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Structures of price volatility: transmission, exchange rate and transactions costs

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Abstract: *This study analyzes the structure of volatility, intra-price transmission and the effects of exchange rate variability and transaction costs. Thanks to GARCH, MGARCH and EGARCH, the results show that structural volatility characterizes prices, that corn plays a central role in transmission and that upward expectations are more worrying than downward ones due to non-diversification. food consumed. The exchange rate and transaction costs contribute little to the increase in price volatility*.

Keywords*: food price Volatility Structures, Exchange Rates, Transaction Costs,* Transmission

1. Introduction

The presence of food price volatility and its impact on well-being [1]no longer needs to be proven. This volatility is often driven by a set of factors linked either to supply or demand (or structures and economic conditions) [2]apprehended in several models such as GARCH, VAR, VECM, VEC (Abbott and Borot de Battisti, 2009; Alvaro et al., 2017; Apergis and Rezitis, 2011; Anteneh, 2014; Asmare et al., 2014 ; Bouhdoud, 2012 ; Boobra et al., 2015 ; CAADAP, 2012 ; Donmez and Magrini, 2013; Ederer et al., 2013; Gilbert, 2010; Gilbert and Mugera, 2014 ; Harri and Hudson, 2009; Henry et al., 2023; Huchet-Bourdon, 2011; Ikuemonisan et al., 2018; Luhiriri (2014 and 2018); Moctar et al., 2014; Mustafa; et al., 2023; Mothana and Korcek, 2014; Onubogu and Oladapo, 2020 ; Pala, 2013; Siami-Namini, 2019; Siami-Namini and Hudson, 2017; Tadesse et al., 2013; von Braun and Tadesse, 2012; Shiferaw , 2023; Xiarchos and Burnett, 2017; Zmami and Ben-Salha, 2023, Chen et al., 2019).

Of these factors, the exchange rate and the cost of transactions (including other costs: opportunity, fuel, transport, etc.) stand out as major sources of volatility affecting the PED more . Indeed, developing countries bear several transaction costs related to their structures and are victims of exchange rate disturbances (Balcilar and Bekun, 2016; Díaz-Bonilla, 2016; Onwusiribe et al., 2021; Sarris, 2014; von Braun and Tadesse, 2012) because of their alignment with international trade as a means of development. Yet, despite recent (2006-2018) disruptions in the exchange rate and transport price; few current or past studies have analyzed the impact of the exchange rate (Aminah, 2022; Asmare et al., 2014 ; Boobra et al., 2015; Harri and Hudson, 2009; Ikuemonisan et al., 2018; Makrop et al., Olaoluwa, 2020; Onubogu and Oladapo, 2020 ; Olawale, 2019; Siami-Namini, 2019; Siami-Namini and Hudson, 2017 ; Xiarchos and Burnett, 2017) without worrying about the effect that transaction costs may generate .

Similarly, the analyzes often encountered set aside theoretical training (Mustafa ; et al., 2023) by often limiting themselves to a definition which is moreover subject to controversy in most cases; with the exception of Moctar et al (2014). Nevertheless, the latter present a model of spatial variability and not of volatility by considering the climate (random factor) as volatility, yet it is rather a source of the latter. Luhiriri and Muko (2018) tried to bring the improvements to this model but the same remark persists for them too. In these studies, the impact of volatility on well-being did not emerge even if cited in some of them (Ivan and Martin, 2015; Mbegalo and Yu, 2016; Minot and Dewina, 2013 Onubogu and Oladapo, 2020; Onwusiribe et al., 2021; Van and Dlamini, 2018).

In this study, we try to overcome these limitations. It is made in the DRC; where the volatility of food prices is no longer demonstrated as shown in the study by Pierre, Morales-Opazo and Demeke (2014) . Indeed, according to the latter, the volatility of corn and wheat flour prices amounted respectively to 33.6% and 3.51% in 2008; 14.60% and 11.755% in 2011. This study analyzes urban volatility with particular attention to the city of Bukavu where Luhiriri and Muko (2014, 2015, 2017, 2018) have enriched the documentation relating to this phenomenon by reporting that food and transport prices experience volatilities of 7% and 8% respectively, and that exchange rate volatility stands at 3% between 2008 and 2018. They argue that exchange rate volatility is increasing an average of 118% during these periods. Such a variation cannot be without influence on the volatility of food prices which increase on average

[1] *These are malnutrition and episodes of famine which in turn have consequences on the economy following the deterioration of capital (increase in health costs), a drop in productivity, etc.*

[2] *The evolution of the world population and the standard of living of certain countries and production; financialization, climatic accidents and economic policies; the evolution of global and national stocks of speculation; movements in the supply of money, the exchange rate, the price of oil, energy and the savings rate...*

by 22% and transport prices by 7%. Similarly, the econometric analyzes of these authors show that a rise in the exchange rate or the price of transport also leads to an increase in food prices.

This volatility is not without consequence on the economic activities and on the standard of living of household. In a recent study, Luhiriri et al. (2019) find that the instability of prices (food-transport) and the exchange rate reduced the profit of traders by more than 100% (total-average or marginal); at the same time leading to more than 80% of households in food insecurity (i.e. 76.6% in moderate insecurity and 5.3% in severe insecurity) and by accentuating inequalities in household purchasing power by 16% between 2015 and 2018. Minot and Dewina (2013), Mbegalo and Yu (2016), Onwusiribe et al. (2021), Woldehanna and Tafere (2015), Van and Dlamini (2018), Ivan and Martin (2015), von Braun and Tadesse (2012), reported that food prices had a negative impact on well-being (Malnutrition, poverty, famine, income, consumption…) of households in the short term for Ghana, Tanzania, Nigeria, Ethiopia, South Africa and in the world respectively.

We complete the present study by incorporating the transmission of food price volatilities through an MGARCH model. Unlike Xiarchos & Burnett (2017), we analyze transmission within food products and not between the agricultural and energy markets.
The objective of this work is therefore to analyze the impact of exchange rate and transport price disturbances on the structure of food price volatility and the way in which it is transmitted through food prices. This study tries to show how urban volatility is structured and is limited to a few products, i.e. eleven foodstuffs from the city of Bukavu for a period of 11 years from January 2008 to December 2018 . This limit is linked to the availability of data, the constraints of time and means, otherwise, it would be necessary to conduct the study over the entire extent of the province of South Kivu or even the whole country . This work is divided into three parts apart from the introduction and the conclusion. The first addresses the concept of volatility, the second focuses on methodology while the last focuses on the presentation and interpretation of results.

2. Conceptualizing Volatility: Definition and Formation

This section discusses the conceptualization of volatility, how it is formed, and how it can be impacted by the exchange rate and transaction costs.

2.1. Volatility: definitions

Volatility is often defined as the change in the price variation of products around their averages (Bouhdoud, 2013 ; Díaz- Bonilla, 2016 ; Huchet, 2012) or as a measure of the magnitude and speed [3]of the evolution of the price of an asset (Alioune, 2011). Unlike instability, volatility amplitudes are large and occur very frequently, or suddenly but mostly in one direction (Balcombe, 2011), arise following shocks and represent the unexplained, hence unpredictable part of prices (unpredictable nature of fluctuations) (Aziz, 2012; Asmare et al., 2014 ; Sarris, 2014), difficult to anticipate by overriding the adaptability of producers and consumers (Nahoua, 2012; FAO et al., 2011; OECD and FAO, 2012). Seen from this angle, volatility becomes problematic, a source of food shortages (Balcombe, 2011), uncertainty and instability (Bouhdoud, 2013; HLPE, 2011) [4]; preventing the formation of correct expectations and favoring the disconnection of the price from market fundamentals (Nahoua, 2012) .

The major criticism that can be attributed to these approaches is the fact that they analyze volatility in a single direction while considering it as a symmetrical process (a price increase is partially transmitted over the forecast horizon), to a rigged toss-up coin on which price increases are more likely to occur and persist than price decreases. In practice, for example, a price increase often

[3] *Magnitude is measured by the change from one period to another. Speed alludes to uncertainty, ie unpredictable variations.*

[4] *These uncertainties can lead to lower production if producers are risk averse or lack the ability to predict the future. Moreover, the situation can worsen if producers or distributors engage in speculation (if storage capacities exist), this behavior can kill both production and consumption in areas like Bukavu where households have low income. Nevertheless, it would be necessary to analyze the duration for which the median household can face the volatility, the nature of the product and the ability of the producer or distributor to cope with the cost of storage. In an environment like Bukavu, it would be necessary to integrate the taxes that many producers suffer and discourage.*

leads to a decrease due to the expectations of the players (Zheng et al., 2008). This leads us to define volatility as sudden upward movements accompanied by downward movements over a period that can approach zero or become more important [5]. Finally, volatility is associated with the speed of price changes, both upwards and downwards.

Volatility has unexpected effects on the economy as a whole (creates a direct cost on efficiency and inequality. Eliminating volatility increases a gain of 40%) (Asmare et al., 2014; von Braun and Tadesse, 2012) contrary to the economic postulate (Tadesse et al., 2013) which postulates that when the price increases, the supply increases, the demand decreases and the price returns to the equilibrium level. This postulate is justified in the presence of large farmers who are able to take advantage of the rise in prices in the short term by increasing the possibility of production and employment (reducing the number of poor farmers) through investment (Díaz - Bonilla , 2016; Kalkuhl et al., 2016; Martin and Ivanic , 2016; Tadasse et al., 2016 **)** ; and not in the presence of smallholders who, for lack of sufficient leeway, do not diversify their activity, combine production and consumption decisions, risk becoming net buyers and therefore vulnerable if volatility persists (De Janvry et al. , 1991; Naomi and Duncan, 2011; von Braun and Tadesse, 2012) [6]. Also in economic exchanges with other countries the assumption is put to the test. The powerful transmission of price effects from external markets introduces a risk of budget deficits for the state, which is a net importer of food products .

2.2. Samuelson, Takayama and Judge's Spatial Price Equilibrium Model of Price Formation

The models developed by Enke in 1951, Samuelson in 952, Takayama and Judge in 1971, Fackler and Goodwin in 2001 (Glauber and Miranda, 2016) of spatial price formation serve as a reference for this work to build price variability between the market rural and urban. In these models two important variables drive the variability in world trade, transaction costs (transport price, storage cost, etc.) and the exchange rate. To these models we associate the cobweb theory introduced by Ezekiel in 1938 and the storage theory developed by Williams and Wright in 1991 (Onubogu and Oladapo, 2020).

2.2.1. Formation of quantities.

Suppose a competitive economy where there are m supply markets and n demand markets involved in the production of a homogeneous product (having the same characteristics).

