties of return price series

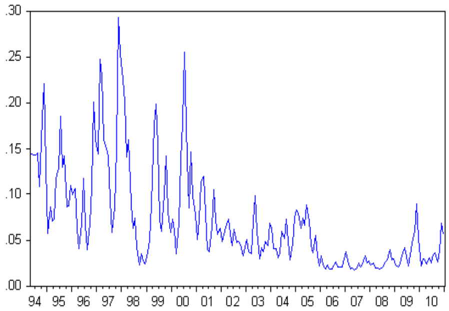
Commodity	Price series	I(d)	ARMA process	ARCH LM test	Process of series
Bread	R_RBR_BAF	I(0)	ARMA(4,0)	Homoskedasticity	ARMA(4,0)
	R_RBR_BAM	I(0)	ARMA(0,2)	Heteroskedasticity	GARCH(0,1)
	R_RBR_DLA	I(0)	ARMA(1,1)	Homoskedasticity	ARMA(1,1)
	R_RBR_GAR	I(0)	ARMA(3,0)	Homoskedasticity	ARMA(3,0)
	R_RBR_YDE	I(0)	ARMA(1,0)	Homoskedasticity	ARMA(1,0)
Cassava	R_RCA__GAR	I(0)	ARMA(1,1)	Homoskedasticity	ARMA(1,1)
	R_RCA_BAF	I(0)	ARMA(1,1)	Heteroskedasticity	GARCH(1,0)
	R_RCA_DLA	I(0)	ARMA(1,1)	Homoskedasticity	ARMA(1,1)
	R_RCA_YDE	I(0)	ARMA(1,1)	Heteroskedasticity	GARCH(1,1)
	R_RCAWF_BAM	I(0)	ARMA(1,1)	Homoskedasticity	ARMA(1,1)
Cocoyam	R_RCOCO__BAF	I(0)	ARMA(1,2)*	Heteroskedasticity	GARCH(1,1)
	R_RCOCO__BAM	I(0)	ARMA(3,1)	Heteroskedasticity	GARCH(1,0)
	R_RCOCO__DLA	I(0)	ARMA(2,1)	Homoskedasticity	ARMA(2,1)
	R_RCOCO__YDE_SA	I(0)	ARMA(3,3)	Heteroskedasticity	GARCH(3,0)
Maize	R_RMA__BAF_SA	I(0)	ARMA(1,1)	Heteroskedasticity	GARCH(1,1)
	R_RMA__BAM_SA	I(0)	ARMA(0,1)	Heteroskedasticity	GARCH(0,1)
	R_RMA__DLA_SA	I(0)	ARMA(2,1)	Homoskedasticity	ARMA(2,1)
	R_RMA__GAR_SA	I(0)	ARMA(0,1)	Heteroskedasticity	GARCH(1,1)
	R_RMA__YDE_SA	I(0)	ARMA(1,0)	Heteroskedasticity	GARCH(1,1)
Plantain	R_RPLA__BAM	I(0)	ARMA(2,0)	Homoskedasticity	ARMA(2,0)
	R_RPLA__DLA_SA	I(0)	ARMA(2,1)	Homoskedasticity	ARMA(2,1)
	R_RPLA_BAF_SA	I(0)	ARMA(4,0)	Homoskedasticity	ARMA(4,0)
	R_RPLA_YDE_SA	I(0)	ARMA(4,0)	Homoskedasticity	ARMA(4,0)
Rice	R_RRI___BAM	I(0)	ARMA(4,2)	Heteroskedasticity	GARCH(1,0)
	R_RRI___GAR	I(0)	ARMA(1,4)	Heteroskedasticity	GARCH(1,1)
	R_RRI__BAF	I(0)	ARMA(2,1)	Heteroskedasticity	GARCH(1,1)
	R_RRI__DLA	I(0)	ARMA(3,4)	Heteroskedasticity	GARCH(2,0)
	R_RRI__YDE	I(0)	ARMA(2,1)	Homoskedasticity	ARMA(2,1)
Others	R_RMIL_GAR	I(0)	ARMA(0,1)	Heteroskedasticity	GARCH(1,1)

ARMA(1,2)* correspond to the ARMA(1,2) model where the first component of the moving average part is remove to eliminate serial correlation.

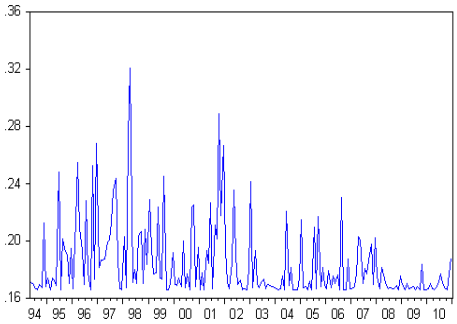
Appendix Table 1.10 : Evolution of conditional standard deviation for GARCH process



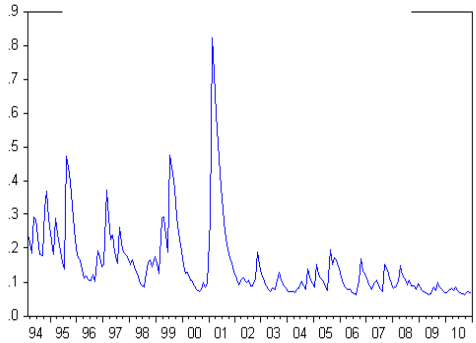
R_RCOCO__BAF



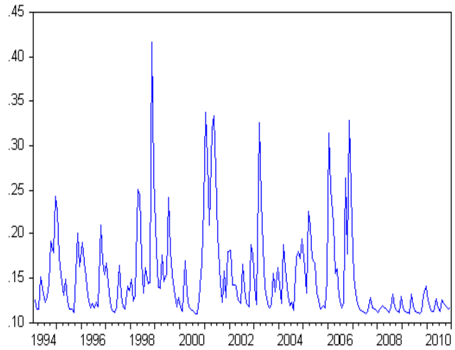
R_RCOCO__YDE_



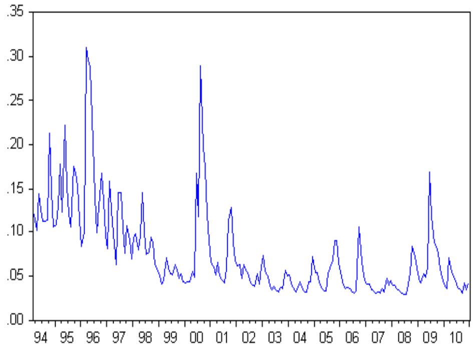
R_RCOCO__BAM



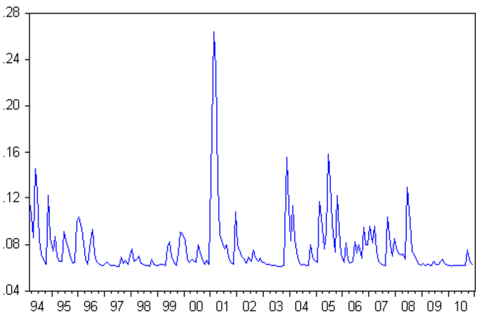
R_RMA__BAF_SA



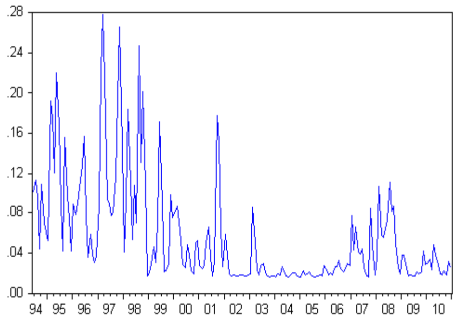
R_RMA__GAR_SA



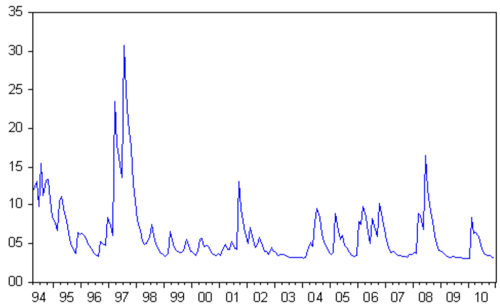
R_RMA__YDE_SA



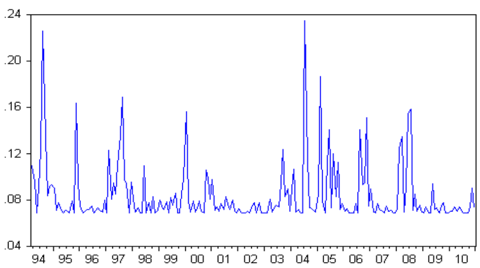
R_RRI__BAF



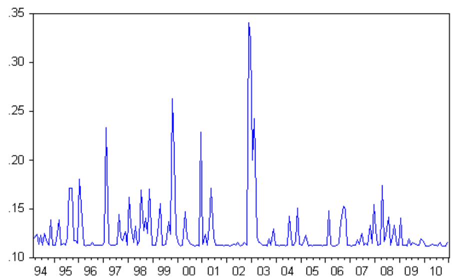
R_RRI_DLA



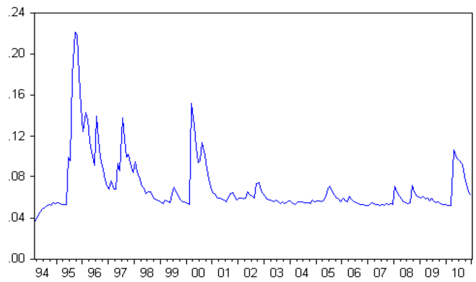
R_RRI___GAR



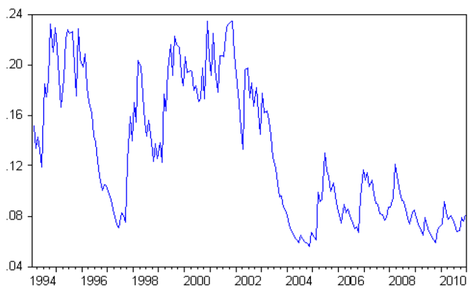
R_RRI___BAM



R_RCA_BAF



R_RCA_YDE



R_RMIL_GAR

Appendix Table 2.1: Seasonality test for monthly rice real price

	F-tests	Q2 parameter	Conclusion
RIRICE	4.571***	0.83	Seasonality present at the 0.1 per cent level, then we will used seasonal adjusted data
RRI_YDE	0.576	1.67	No evidence of stable seasonality at the 0.1 per cent, then we will used the series without adjustment
RRI__DLA	1.437	1.52	No evidence of stable seasonality at the 0.1 per cent, then we will used the series without adjustment
RRI__ BAF	2.723	1.27	No evidence of stable seasonality at the 0.1 per cent, then we will used the series without adjustment