Let s_i, $\pi_i$denote respectively the supply of the good and its associated price on the $i$supply market . Consider $d_j$the demand for the good in the demand market $j$and $\rho_j$its price. Let's group the bid and its price into the column vector $s \in R^m$and a row vector respectively $\pi \in R^m$. Similarly let us group the demand and its price into the column vector $d \in R^n$and a row vector respectively $\rho \in R^n$. Consider $Q_{ij}$the good transported from $i$to $j$and $c_{ij}$the unit transaction cost (transport, tax/tariff, obligation, fee, subsidy, etc.) associated with the exchange of the good between $i$and j. Let us group the disposal good in the column vector $Q \in R^{mn}$and the transaction cost in the row vector $c \in R^{mn}$.

The supply function of the price associated with each supply market $i$is $\pi_i = \pi_i(s_i)$assumed to be increasing. Similarly the demand function of the price associated with each demand market j is $\rho_j = \rho_j(d_j)$assumed to be decreasing. Let us also associate to each pair of markets of supply and demand (i,j)their unit disposal cost, that is: $c_{ij} = c_{ij}(Q_{ij})$assumed to be increasing. The functions $\pi_i(s_i), \rho_j\left(d_j\right) et c_{ij}(Q_{ij})$are known and affine.

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[5] *Price movements close to zero constitute low volatility which is nothing but variability and those that are significant constitute high volatility.*

[6] *In the case of developing countries, particularly in the vicinity of Bukavu where the production originates, other factors should be added such as the poor state of the infrastructure (agricultural feeder roads, ports, airport, etc.) which can slow down distribution (favouring self-consumption, for example in the territory of Shabunda, the rice is thrown away for lack of means to transport it to the city), the infertility of the soil (especially in the Bushi), the characteristic of farms generally of small sizes which reduce the production ; imperfections in labor, credit and insurance markets limit the supply response to incentives. Similarly, the limited access to capital and the poverty of producers expose them to external food price shocks.*

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Mathematically the state of equilibrium is presented as follows:

$$\pi_i(s_i) + c_{ij}(Q_{ij}) \begin{cases} = \rho_j(d_j), \ si\ Q_{ij} > 0 \\ \geq \rho_j(d_j), si\ Q_{ij} = 0 \end{cases}$$

A set $K \equiv (\mathrm{s, Q, d})$ constitutes a spatial equilibrium price if the demand price of the good in the demand market is equal to the supply price in the supply market plus the transaction cost and there is exchange between the markets of supply and demand. There will be no trade between these two markets when the bid price plus transaction cost exceeds the ask price.
Subject to the following feasibility condition:
$s_i = \sum_j^n Qij\ , pour\ tous\ les\ offres\ des\ \ march\acute{e}s\ i$
$d_j = \sum_j^n Qij\ , pour\ toutes\ les\ demandes\ du\ \ march\acute{e}s\ j$
$Q_{ij} \geq 0, pour\ toutes\ paires\ (i, j).$

Similarly, the production, disposal and consumption of a good $(s^*, Q^*, d^*) \in K$is in equilibrium if and only if the problem of variational inequality is satisfied:$\langle \pi(s^*), s - s^* \rangle + \langle c(Q^*), Q - Q^* \rangle - \langle \rho(d^*), d - d^* \rangle \geq 0, \forall (s, Q, d) \in K$
For all markets we have:

$$\sum_{i=1}^m \pi_i(s^*) \times (s_i - s_i^*) + \sum_{i=1}^m \sum_{j=1}^n c_{ij}(Q^*) \times \left(Q_{ij} - Q_{ij}^*\right) - \sum_{j=1}^n \rho_j\left(d_j - d_j^*\right) \geq 0, \forall (s, Q, d) \in K,$$

When the price supply functions, price demand functions and transaction costs are continuous and have symmetric Jacobians [7]; and the supply functions of price and transaction costs are monotonically non-increasing; in this case the spatial equilibrium price between supply and demand is solved in a following convex optimization problem:

$$Minimize\ \sum_{i=1}^m \int_0^{s_i} \pi_i(x) dx + \sum_{i=1}^m \sum_{j=1}^n \int_0^{Q_{ij}} c_{ij}(y)\, dy - \sum_{j=1}^n \int_0^{d_j} \rho_j(z)\, dz \ \ (1)$$

2.2.2. Volatility model

Assume a spatial volatility model between two markets: places of production and distribution. Let us summarize the set of supply markets as rural or place of production and the set of demand markets as urban or place of sale of consumption (note that the conditions of exchange are pre-established). In this model assume that changes in volatility are related to transaction costs associated with the exchange rate and disturbances. Suppose the actors compare their price $P_t^i$to that of other products P_t^j, to an aspiration P_t^a. The price of production (P_t^P)is a function of expectations relativized to the good $j$expressed in local currency, i.e.:

$$P_t^P = \left(\frac{P_t^j}{P_t^i - P_t^a} e_t \right) \ (2)$$

Either$P_t^i - P_t^a = \sigma_{it}$
The price anticipates for the outflow (P_t^e)is a function of the price anticipated for production (expectations relativized to the good $j$expressed in local currency) added transaction costs (C) and error terms (μ_t):

$$P_t^e = \left(\frac{P_t^j}{\sigma_{it}} e_t + C, \mu_t \right) \ \ (3)$$

At equilibrium, the total variation is zero, ie $dP_i^e = 0$. Totally differentiating equation (3) we have :

$$\frac{\partial P_i^e}{\partial P_t^j} dP_t^j + \frac{\partial P_i^e}{\partial \sigma_{it}} d\sigma_{it} + \frac{\partial P_i^e}{\partial e_t} de_t + \frac{\partial P_i^e}{\partial \mathrm{C}} d\mathrm{C} + \frac{\partial P_i^e}{\partial \mu_t} d\mu_t = 0$$

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[7] *Indeed, the Kuhn-Tucker conditions of the optimization problem are equivalent to the spatial equilibrium conditions. In the case where the Jacobins of the supply price functions, the demand price and the transaction cost are symmetric, the conditions for optimizing the spatial equilibrium of the price are:*
$\left[\frac{\partial \pi_i}{\partial s_k} = \frac{\partial \pi_k}{\partial s_i}\right]$ $pour\ tout\ i = 1, \dots, n;\ \ k = 1, \dots n$ $\left[\frac{\partial \rho_j}{\partial d_i} = \frac{\partial \rho_l}{\partial d_j}\right]$ $pour\ tout\ j = 1, \dots, m;\ \ l = 1, \dots n$ $\left[\frac{\partial c_{ij}}{\partial Q_{kl}} = \frac{\partial c_{ii}}{\partial Q_{kl}}\right]$

$$\frac{e_t P_t^i}{\sigma_{it}^2} dP_t^j - \frac{e_t P_t^j}{\sigma_{it}^2} d\sigma_{it} + C' \mathrm{dC} + \frac{\partial \left(P_t^j / \sigma_{it} \right)}{\partial e_t} de_t + \mu' d\mu_t = 0$$

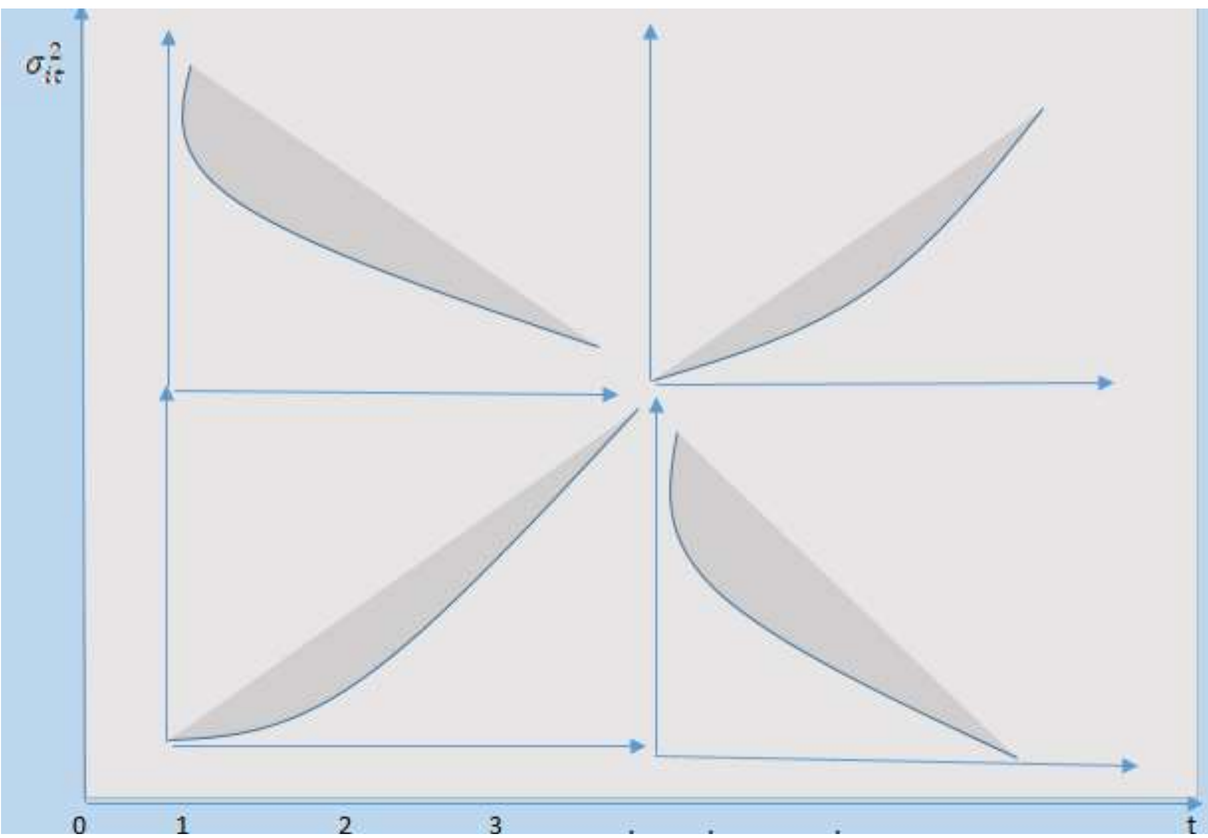
Assuming that the actors are rational, therefore are not mistaken in their expectations ($d\sigma_{it} = 0$) we derive the volatility equation:

$$\sigma_{it}^2 = -\frac{C' \left(P_t^j / \sigma_{it} \right) \mathrm{dC} + \left(P_t^j / \sigma_{it} \right)' de_t + \mu_t' d\mu_t}{e_t P_i dP_t^j} \quad (4)$$

The impact of the exchange rate and transaction costs is not easy to identify. Each rise in goods $j$causes the producer of the good $i$to reconsider their downward anticipation, then those of the goods j do the same, and so on. This means that upside expectations are more disruptive to volatility than downside expectations. :

$$d\sigma_{it}^2 = \frac{\partial \sigma_{it}^2}{\partial C'} dC' + \frac{\partial \sigma_{it}^2}{\partial \left(P_t^j / \sigma_{it} \right)'} d\left(P_t^j / \sigma_{it} \right) + \frac{\partial \sigma_{it}^2}{\partial e_t} de_t \pm \frac{\partial \sigma_{it}^2}{\partial \mu_t'} d\mu_t' \quad (5)$$

The volatility follows a monotonous increase or decrease with each variation of one of the parameters of the model. This monotonic variation is represented in the following graph:



Empirically, the work of Apergis and Rezitis (2011), Asmare et al. (2014), Čermák (2017), Siami-Namini and Hudson (2017), Zheng et al. (2008) and Onubogu and Oladapo (2020) find the presence of an asymmetric effect which becomes destabilizing when a price increase is anticipated. Apergis and Rezitis (2011), from Asmare et al. (2014), Luhiriri (2014 and 2018), Siami-Namini (2019) when they demonstrate the presence of symmetrical conditional volatility and more particularly its persistence in agricultural yields and prices. Other works that analyze the impact of the exchange rate find that the deterioration of the exchange rate causes the price of agricultural products to fluctuate and increases the volatility of food prices (Asmare et al., 2014; Boobra et al ., 2015; Onubogu and Oladapo, 2020 ; Luhiriri, 2018). Aminah (2022) finds through a VAR (analysis of impulse response functions and variance decomposition.) that oil and exchange rate shocks have contributed to food price volatility in South Asian countries. Harri and Hudson (2009), Olawale (2020), Apergis and Rezitis (2011), Makrop and Olaoluwa (2020), Siami-Namini and Hudson (2017), Siami-Namini (2019) find that exchange rate volatility is transmits in the price volatility of agricultural products in various parts of the world.

3. Methodological approach , data and data analysis

3.1. Data sources

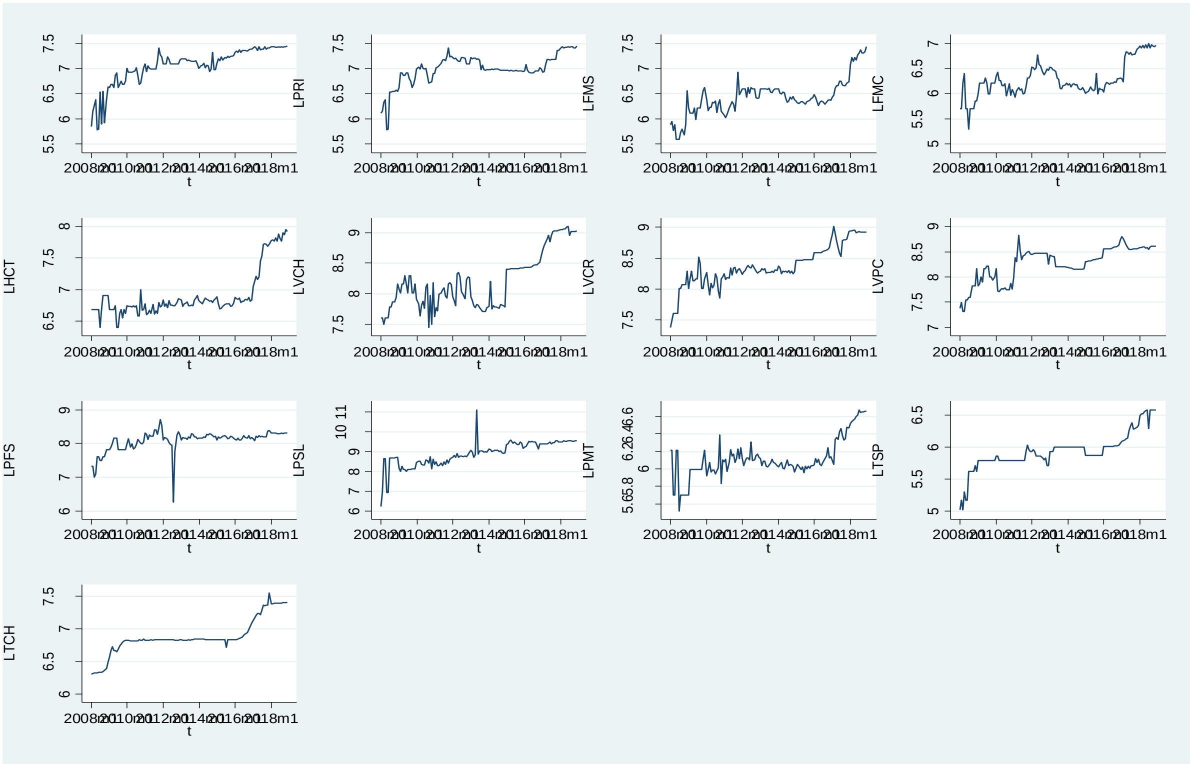
In this study, data on food prices come from the INS, with the exception of pork and transport prices, and the exchange rate, which come from the Central Bank of Congo (BCC). Only one city is considered in this work, that of Bukavu. Also, the analyzes cover a period of 11 years from January 2008 to December 2018. The foodstuffs selected are eleven in number, in particular rice (local and imported), flour (corn and cassava), beans, meats (goat, beef and pork), fish (fresh and salted) and potatoes . The choice of these products is justified by the availability of data and also because they are the most consumed products in households in Bukavu (PAM, FAO and CNR, 2011). It should also be noted that the data from the BCC are weekly series which have been transformed into monthly series by the calculations of moving averages. We also corrected the trend (the 12th order moving average method) and the seasonality present in the data (Droesbeke et a1., 2015)

3.2. The variables

The prices of agricultural products : The consumer prices of food products expressed in Congolese francs are the endogenous variables. These quantitative variables made it possible to measure the extent of volatility (after a transformation) and the evolution of prices in the city of Bukavu. Chart 1 shows the evolution of prices. It appears that in their evolution prices are disturbed by exogenous and endogenous shocks to the markets or to the production chain (Luhiriri, 2018).

The exchange rate : exchange rate volatility leads to higher agricultural price volatility (Balcombe, 2009; Boobra et al., 2015 ; Dönmez and Magrini, 2013; Huchet-Bourdon, 2012; Muko and Luhiriri, 2015 ; Onubogu and Oladapo, 2020). The volatility of the exchange rate increases the risk of profitability (Balcombe, 2005), and thus it is hoped that there is a positive transmission of the volatility of the exchange rate on the volatility of agricultural prices. During the 2016-2019 periods, there were disturbances in the nominal rate in the DRC, of which 1 USD rose from 1500 FC in 2015 to settle around 1700 FC in 2019. This seems to have led to instability as shown Figure 1. Nevertheless, we are thinking of an ambiguous sign due to the magnitude of the first period which seems to prevail according to our previous studies. The expected sign is therefore either positive or negative.

Figure 1: Evolution of food prices, transport prices and exchange rate



Legend: *LPRI=logarithm of imported rice price, LFSM=logarithm of maize flour price, LFMC=logarithm of cassava flour price, LHCT=logarithm of bean price, LVCH=logarithm of cow meat price, LVCR= logarithm of dear meat price, LVPC=logarithm of pork meat price, LPFS=logarithm of fresh fish price, LPSL=logarithm of salted fish price, LPMT=logarithm of potato price, LTSP= logarithm of the transport price, LTCH=logarithm of the nominal exchange rate.*

Transaction costs : is a quantitative variable measured by the price of transport which is an important element in determining the volatility of agricultural prices (Balcombe, 2009; Huchet-Bourdon, 2012). An increase in the price of transport generates an increase in the cost of transporting food from its place of production to the corresponding urban markets (Muko and Luhiriri, 2015) and leads to an increase in volatilities. However, this effect will depend on the nature of the products, the transport infrastructure, the processing and conservation mechanisms. For less processed products Luhiriri and Muko (2015) find that the price of public transport influences the price volatilities of food products differently in the city. For corn flour, local and imported rice, which are less perishable products, the price of transport has a negative influence , but has a positive effect on the prices of beans, goat, beef, salted fish... The expected sign is therefore ambiguous.

Well-being: is captured by the price index. We assume that a change in the set of prices has an impact on household purchasing power (real income), hence their well-being

Table 1 presents the summary of the variables and highlights the variability of the data. Positive average returns ($r_t = \log P_t - \log P_{t-1}$) mean that prices change when there is a rise than when there is a fall. The coefficients of variations indicate a strong heterogeneity in the level data and the presence of volatility in the first difference data.

Table 1: Variables, measures and statistics

Variables	Sources	In level			Log in first difference (Returns)			expected sign	
		N=132			N=131				
		MY	AND	resume	MY	AND	resume	Exchange rate	Transportation
LOCAL RICE	NSI	1221	349	29%	0.012	0.16	1333%	+	+/-
IMPORTED RICE	NSI	132	1129	855%	0.01	0.106	1060%	+	+/-
CORN FLOUR	NSI	670	278	41%	0.012	0.132	1100%	+/-	+/-
CASSAVA FLOUR	NSI	571	208	36%	0.01	0.138	1380%	+/-	+/-
BEAN	NSI	1093	550	50%	0.009	0.099	1100%	+	+
COW MEAT	NSI	4087	2074	51%	0.011	0.178	1618%	+	+

GOAT MEAT	NSI	4544	1489	33%	0.012	0.102	850%	+	+
PORK MEAT	INS and BCC	4082	1210	30%	0.009	0.111	1233%	+	+
FRESH FISH	NSI	3371	774	23%	0.008	0.231	2888%	+	+
DIRTY FISH	NSI	8613	6364	74%	0.025	0.414	1656%	+	+
POTATO	NSI	465	112	24%	0.003	0.131	4367%	+	+
TRANSPORT PRICE	INS and BCC	393	119	30%	0.012	0.076	633%	+	
EXCHANGE RATE	BCC	1004	287	29%	0.008	0.034	425%		
Price index	BCC	123	33	27%	0.001	0.321	40.8%		

Sources: author's calculations based on survey data

3.3. Estimating measures of agricultural product price volatility

The estimation of the volatility is made on the data transformed into first difference. In this case, the price returns (r_t) follow a unit root process with a multiplicative error term. They will then be stationary and their standard deviations will not depend on sample size or length of time. An approach found in the studies of Apergis and Rezitis, (2011), Gilbert and Morgan (2010), Luhiriri (2014 and 2018), Balcombe (2009), is to test the conditional variance of profitability using Autoregressive models Conditional Heteroskedasticity (ARCH) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH). The model looks like this:

$$r_t = \beta_0 + \gamma X_t + \varepsilon_t \quad (1) \qquad \varepsilon_t \text{Next } N(0, h_t^2)$$

$$h_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_j k_{t-1}^2 + \mu_t \quad (2)$$

Where t represents the time, r the returns, X the exogenous variables (exchange rate, the price of transport), $\varepsilon_t$the error term whose variance h_t^2 is heteroscedastic. The latter is expressed by $\beta_j$the conditional variance and by $\mu_t$white noise.