RRI__ BAM	0.606	1.68	No evidence of stable seasonality at the 0.1 per cent, then we will used the series without adjustment
RRI__ GAR	1.722	1.40	No evidence of stable seasonality at the 0.1 per cent, then we will used the series without adjustment

RIRICE is the log of international price of rice in local currency (real price); RRI_YDE is the log of real price of rice in Yaoundé; RRI_DLA is the log of real price of rice in Douala; RRI_BAF is the log of real price of rice in Bafoussam; RRI_BAM is the log of real price of rice in Bamenda; RRI_GAR is the log of real price of rice in Garoua.
*** Significant at 1% ; ** Significant at 5%.

Appendix Table 2.2 : Correlation between rice return series

Correlation Probability	RIRICE_SA	RRI__YDE	RRI_DLA	RRI___BAM	RRI__BAF	RRI___GAR
RIRICE_SA	1.000000					

RRI__YDE	0.099677	1.000000				
	0.1561	-----------				
RRI_DLA	-0.229578	0.474604	1.000000			
	0.0010	0.0000	-----------			
RRI___BAM	0.100291	0.601019	0.474348	1.000000		
	0.1535	0.0000	0.0000	-----------		
RRI__BAF	-0.250713	0.581578	0.612495	0.604101	1.000000	
	0.0003	0.0000	0.0000	0.0000	-----------	
RRI___GAR	-0.045283	0.401141	0.380323	0.567430	0.475722	1.000000
	0.5201	0.0000	0.0000	0.0000	0.0000	-----------

Appendix Table 3.1 : Descriptive statistics of the variables used in the analysis