In the models described above, positive and negative innovations of the same magnitude are assumed to have a symmetric effect on conditional volatility. In particular, these models assume that the magnitude and not the sign of the anticipated variations determines the volatility, ie the squared innovations ε_t^2; affect the conditional variance h_t, so that $h_t$is invariant to the sign of the innovations. However, in most cases price variations are highly asymmetrical, in the sense that negative variations in asset prices are followed by more marked increases in volatility than positive variations of the same magnitude (leverage effect). In terms of food prices, the household does not react in the same way to forecasts of rising and falling food prices following news of the same magnitude (Apergis and Rezitis, 2011; Mukassa, 2015; Siami-Namini and Hudson, 2017). In this case each food price follows some process.

Many models have been developed to allow this asymmetry: the augmented GARCH model (GAARCH) of Bera and Lee (1990), the exponential (G)ARCH model (EARCH or EGARCH) of Nelson (1991), the quadratic GARCH model (QGARCH) of Engle (1990) and Sentana (1991), the asymmetric GARCH model of Engle and Ng (1993), the asymmetric power model (APARCH) of Ding, Engle and Granger (1993), the absolute GARCH model (AGARCH) of Hentschel (1994) or the threshold model GARCH (TGARCH) of Zakoian (1994). In these models, the conditional varianceh_t responds asymmetrically to positive and negative innovations. The most widely used model in practice is Nelson's EGARCH model (1991), which we specify as follows:

$$\log h_t = \omega + \emptyset \mu_{t-1} + \gamma \left[|\mu_{t-1}| - \left| \sqrt{2/\pi} \right| \right] + \beta \log h_{t-1} \quad (3)$$

$$\mu_{t-1} = \epsilon_{t-1}/h_{t-1}$$

where the settings$\omega\ et\ \beta$ are not constrained to be non-negative. The parameter $\emptyset$allows asymmetry. If $\emptyset$=0, a positive innovation *(* ε_t>0) has the same effect on volatility as a negative innovation of the same magnitude in this case we return to standard GARCH (1 1). If $-1 < \emptyset < 0$, a positive innovation increases volatility less than a negative innovation of the same magnitude. Finally if $\emptyset < -1$, a positive innovation reduces volatility, while a negative innovation tends to increase it. The effect of a news that the price will increase (the anticipation of a price increase) or decrease (anticipation of a price decrease) on the conditional variance will be respectively given by and (Zheng et al, $\gamma + \emptyset$ 2008 $\gamma - \emptyset$) . If γ- $\emptyset$ > γ+ $\emptyset$, low price news has more effect on the conditional variance than high price news of the same magnitude.

While asymmetric models constitute a remarkable advance for GARCH models, the analysis of volatility remains limited to the inconvenient case of a single price of a food product. In other words, we know nothing about the possible impact on the volatility of one food product or market of that of another food product or market price. Indeed, volatility can be transmitted from one food product to another through integrated markets. To overcome this, the class of multivariate GARCH models was created: the latter can be constant, in the case of the CCC model (Bollerslev, 1990), or dynamic, as proposed by Engle (2002) and variable Tse and Tsui (2002) [8].

News from all food product prices is now relevant: on the one hand, the variance generated by shocks specific to one food product price can directly influence another food price; on the other hand, covariance, or the common trend between food prices, contributes to the transmission of volatility.
Estimating a CCC MGARCH model looks like this:

$$\boldsymbol{y_t = CX_t + \varepsilon_t}$$
$$\boldsymbol{\epsilon_t = H_t^{1/2} v_t}$$
$$\boldsymbol{H_t = D_t^{1/2} \mathrm{R} D_t^{1/2}}$$

Or
y_t is a vector of m dependent variables (food price yield)
C a parameter matrix $m \times k$,
X_t a vector of $k \times 1$explanatory variables, which may contain the lags of the variablesy_t
$H_t^{1/2}$is the Cholesley factor of the change over time of the $H_t$conditional covariance matrix;

$\boldsymbol{v_t}$is a vector of $\boldsymbol{m \times 1}$whose innovations are normally distributed, independent and identically distributed with mean zero and unit variance;
D_t is a diagonal matrix of the conditional variances resulting from the estimation of the preceding equations according to a univariate GARCH process and can be written as follows:

$$D_t = \begin{pmatrix} \sigma_{1,t}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{2,t}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{m,t}^2 \end{pmatrix}$$

the $\sigma_{m,t}^2$come from a univariate GARCH whose form is:

$$\sigma_{i,t}^2 = s_i + \sum_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2$$

R is the time-invariant (constant) unconditional correlation matrix of standardized residuals $D_t^{-1/2}\epsilon_t$from the univariate GARCH model

$$\boldsymbol{R} = \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1m} \\ \rho_{12} & 1 & \cdots & \rho_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1m} & \rho_{2m} & \cdots & 1 \end{pmatrix}$$

In the CCC MGARCH model $h_{ii,t}$and $h_{jj,t}$are elements of the diagonal coming from a univariate GARCH process and $\rho_{ij}$is the invariant weight interpreted as the conditional correction (element of the main diagonal in the matrix R)
Constant conditional correlations $\rho_{ij} = \frac{h_{ij,t}}{\sqrt{h_{ii,t}h_{jj,t}}}$
Admitting an invariability of conditional correlations across periods is a strong restriction of where in the DCC model GARCH ρ_{ij}varies with time. It is specified as follows:

$$\boldsymbol{y_t = CX_t + \epsilon_t}$$
$$\boldsymbol{\epsilon_t = H_t^{1/2} v_t}$$
$$\boldsymbol{H_t = D_t^{1/2} R_t D_t^{1/2}}$$
$$\boldsymbol{R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}}$$

[8] *These allow the price volatility of a commodity to be a function of its own past volatility as well as that of one or more other food commodity prices. The calibration of these models can be done in two steps: first, the variances of each food price series are estimated with a GARCH model of your choice; then the conditional correlation matrix is specified.*

$\boldsymbol{Q_t = (1 - \lambda_1 - \lambda_2)R + \lambda_1 \tilde{\epsilon}_{t-1} \tilde{\epsilon}'_{t-1} \lambda_2 Q_{t-1}}$

Or

y_t is a vector of m dependent variables (food price returns)

C a parameter matrix $m \times k$,

X_t a vector of $k \times 1$explanatory variables, which may contain the lags of the variablesy_t

$H_t^{1/2}$is the Cholesley factor of the change over time of the $H_t$conditional covariance matrix;

$\boldsymbol{v_t}$is a vector of $\boldsymbol{m \times 1}$whose innovations are normally distributed, independent and identically distributed with zero mean and unity variance;

D_t is a diagonal matrix of the conditional variances resulting from the estimation of the preceding equations according to a univariate GARCH process and can be written as follows:

$$D_t = \begin{pmatrix} \sigma_{1,t}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{2,t}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{m,t}^2 \end{pmatrix}$$

the $\sigma_{m,t}^2$come from a univariate GARCH whose form is:

$$\sigma_{i,t}^2 = s_i + \sum_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2$$

$\boldsymbol{R_t}$ is the matrix of the conditional quasi-correlations of the standardized residuals :

$$\boldsymbol{R_t} = \begin{pmatrix} 1 & \rho_{12,t} & \cdots & \rho_{1m,t} \\ \rho_{12,t} & 1 & \cdots & \rho_{2m,t} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1m,t} & \rho_{2m,t} & \cdots & 1 \end{pmatrix}$$

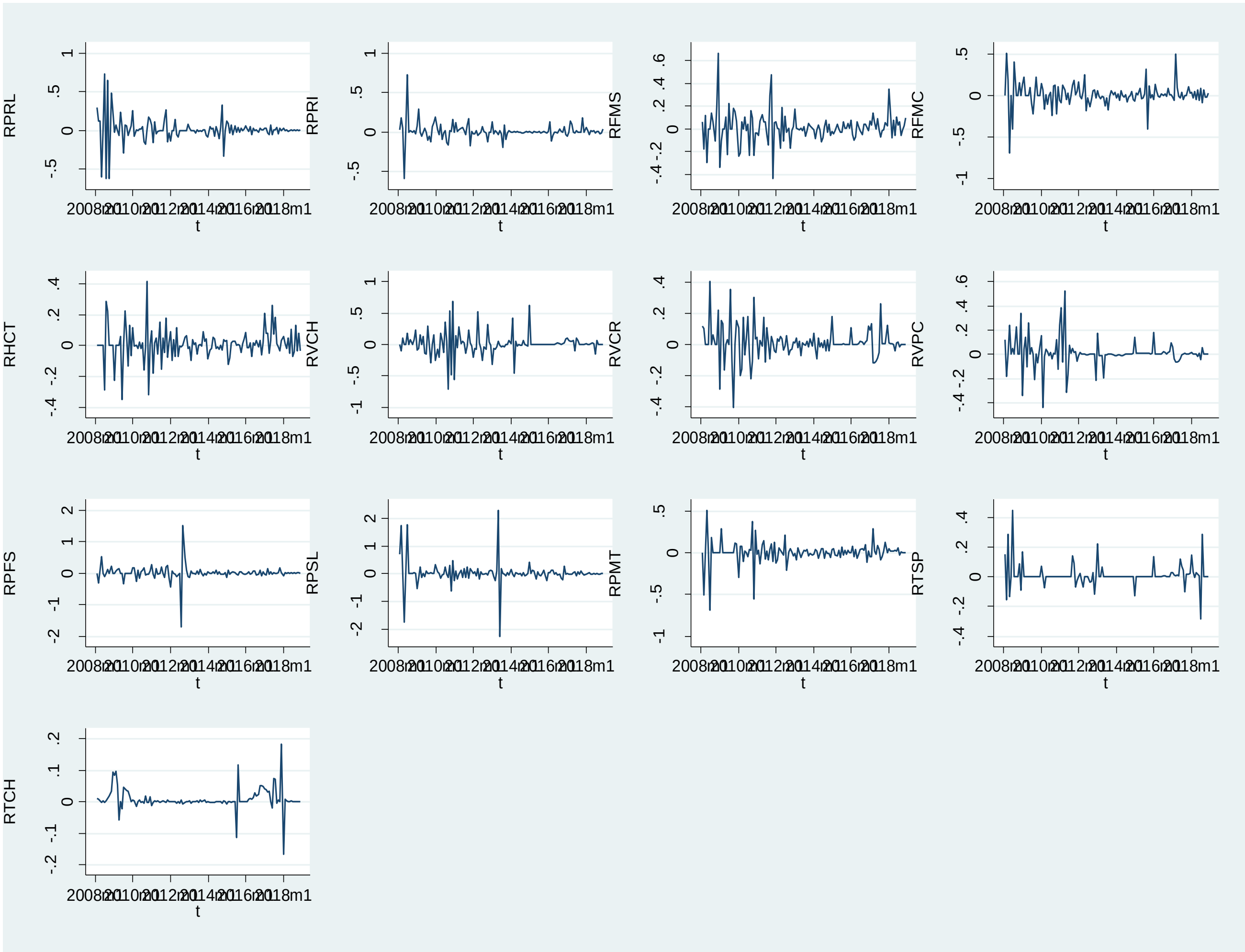
$\lambda_1 \tilde{\epsilon}_{t-1}$is a vector $m \times 1$of standardized residues, $D_t^{-1/2} \epsilon_t$; Andλ_1 et λ_2 are adjustment parameters that govern the evolution of quasi-correlations (they intercept, respectively, the effects of shocks and delayed dynamic correlations on the contemporary level of the latter) and must be positive with their sum less than 1 . $\boldsymbol{\lambda_1}$ **And** $\lambda_2$are non-negative and satisfied $0 \le \lambda_1 + \lambda_2 < 1$.

The preliminary processing was done in Excel 2016 and the models were estimated using the Stata 14 software.

4. Results and analysis

In the evolution of volatility we observe two changes, from 2008-2011 and from 2016-2018 (Figure 2). These periods are recognized as holding records in the rise in food prices (Onubogu and Oladapo, 2020). The variations between 2008 and 2011 coincide with the global food price crisis, marked by price increases of these products for different reasons, such as financial speculation and the use of food as fuel (Alvaro et al., 2017 HLPE, 2011; Tadesse et al., 2013; von Braun and Tadesse, 2012) or other factors such as the reliability of supplies of imported products (Sarris, 2014). The price movements observed during 2016 and 2018 are driven by geopolitical risk (Zmami and Ben-Salha, 2023; OECD and FAO, 2021) . These events also had effects on disturbances in the exchange rate, oil, production costs as raised by Aminah (2020) and Gbaka et al. (2023), Mothana and Korček (2014), Siami-Namini and Hudson (2017), Siami-Namini (2019), Chen et al. (2019).

Figure 2: Evolution of unconditional volatility



4.1. Estimates of symmetric conditional volatilities and inter-price transmission (GARCH and MGARCH)

Table 2 presents the estimation of a univariate GARCH, tables 3 and 4 contain the elements of a multivariate GARCH. These models were estimated on the basis of the elements of the univariate models of table 1. By analyzing these different tables, we note that the sum of the coefficients ($\alpha_1 + \beta_1$)is close to or equal to 1. These results indicate a persistence of volatility. For the prices of products such as local rice, imported rice, beans, cow meat, beef and potatoes; the largest component of volatility is attributed to the naturally unstable nature (or long-term component, edt volatility term) of these markets since $\beta_1 > \alpha_1$. The price series for maize and cassava flour and pork are characterized by structural instability linked to exogenous factors affecting the prices of these products (such as the natural tendency of the market to converge towards its equilibrium value , factors relating to climatic hazards, or even the expectations of actors present in the field and whose decisions affect the price level). It should be noted that the prices of fresh and salted fish reject a specification of the GARCH type, but this does not imply an absence of volatility, the tests of which are, moreover, conclusive (presented at the bottom of Table 5). These results are similar to those of Apergis and Rezitis, (2011), Chigozirim et al. (2021), Luhiriri (2014 and 2018), Sendhil et al. (2014), Siami-Namini (2019) in the persistence of volatility and the rise in long-term average prices, and the future forecast of high variance for an extended time.

Table 2: Results of the GARCH (1, 1) model estimation

	RPRL	RPRI	RFMS	RFMC	RHCT	RVCH	RVCR	CPPR	RPFS	List PR	RPMT
RTCH	-0.029	0.001	-0.38***	0.744***	0.132	0.136	0.282	0.064	-	-	-0.141
	(0.232)	(0.350)	(0.109)	(0.195)	(0.232)	(0.548)	(0.194)	(0.271)	-	-	(0.278)
RTSP	0.028	0.352***		-0.027	-0.007	0.034	0.152***	0.217***	-	-	-0.093
	(0.095)	(0.062)		(0.160)	(0.065)	(0.121)	(0.042)	(0.048)	-	-	(0.105)

Cons	0.001	0.003	-0.002	0.009	0.009	0.022*	0.008	-0.002	-	-	0.007
	(0.005)	(0.006)	(0.007)	(0.009)	(0.008)	(0.012)	(0.008)	(0.005)	-	-	(0.007)
Variance equation: $h_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 k_{t-1}^2 + \mu_t$											
α_1	0.496***	0.238***	0.969***	0.467***	0.082**	0.396**	0.195**	0.781***	-	-	0.253***
	(0.083)	(0.074)	(0.198)	(0.135)	(0.036)	(0.201)	(0.078)	(0.207)	-	-	(0.056)
β_1	0.637***	0.715***	-0.036*	0.388***	0.884***	0.452**	0.777***	0.445***	-	-	0.784***
	(0.037)	(0.072)	(0.022)	(0.113)	(0.036)	(0.183)	(0.068)	(0.056)	-	-	(0.028)
α_0	0.000**	0.001**	0.006***	0.004***	0.000**	0.007***	0.000**	0.001***	-	-	0.000
	(0.000)	(0.00)	(0.001)	(0.002)	(0.000)	(0.003)	(0.000)	(0.000)	-	-	(0.000)
$\alpha + \beta$	**1.13**	**0.95**	**0.93**	**0.86**	**0.97**	**0.85**	**0.97**	**1.23**			**1.04**
NOT	131	131	131	131	131	131	131	131	-	-	131

Legend: *RPRL=local rice profitability, RPRI=imported rice profitability, RFMS=rice maize flour profitability, RFMC=cassava flour profitability, RHCT=bean profitability, RVCH=cow meat profitability, RVCR=goat meat profitability, RVPC= profitability of pork, RPFS= profitability of fresh fish, RPSL= profitability of salted fish, RPMT= profitability of potatoes*

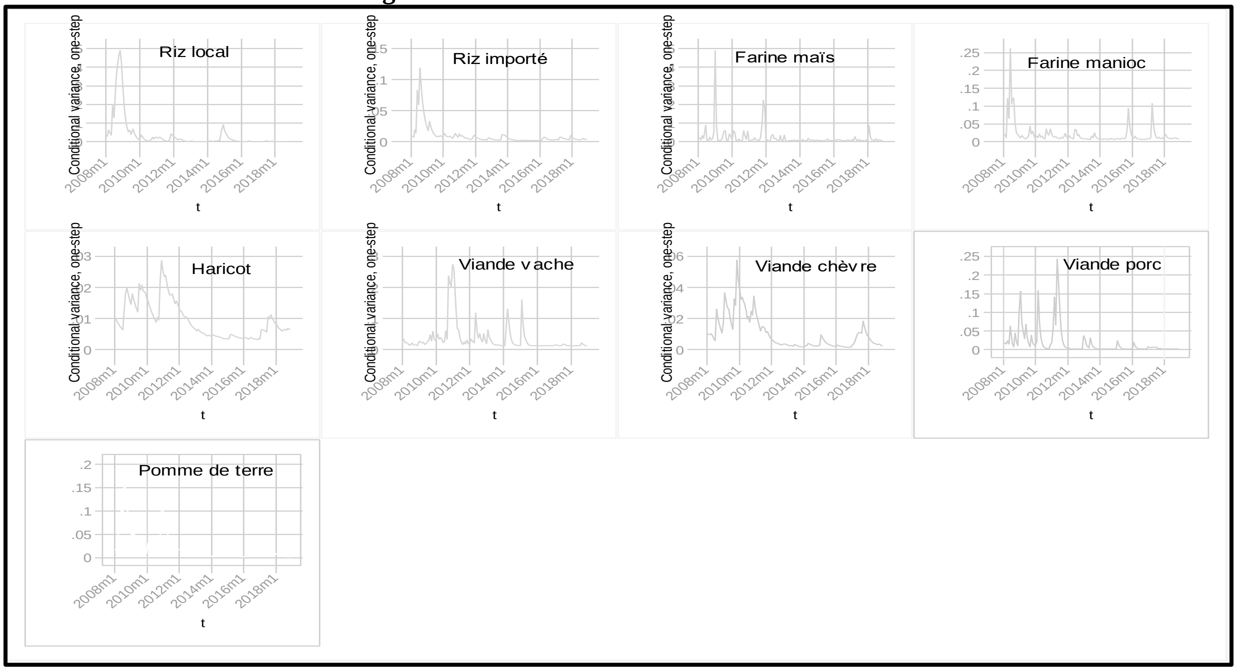
Significance level *: * p<0.1; **p<0.05; ***p<0.01*

Standard deviations are shown in parentheses

Contrary to all expectation, the exchange rate has no influence on variations in the yields of rice, beans, meats and potatoes; and contrary to our assumption, the price of corn flour drops significantly by 38% at a 1% rise in the exchange rate at the 1% significance level. Such results are also contrary to those found by Aminah (2022), Asmare et al. (2014) , Balcilar and Bekun (2016), Boobra et al. (2015), Ikuemonisan et al. (2018) Onubogu and Oladapo (2020), Makrop and Olaoluwa (2020) , Siami-Namini and Hudson (2017), Siami-Namini (2019), and seem to indicate a specification problem. It could be that endogeneity is present in the data. Variations in the price of cassava flour are sensitive to variations in the exchange rate at the 1% threshold and seem to meet the hypothesis put forward. Each marginal deterioration in the exchange rate induces an increase in the price of cassava flour by 74%. On the other hand, the price of transport affects only very significantly at the 1% threshold the prices of imported rice, goat meat and meat. An additional 1% increase in transport leads to an increase in the prices of imported rice, goat meat and pork by 35%, 15% and 22% respectively. These results partially confront the hypothesis put forward on transaction costs. A rise in the price of transport and the exchange rate have repercussions on the cost of production and consequently on the prices of food products. These variables explain price variations due to shocks not taken into account in this particular work on oil (Aminah, 2022; Apergis and Rezitis, 2011; Gbaka et al., 2023; Siami-Namini, 2019; Tadesse et al., 2013 ; Xiarchos & Burnett, 2018). To this effect, Aminah (2022) argues that an increase in the passed-on price of crude oil reduces the supply of food and agricultural products due to increased costs of fertilizers, transport and capital. She goes on to admit that since oil is a fundamental component of fertilizers, a spike in energy prices jeopardizes agricultural and food commodity prices; that the cost of processing and shipping agricultural products is influenced by energy prices in world agricultural markets. These assumptions show the exchange rate and the transport price are endogenous to the models.
Furthermore, it is also worth mentioning as pointed out by Dönmez and Magrini (2013) that these factors and the energy markets play a significant but less important role across the entire sample in all markets.