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
LAREA_CAS	ha	11.94	0.37	11.24	12.82
LAREA_GNT	ha	12.61	0.21	12.14	13.13
LAREA_MZE	ha	12.95	0.41	12.13	13.83
LYIELD_CAS	tonnes/ha	2.22	0.41	1.68	2.79
LYIELD_GNT	tonnes/ha	-0.49	0.58	-1.45	0.55
LYIELD_MZE	tonnes/ha	0.34	0.40	-0.29	0.95
LPRICE_CAS	XAF per ton	10.37	0.98	8.29	12.24
LPRICE_GNT	XAF per ton	11.87	0.87	10.16	12.93
LPRICE_MZE	XAF per ton	11.09	0.80	9.47	12.27
LVOL_CAS		-1.91	0.44	-2.90	-0.92
LVOL_GNT		-2.08	0.55	-3.56	-1.13
LVOL_MZE		-2.079	0.53	-3.38	-1.15
LRAINFALL	mm	4.89	0.06	4.71	5.02

Notes: L=log; VOL=volatility; CAS=cassava; GNT=groundnuts; MZE=maize; XAF (CFA Franc) is the local currency unit of Cameroon

Appendix Table 3.2 : ARDL estimations for cassava

	Area equation ARDL(4, 4, 2, 3, 3, 4)		Yield equation ARDL(4, 4, 2, 2, 4, 4)	
	coefficients	**t-statistics**	**coefficients**	**t-statistics**
Y_CAS(-1)	0.0562	0.2644	0.2387	1.0043
Y_CAS(-2)	-0.1588	-0.7742	-0.1872	-0.8068
Y_CAS(-3)	-0.0871	-0.4353	-0.0119	-0.0563
Y_CAS(-4)	-0.8361***	-4.0325	-0.6098**	-2.8596
LPRICE_CAS	-0.4085	-1.4608	0.7028*	1.7863
LPRICE_CAS(-1)	-0.2499	-0.5087	-0.2630	-0.5001
LPRICE_CAS(-2)	-1.4478***	-3.0254	1.4087**	2.1942
LPRICE_CAS(-3)	-0.8985	-1.5174	0.1960	0.2718
LPRICE_CAS(-4)	1.4944***	3.2569	-1.1057*	-2.0496
LPRICE_GNT	-0.3407	-1.3602	0.1032	0.3247
LPRICE_GNT(-1)	-1.3202***	-4.1552	1.1943***	3.4684
LPRICE_GNT(-2)	-1.3348***	-3.3595	0.9588**	2.6513
LPRICE_MZE	0.9689***	3.8056	-0.7744**	-2.7550
LPRICE_MZE(-1)	0.9792**	2.9354	-0.8355**	-2.7338
LPRICE_MZE(-2)	1.5030***	3.7555	-1.2085**	-2.9154
LPRICE_MZE(-3)	0.5494*	1.7828	---------	---------
LVOL_CAS	0.3107*	2.0231	-0.3340*	-1.9729
LVOL_CAS(-1)	-0.2746	-1.4962	0.3603	1.7687
LVOL_CAS(-2)	0.4142**	2.4262	-0.4219*	-1.8203
LVOL_CAS(-3)	0.0660	0.5265	0.0896	0.3341
LVOL_CAS(-4)	---------	---------	-0.2658	-1.4652
LRAINFALL	0.4902	0.6695	-0.8609	-1.1713
LRAINFALL(-1)	-1.3569	-1.2901	0.0923	0.1017
LRAINFALL(-2)	-1.3901	-1.3894	-0.4339	-0.6352
LRAINFALL(-3)	-1.3162	-1.6001	-0.2245	-0.3070
LRAINFALL(-4)	0.2361	0.4669	-1.1641*	-1.9289
C	46.125*	1.9077	9.9870	0.7403
T	0.0984**	2.9923	-0.0159	-0.9584
	Diagnostic test statistics			
Adjusted R-squared	0.93		0.90	
F-statistic [p-value]	22.28[0.00]		14.49[0.00]	
Serial Correlation LM Test [p-value]	0.38[0.69]		0.62[0.55]	
Heteroskedasticity Test [p-value]	1.40[0.26]		0.57[0.88	

*Note: (i) Y is the log of the dependent variable (area or yield); (ii) Serial Correlation LM Test: Breusch-Godfrey; (iii) Heteroskedasticity Test: Breusch-Pagan-Godfrey. (iv) *** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

Appendix Table 3.3: ARDL estimations for groundnuts

	Area equation ARDL(4, 3, 4, 0, 0, 0)		Yield equation ARDL(2, 3, 2, 2, 1, 4)	
	coefficients	**t-statistics**	**coefficients**	**t-statistics**
Y(-1)	0.3849**	2.5197	0.1569	0.8160
Y(-2)	0.0421	0.2466	-0.2820	-1.4417
Y(-3)	-0.3099*	-1.8669	--------	--------
Y(-4)	0.2074	1.2918	--------	--------
LPRICE_CAS	-0.0306	-0.1491	0.2301	0.5132
LPRICE_CAS(-1)	1.0704***	3.0838	-1.0504	-1.3883
LPRICE_CAS(-2)	-0.9945***	-2.8488	-0.2539	-0.2996
LPRICE_CAS(-3)	0.8164***	3.1476	-1.2224*	-1.9442
LPRICE_GNT	0.1350	0.6082	-0.0966	-0.1716
LPRICE_GNT(-1)	-0.2106	-1.1371	-0.7762	-1.3761
LPRICE_GNT(-2)	-0.3284	-1.5209	-1.5110**	-2.2335
LPRICE_GNT(-3)	0.1682	0.8319	---------	---------
LPRICE_GNT(-4)	-0.4230**	-2.4471	---------	---------
LPRICE_MZE	0.0603	0.3199	0.9023*	1.8175
LPRICE_MZE(-1)	---------	-------	0.1085	0.2016
LPRICE_MZE(-2)	---------	-------	1.4566**	2.7298
LVOL_GNT	0.0024	0.0480	-0.308**5	-2.2645
LVOL_CAS(-1)	---------	---------	-0.2230	-1.1931
LRAINFALL	1.0197**	2.1395	-1.5581	-1.3259
LRAINFALL(-1)	--------	--------	-3.1547**	-2.5856
LRAINFALL(-2)	--------	--------	-3.2832**	-2.6428
LRAINFALL(-3)	--------	--------	-2.6502**	-2.4176
LRAINFALL(-4)	--------	--------	-2.2666**	-2.5331
C	2.1780	0.6234	81.837***	3.6234
T	-0.0179**	-2.3569	0.1727***	4.9110
		Diagnostic test statistics		
Adjusted R-squared	0.64		0.84	
F-statistic [p-value]	5.49[0.00]		12.05[0.00]	
Serial Correlation LM Test [p-value]	1.17[0.32]		1.22[0.31]	
Heteroskedasticity Test [p-value]	1.13[0.37]		0.62[0.84]	

Appendix Table 3.4: ARDL estimations for maize

	Area equation ARDL(2, 1, 2, 0, 2)		Yield equation ARDL(3, 1, 2, 1, 2)	
	coefficients	**t-statistics**	**coefficients**	**t-statistics**
Y(-1)	0.7339***	4.1701	0.7235***	4.8477
Y(-2)	-0.2300	-1.4971	-0.0711	-0.4015
Y(-3)	---------	---------	-0.2360*	-1.7186
LPRICE_CAS	0.0222	0.1137	-0.0169	-0.1036
LPRICE_GNT	-0.1221	-0.4576	0.0104	0.0448
LPRICE_GNT(-1)	-0.4332*	-1.7874	0.0893	0.4550
LPRICE_GNT(-2)	-0.5748**	-2.6544	0.4704**	2.5275
LPRICE_MZE	0.0958	0.4258	0.4242**	2.2796
LPRICE_MZE(-1)	0.6281**	2.3063	-0.7807***	-3.7599
LVOL_MZE	0.0674	1.3880	0.0781	1.2603
LVOL_MZE(-1)	---------	---------	-0.1842***	-2.8431
LRAINFALL	-0.2908	-0.5269	0.0437	0.0926
LRAINFALL(-1)	0.6629	1.4416	-0.4029	-1.0012
LRAINFALL(-2)	-0.6893	-1.4247	1.1696***	2.8253
C	12.474*	1.7706	-6.6285	-1.2473
T	0.0325***	3.2665	0.0003	0.0525
		Diagnostic test statistics		
Adjusted R-squared	0.89		0.90	
F-statistic [p-value]	27.84[0.00]		27[0.00]	
Serial Correlation LM Test [p-value]	0.50[0.58]		0.72[0.49]	
Heteroskedasticity Test [p-value]	1.40[0.21]		0.92[0.55]	