We also predicted symmetric conditional volatilities. Variance prediction only applies to products whose price volatility follows a GARCH model. From these predictions, it can be seen that the greatest disturbances in volatility appear from the period 2008-2011, for all the products selected. We notice more or less rapid change during 2016-2018. The latter would be due for the most part to recent exchange rate disturbances, as corroborated in previous studies (Aminah, 2020 ; Balcombe, 2011 ; Gbaka et al., 2023).

Figure 3: Evolution of Conditional Volatilities



Tables 3 and 4 present the multivariate GARCH estimates of constant conditional correlations and dynamic conditional correlations, respectively.

Table 3: Multivariate GARCH-CCC estimates

	RPRL	*RPRI*	*RFMS*	*RFMC*	*RHCT*	*RVCH*	*RVCR*	*RPMT*
Estimation of the CCC Multivariate GARCH model								
α_1	0.45***	0.36**	0.75***	0.15*	0.08**	0.12***	0.13***	0.10**
	(0.10)	(0.18)	(0.21)	(0.08)	(0.03)	(0.04)	(0.05)	(0.05)
β_1	0.63***	0.62***	-0.05**	0.48**	0.88***	0.89***	0.82***	0.85***
	(0.04)	(0.13)	(0.02)	(0.19)	(0.04)	(0.03)	(0.04)	(0.04)
α_0	0.00	0.00*	0.01***	0.01**	0.00*	0.00	0.00**	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\alpha_1 + \beta_1$	1.08	0.98	0.80	0.63	0.96	1.01	0.95	0.95
Correlations:								
DCC	RPRL	RPRI	RFMS	RFMC	RHCT	RVCH	RVCR	RPMT
RPRI	0.35***							
	(0.08)							
RFMS	0.10	0.25***						
	(0.09)	(0.08)						
RFMC	0.16*	0.44***	0.24***					
	(0.08)	(0.07)	(0.08)					
RHCT	0.02	-0.08	0.29***	0.18**				
	(0.08)	(0.08)	(0.08)	(0.08)				
RVCH	0.18**	0.05	0.00	-0.06	0.18**			
	(0.09)	(0.09)	(0.09)	(0.09)	(0.08)			
RVCR	0.30***	0.14*	-0.07	-0.22***	-0.02	0.42***		
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)		
RPMT	-0.17**	-0.02	0.19**	0.07	0.28***	0.13	-0.30***	
	(0.08)	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	
NOT	131	131	131	131	131	131	131	131

Significance level: * p<0.1; **p<0.05; ***p<0.01

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Standard deviations are shown in parentheses

The adjustment test presented at the bottom of Table 4 rejects the hypothesis that $\boldsymbol{\lambda_1} = \lambda_2 = 0$since *the chi2(2) = 36592.05* has a p-value of 0.000 less than 0.01 and therefore the hypothesis of the constancy of correlations over time is rejected. We conclude that the DCC model is the preferred specification that the CCC (is too restrictive for the data) and what we therefore focus on now (GARCH DCC estimates).

Interpreting the dynamic correlations at the bottom of Table 4, the price volatilities of local rice, maize flour, and cassava flour have significant positive connections between them, and between other commodities. The volatility of the price of imported rice is strongly correlated with the volatility of the price of potato (0.93), the price of maize flour (0.62) and the price of cassava flour (0.73). The yield volatility of maize flour maintains a positive dynamic correlation with the yield volatility of potato (0.64), the yield volatility of cassava flour (0.48) and bean (0.39). The dynamic correlation coefficient between cassava yield volatility and potato yield volatility is significantly positive (0.98). The positive signs of these coefficients mean that these products are substitutable. The interpretation is that an increase in price volatility observed on a food market is transmitted to other markets. In other words, if a shock increases the price of one of these products, it will be abandoned in favor of other cheaper ones. On the other initially stable markets, this additional unforeseen demand will cause sellers to increase their price to meet it since the supply is fixed. In the eyes of consumers, local rice is less important than imported rice. Cassava flour and corn flour are also the two flagship products in the city, since they play a central role in the cereal and food complex, are essential in the tuber. Cow meat is a complement to potatoes (-0.44) and a substitute for meat (0.44). This recipe is often found in the dishes consumed by Congolese households. These results reflect local realities in terms of food habits and the structure of the local economy. Often the dish eaten at noon consists of rice and beans or potatoes and beans. In the evening, in Foufou households, cassava flour or corn-meat is consumed. These products are more produced, sold and found in every market.

Table 4: Multivariate GARCH-DCC estimates

	RPRL	RPRI	RFMS	RFMC	RHCT	RVCH	RVCR	RPMT
Estimation of the Multivariate GARCH DCC model								
α_1	0.42***	0.28*	0.72***	0.22*	0.09**	0.11***	0.14***	0.11**
	(0.10)	(0.17)	(0.22)	(0.12)	(0.04)	(0.03)	(0.05)	(0.06)
β_1	0.64***	0.65***	-0.06**	0.28	0.87***	0.89***	0.81***	0.82***
	(0.04)	(0.16)	(0.03)	(0.22)	(0.04)	(0.03)	(0.05)	(0.07)
α_0	0.00	0.00	0.01***	0.01**	0.00*	0.00	0.00**	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\alpha_1 + \beta_1$	1.06	0.93	0.66	0.5	0.96	0.89	0.95	0.93
DCC parameters:								
	RPMT	**RPRI**	**RFMS**	**RFMC**	**RHCT**	**RVCH**	**RVCR**	**RPRL**
RPRI	**0.93*** **							
	(0.13)							
RFMS	**0.64*** **	**0.62*** **						
	(0.16)	(0.16)						
RFMC	**0.98*** **	**0.73*** **	**0.48*** **					
	(0.12)	(0.13)	(0.18)					
RHCT	0.27	0.18	**0.39** **	0.21				
	(0.24)	(0.24)	(0.20)	(0.24)				
RVCH	-0.13	0.07	-0.09	0.12	0.19			
	(0.32)	(0.31)	(0.30)	(0.30)	(0.24)			
RVCR	**-0.44* **	-0.34	-0.24	-0.31	0.21	**0.44** **		
	(0.24)	(0.26)	(0.25)	(0.24)	(0.25)	(0.20)		
RPRL	0.08	-0.05	0.01	-0.02	0.13	0.25	0.28	
	(0.30)	(0.30)	(0.28)	(0.29)	(0.24)	(0.26)	(0.24)	
Adjustment								
λ_1	0.01*							

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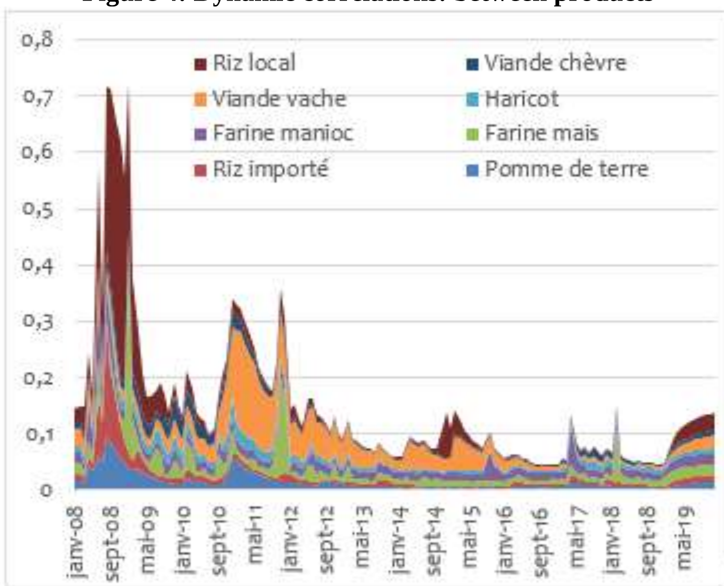
	(0.01)							
λ_2	0.96***							
	(0.01)							
NOT	131	131	131	131	131	131	131	131
chi2(2) =36592.05 Prob > chi2 = 0.0000								

Significance level: * p<0.1; **p<0.05; ***p<0.01
Standard deviations are shown in parentheses

Charts 4, 7, 8 and 8 (see appendix) present the dynamic forecasts of our sample between 2008 and 2018 and of the non-sample from 2019. It shows the enormous increase in the volatility of returns recorded in 2007 and in 2008, also with dynamic forecasts converging rapidly. These results meet the conclusions issued previously for univariate GARCHs.

Figure 4: Dynamic correlations: between products



4.2. Estimates of asymmetric conditional volatilities

The results of the estimates of the asymmetric conditional volatilities are presented in Table 5. Price expectations based on past prices (r_{t-1}) have a significant influence on the variation of current prices. A rise in the price observed one month before the current period reduces the price for the month incurred by 34% for corn flour and 24% for potatoes at the 1% threshold. Households that have observed a high price in past periods will buy less of their supplies now. This will lead distributors to revise their prices downwards to attract additional consumers. The change in the exchange rate of 1% leads to an increase in the price of cow meat by 33% at the 10% significance level. Similarly, a 1% increase in transport leads to lower prices for salted fish and potatoes respectively by 40% and 53% against all expectations.

Table 5: Estimates

	RPRL	RPRI	RFMS	RFMC	RHCT	RVCH	RVCR	CPPR	RPFS	List PR	RPMT
r_{t-1}				-0.34***							-0.238***
				(0.119)							(0.028)
RTCH						0.33*					
						(0.196)					
RTSP				-0.095						-0.4***	-0.528***
				(0.129)						(0.120)	(0.039)
Cons	0.001	0.007	-0.002	0.022**	0.009	0.013*	0.012*	0.013**	0.018	-0.02*	-5.474**

											*
	(0.004)	(0.005)	(0.009)	(0.009)	(0.009)	(0.007)	(0.006)	(0.006)	(0.015)	(0.01)	(0.370)
γ	-0.076	0.021	0.369***	-0.124	0.243***	-0.170***	0.100*	0.358***	-0.11***	1.275***	1.093***
	(0.060)	(0.045)	(0.103)	(0.139)	(0.089)	(0.064)	(0.057)	(0.087)	(0.023)	(0.066)	(0.127)
$\emptyset$	0.704***	0.517***	0.824***	0.832***	0.170**	0.173***	0.281***	0.491***	0.316***	0.272	0.023
	(0.071)	(0.075)	(0.166)	(0.157)	(0.079)	(0.043)	(0.061)	(0.089)	(0.028)	(0.176)	(0.240)
β	0.966***	0.893***	0.374*	0.623***	-0.69***	0.98***	0.953***	0.744***	-0.82***	-0.18***	-0.247***
	(0.016)	(0.035)	(0.191)	(0.160)	(0.107)	(0.01)	(0.016)	(0.048)	(0.021)	(0.056)	(0.089)
ω	-0.117	-0.45***	-2.78***	-1.55**	-7.99***	-0.050	-0.217***	-1.17***	-6.43***	-3.34***	-5.474***
	(0.084)	(0.169)	(0.879)	(0.680)	(0.562)	(0.0337)	(0.081)	(0.238)	(0.107)	(0.125)	(0.370)
NOT	131	131	131	130	131	131	131	131	131	131	130
LMStat	51.86***	27.63***	16.83***	25.19***	8.13***	21.91***	10.0***	8.11***	32.93***	12.93***	19.84***
$\gamma + \emptyset$	0.628	0.538	1,193	0.708	0.413	0.003	0.381	0.849	0.206	1,547	1,116
$\gamma - \emptyset$	-0.78	-0.496	-0.455	-0.956	0.073	-0.343	-0.181	-0.133	-0.426	1,003	1.07
Leverage effect	No	No	Reverse	No	Reverse	Normal	Reverse	Reverse	Normal	Reverse	Reverse

Standard errors in parentheses
***p<0.01, **p<0.05, *p<0.1

The asymmetrical effect (the impact of an anticipated rise or fall) on the conditional variance is clearly present on all prices with the exception of rice (local and imported) and cassava flour (The estimate of the value of $\gamma$is statistically insignificant) . The γsignificant positive coefficients imply that a positive innovation (anticipation of an increase) destabilizes more than a negative innovation for all products. An anticipated price increase measured by a one-unit increase in standardized residuals $|\epsilon_{t-1}|/h_{t-1}$(i.e. $\epsilon_{t-1} > 0$) leads to an increase of 36.9% in corn flour, 24% in beans, 10% in cow meat, 35.8 % of goat meat, more than 100% for salted fish and potatoes. Similarly, the anticipated $(\epsilon_{t-1} < 0)$price declines imply an increase in volatilities of 37.4% for corn flour, 69% for beans, 28.1% for goat meat, 49.1% for pork, 27.2% for salted fish and 3% potatoes. The work of Apergis and Rezitis, (2011), of Asmare et al. (2014), Čermák (2017), Zheng et al. (2008), Siami-Namini and Hudson (2017) and Onubogu and Oladapo (2020) find similar results stipulating that the presence of an asymmetric effect is destabilizing when a price increase is anticipated. This disruption is explained in Bukavu by food habits and low diversification. Indeed, because households are used to consuming these products and because they are faced with fewer substitute products, they have no choice but to continue to consume even when prices increase or are disrupted. .

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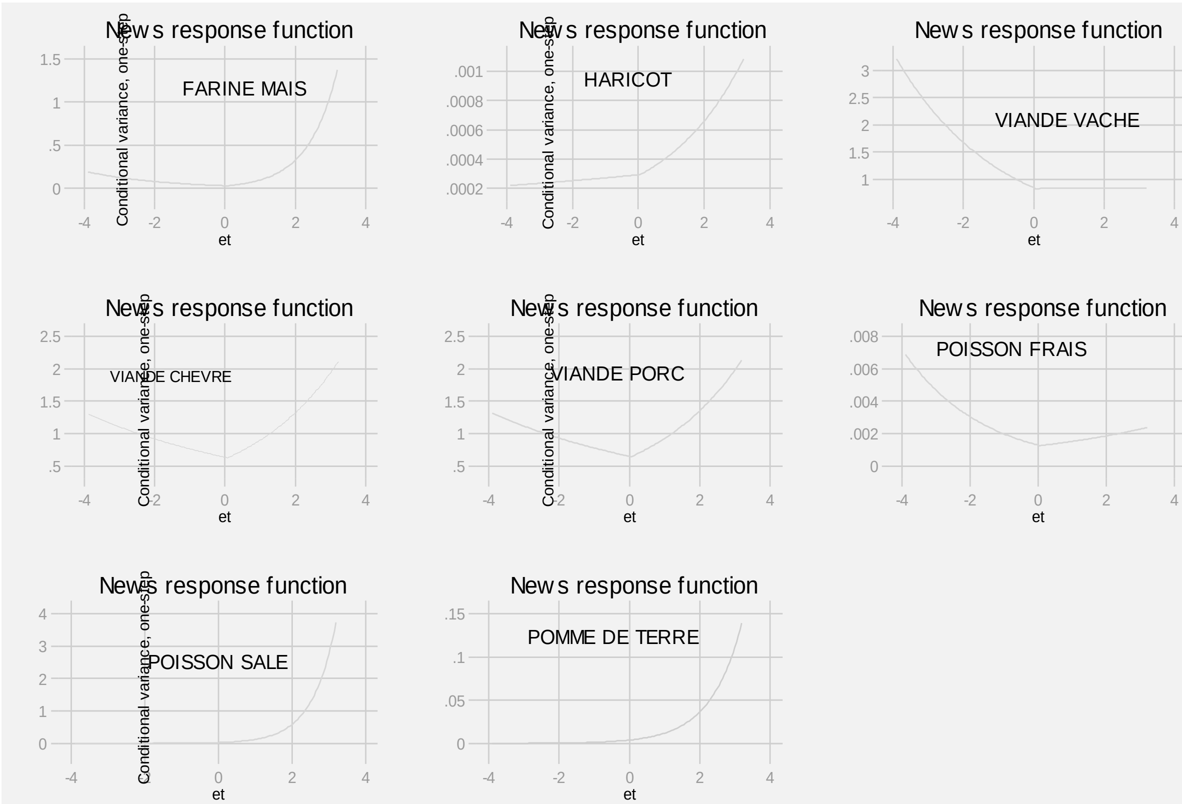
Figure 5:



4.3. Impact on well-being

Price indices measure the effect of price on welfare. It is assumed that a general increase in the prices of a group of products (assuming that the other parameters are held constant) has negative implications on purchasing power (HLPE, 2011; von Braun and Tadesse, 2012) and consequently lowers the household standard of living. Figure 6 shows the evolution of price indices between 2015 and 2020. During these periods, prices rose sharply for each group of products under analysis, and were higher in 2018.

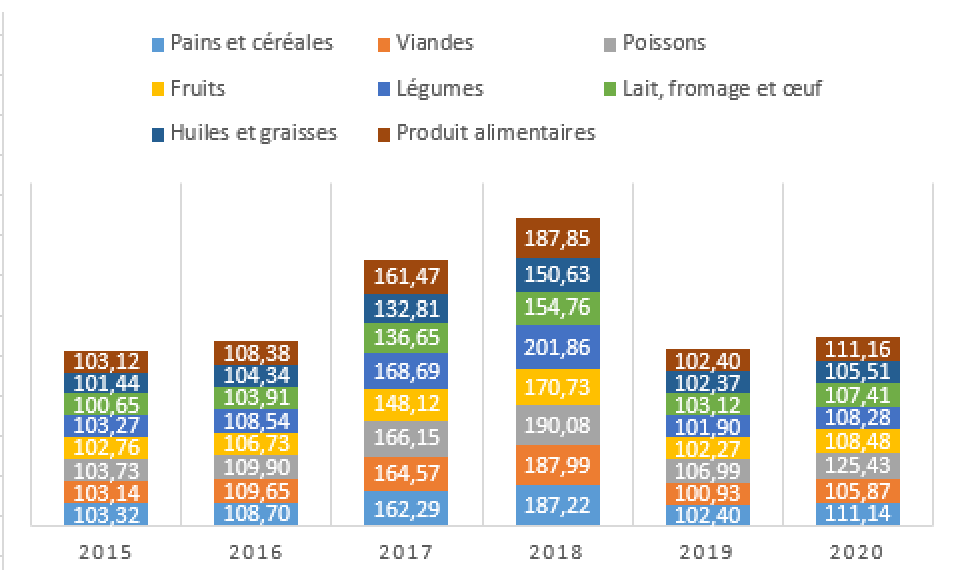


Figure 6: Evolution of price indices

Between 2013 and 2016, prices are stable but suddenly increase between 2017 and 2018, then drop in 2019 and increase slightly in 2020. Food prices increased on average by 2.38% in 2015, by 7.15% in 2016, by 53.29% in 2017, 76.82% in 2018, 2.42% in 2019 and 9.24% in 2020. Between 2013 and 2020, prices are unstable. To highlight the trend in price changes, we group the series of food price indices into two sub-periods, 2013-2015 and 2016-2020 (Table 6).

Table 6: Impact of rising food prices

	2013-15	*2016-2020*	*%*	*UK*	*F-test (p-value)*	*Conclusion*
	N=36	*N=55*		*N=91*		
Breads and cereals	101.75	136.46	34	122.73	0.0013 (0.000)	Significant increase
Meats	101.77	136.34	33.97	12267	0.001(0.000)	Significant increase
Pisces	102.18	141.01	38	125.65	0.0014(0.000)	Significant increase
Fruits	101.54	128.98	26.94	118.12	0.0012(0.00)	Significant increase
Vegetables	101.61	140.54	38.31	125.14	0.001(0.00)	Significant increase
Milk, cheese and egg	100.31	122.42	22.04	113.67	0.0002(0.00)	Significant increase
Oils and fats	100.94	120.37	19.25	112.68	0.0005 (0.00)	Significant increase
Food product	101.68	136.35	34.1	122.64	0.0011(0.00)	Significant increase

Source: Our processing in Stata14

The general level of food prices has increased by 34% suggesting that well-being has decreased. This hypothesis could be confirmed by the fact that during these periods we observed social movements (marches, strikes) in several economic and public sectors demanding higher wages, price stability and the exchange rate between the FC and the US dollar. We can therefore assume that the rise in prices has increased the number of poor people in the DRC. Other countries have experienced similar increases and reductions in household well-being (Minot and Dewina, 2013; Mbegalo and Yu, 2016; Onwusiribe et al., 2021; Van and Dlamini, 2018; Ivan and Martin, 2015)

5. Conclusions and implications

This work analyzes the transmission of intra-food price volatilities, the impact of exchange rate and transport price disturbances on the structure of food price volatility through the GARCH, MGARCH and EGARCH models. The various analyzes have identified two major shocks of 2007-2008 and 2016-2018 in the data which would come from variations in the exchange rate, a connection between the different products and a transmission of intra-price volatilities. The results show that the FC/USD exchange rate and transaction costs have opposite (negative) effects on different volatilities (conditional symmetric and asymmetric) of prices and contribute weakly to the increase in the price volatilities of other products. The recent disruptions caused by Covid19, combined with exchange rate disruptions, have revealed the vulnerability of the economy with its dependence on the outside. This situation can be compared to that of Zaire which depended on minerals whose sudden fall ruined the country. Unfortunately, the country continues to follow this policy. We therefore alarm decision-makers on the fact that it is difficult to develop with this risky strategy which has demonstrated its limits.