*Note: (i) Y is the log of the dependent variable (area or yield); (ii) Serial Correlation LM Test: Breusch-Godfrey; (iii) Heteroskedasticity Test: Breusch-Pagan-Godfrey. (iv) *** significant at 1% level, ** significant at 5% level, * significant at 10% level*

Appendix table 4.1: Estimated results from the QUAIDS model

```
Quadratic AIDS model
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Number of obs          =       2654
Number of demographics =          2
Alpha_0                =          5
Log-likelihood         =   8547.634
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
alpha						
alpha_1	.1834202	.0124637	14.72	0.000	.1589918	.2078487
alpha_2	.3656305	.0211986	17.25	0.000	.3240819	.407179
alpha_3	.3224459	.0122743	26.27	0.000	.2983887	.346503
alpha_4	.1285034	.0080759	15.91	0.000	.1126749	.1443319
beta						
beta_1	-.0242834	.0198023	-1.23	0.220	-.0630952	.0145285
beta_2	.1277094	.0285204	4.48	0.000	.0718105	.1836083
beta_3	-.1007765	.0191925	-5.25	0.000	-.1383931	-.0631599
beta_4	-.0026495	.0100592	-0.26	0.792	-.0223651	.0170662
gamma						
gamma_1_1	-.0423927	.0063842	-6.64	0.000	-.0549056	-.0298799
gamma_2_1	.0318244	.0061417	5.18	0.000	.0197869	.0438619
gamma_3_1	.0035411	.0043442	0.82	0.415	-.0049734	.0120557
gamma_4_1	.0070272	.003432	2.05	0.041	.0003005	.0137539
gamma_2_2	.0022309	.0097897	0.23	0.820	-.0169567	.0214184
gamma_3_2	-.0013853	.0052681	-0.26	0.793	-.0117106	.00894
gamma_4_2	-.0326699	.0049756	-6.57	0.000	-.042422	-.0229179
gamma_3_3	.0139472	.0054768	2.55	0.011	.0032128	.0246816
gamma_4_3	-.016103	.0027738	-5.81	0.000	-.0215395	-.0106665
gamma_4_4	.0417458	.0049239	8.48	0.000	.0320951	.0513964
lambda						
lambda_1	-.0254851	.0119837	-2.13	0.033	-.0489726	-.0019975
lambda_2	.0634517	.0151909	4.18	0.000	.033678	.0932253
lambda_3	-.0461952	.0129555	-3.57	0.000	-.0715876	-.0208028
lambda_4	.0082286	.006278	1.31	0.190	-.004076	.0205333
eta						
eta_hhsz_1	-.0051715	.000897	-5.77	0.000	-.0069296	-.0034134
eta_hhsz_2	.0030233	.0007585	3.99	0.000	.0015367	.0045099
eta_hhsz_3	.0025759	.0007835	3.29	0.001	.0010403	.0041115
eta_hhsz_4	-.0004277	.0004625	-0.92	0.355	-.0013343	.0004789
eta_area_1	.0012719	.0048969	0.26	0.795	-.0083259	.0108698
eta_area_2	-.0133915	.0046223	-2.90	0.004	-.0224511	-.004332
eta_area_3	.0331475	.0066962	4.95	0.000	.0200233	.0462717
eta_area_4	-.0210279	.0055856	-3.76	0.000	-.0319755	-.0100802
rho						
rho_hhsz	.0541223	.0104665	5.17	0.000	.0336082	.0746363
rho_area	-.6298884	.0682057	-9.24	0.000	-.763569	-.4962077

Appendix table 4.2: Uncompensated/Mashallian elasticity from the QUAIDS model

Urban					Rural			
	CER	ANP	ROT	VEG	CER	ANP	ROT	VEG
CER	**-1.149320**	.1582713	.0358988	.0349649	**-1.158581**	.1375937	.0085518	.0271543
ANP	.0707443	**-1.070015**	-.0560114	-.1290592	.1171294	**-1.067641**	-.0133482	-.1422051
ROT	.0059980	.0014720	**-.9620793**	-.0530094	.0042896	.0187711	**-.9711383**	-.0453765
VEG	.1179232	-.1548867	-.0369025	**-.6539663**	.096628	-.2130690	-.0726917	**-.6531585**

Where CER=Cereal; ANP=Animal product; ROT=Root and tuber; VEG=Vegetable

Source: Author's computation from ECAM III