The disturbances are largely of structural origin ($\boldsymbol{\beta_1} > \boldsymbol{\alpha_1}$). Such results can be explained by the conjuncture of Congolese markets which are in bad shape, disconnecting rural supply from urban demand. External innervation in non-standard investments to regularize the food supply would make it possible to overcome this problem. Rising expectations are more disruptive than falling expectations ($\gamma + \emptyset > \gamma - \emptyset$)because of dietary habits and low food diversification. At this level increasing and diversifying production will help mitigate the effect of the exchange rate and sudden price changes on the consumer.

The general level of prices increased between 2017 and 2020 for the selected product groups and seems to affect welfare negatively. The short-term effects show the deterioration of the standard of living of households with the price indices which increase on average by 34% between 2015 and 2020. The burden of volatility continues to increase and leaves no room for maneuver for the decision-makers to long term. Intervening immediately would allow implementing the measures proposed in the literature (Asmare et al., 2014; Countryman and Narayanan, 2017 ; FAO et al., 2011; HLPE, 2011 ; Luhiriri, 2014; Sarris, 2014; von Braun and Tadesse , 2012; Woldehanna and Tafere, 2015) and would have its effects on the currents of the different periods. Leaving the economy to the anticipations and the will of microeconomic actors alone amounts to creating an economic precedent that is difficult to manage given the structure of production .

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Appendices

Figure 7: Dynamic correlations between imported rice, maize and cassava flour, goat and cow meat and potatoes

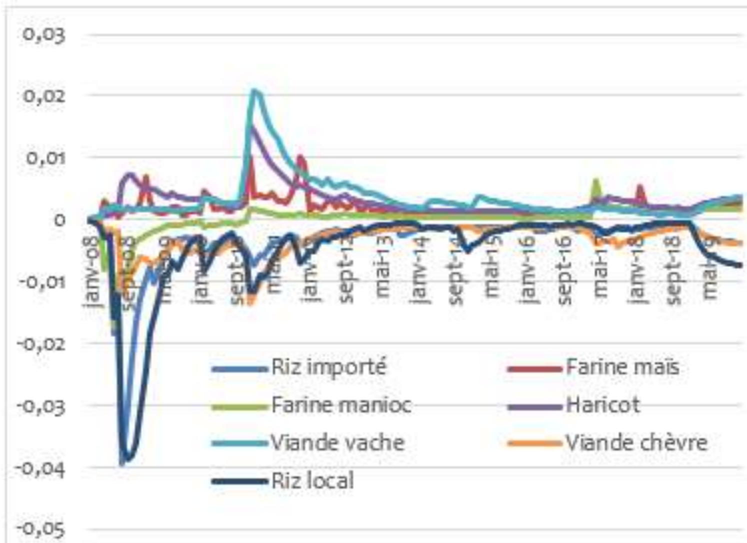

Figure 8: dynamic correlations between maize flour and cassava, beans, cow and goat meat, local rice and imported rice

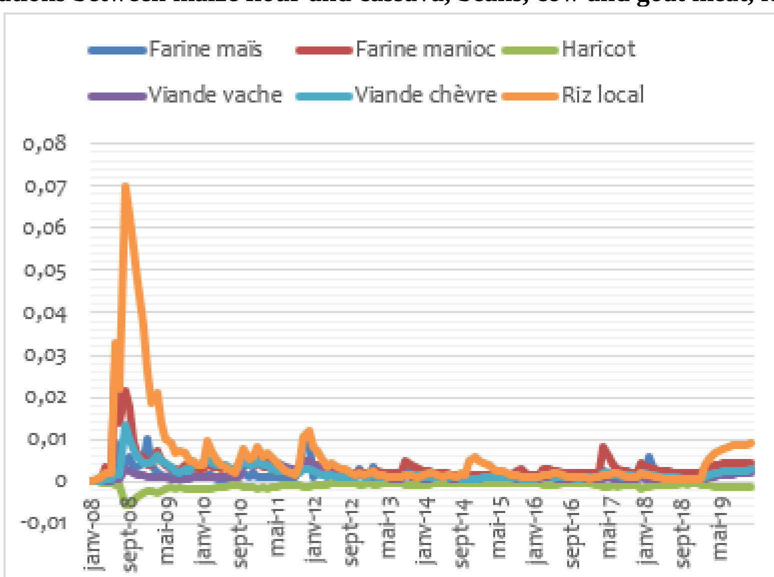

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Figure 9: Dynamic correlations between cassava flour, beans, cow and goat meat, local rice and maize flour

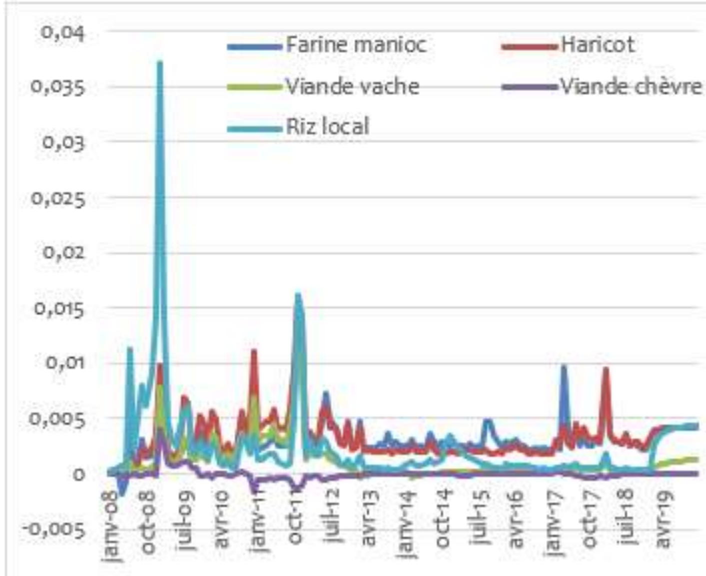
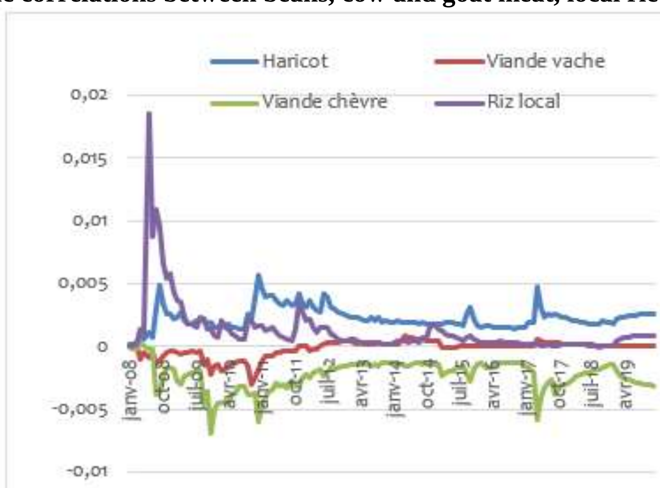


Figure 10: Dynamic correlations between beans, cow and goat meat, local rice and cassava flour



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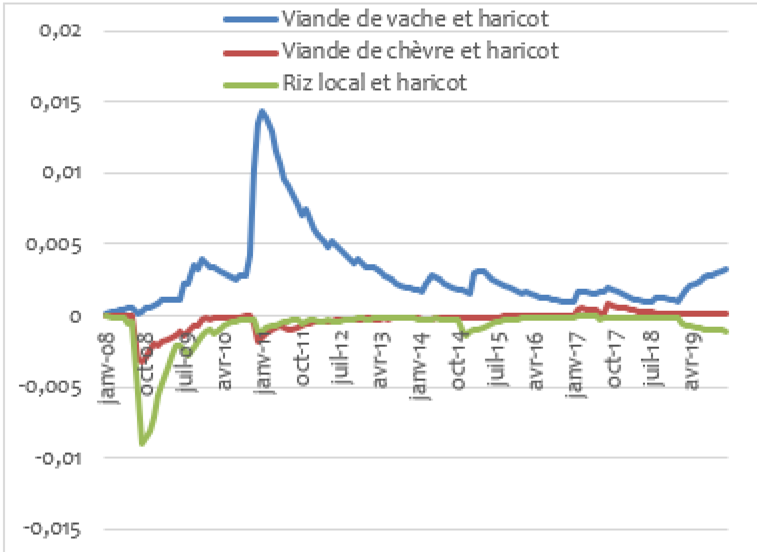

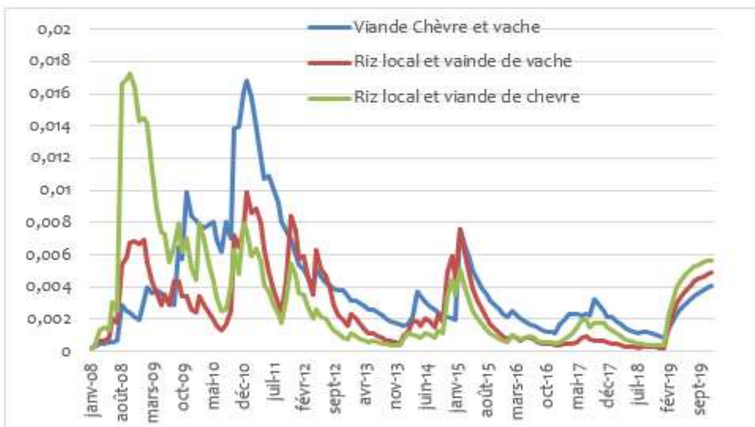

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