Measuring rice price volatility and transmission in West Africa: How important are magnitudes of transmission across countries?

Lessons from Senegal, Niger and Mali.

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Abstract

Rice is one of the most important staple foods in urban area of West African countries. Using monthly retail prices of imported rice from January 2004 to April 2012, this paper mobilizes ARCH/GARCH and ECM/VECM models to estimate and compare the conditional volatilities of imported rice prices. The results show that in the world market, volatility of return rice prices is significantly influenced by volatility of the previous month (57%) and by the shocks of last month (47%).

Comparison among countries show that Senegal rice market is strongly influenced by the volatility (70%) and by the errors squared (63%) of the previous month. This means that Senegal is facing directly high domestic volatility with high sensitivity to a shock. In the Niger and Mali rice markets, results highlight that volatility of returns in rice price is highly influenced by the shocks occurring during the previous month.

The results from the Vector Error Correction Model (VECM) reveal that in the long run there is a significant price transmission between the world and the domestic markets. About 65%, 57% and 56%, respectively for Senegal, Niger and Mali represent price variation transmitted from the world market. Taking the error correction coefficient in absolute terms, Senegal has a high speed of adjustment (31%) as compared to Mali (26%) and Niger (21%).

Keywords: rice price volatility, transmission, West-Africa, ARCH, GARCH, ECM-VCEM.

JEL classification: *C14, C19, C52, E31, Q13.*

1. Introduction

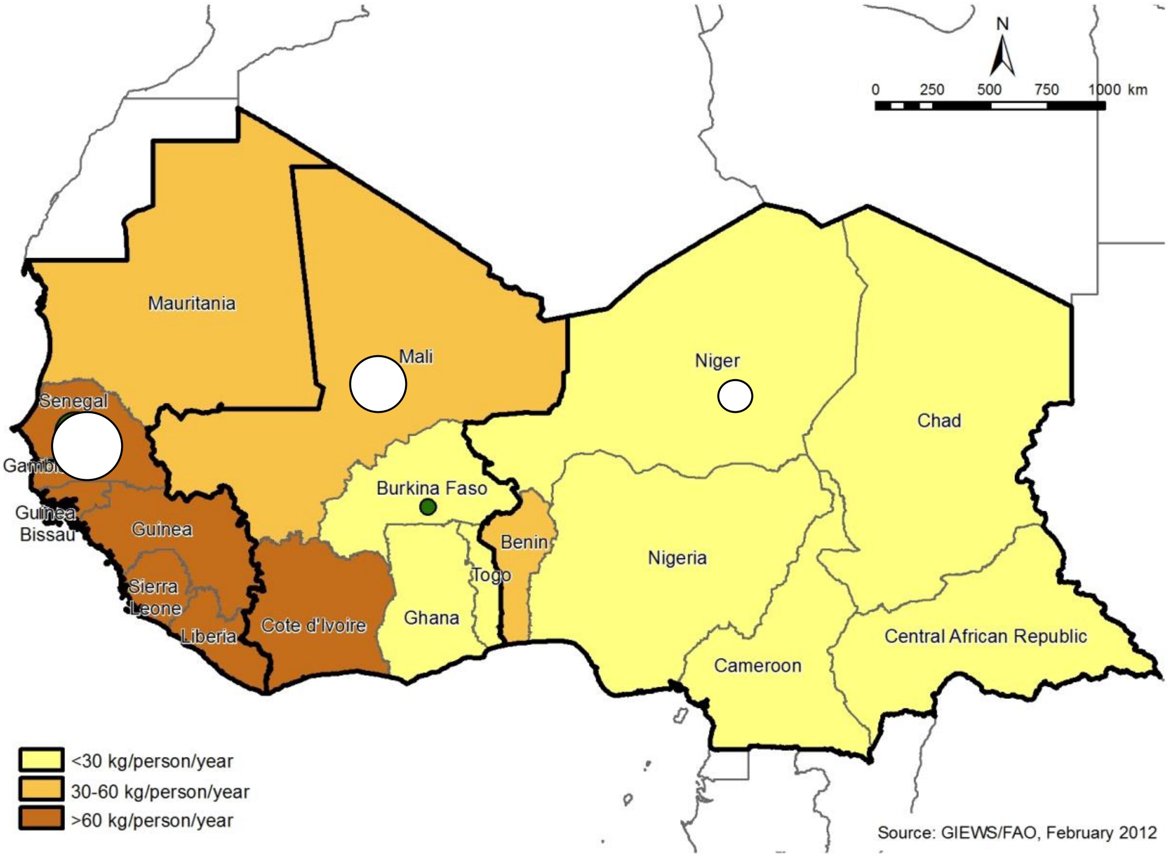
In the recent years, the global food market has been characterized by a dramatic increase in prices of agricultural commodities in levels as well as volatility. Between January 2007 and March 2008, the food price index computed by FAO rose by 61%. Over the same period, the prices of wheat doubled and the maize prices increased by 42%. In the second half of 2009, food prices partially recovered albeit the levels exceeded (FAO 2009). This situation has raised an important concern about price spikes as a major driver of food insecurity in developing countries where a high proportion of households income is spending on purchasing food.

In the world market, the periods of high food prices were also accompanied by high degree of volatility in prices. Those high food price and volatility are somewhat transmitted on the local markets in developing countries, making food accessibility difficult for majority of net buyers.

This study tries to explore rice price volatility in three selected West African countries (Senegal, Niger and Mali). These countries were chosen based on two dimensions: i) they are located in different basins of the West Africa region and ii) they have different trend in terms of rice calorie per capita consumption. The map 1 shows that Senegal is one of the three coastal countries in the West basin that have a high consumption of rice with about 73 kg per capita and per annum. Considering the proportion of rice calorie in total calorie supplies, Senegal presents high values during the period 1970-2009 (see figure 1). The values are over the world mean which is around 20 kg/person/year and so far from the West-Africa average (more less than 15 kg per capita and per annum). Mali is located in the Central Basin and Niger in Eastern Basin of West-Africa. Those two last countries have different patterns in terms of the two indicators discussed above for Senegal. While Mali is in the medium position regarding the per capita consumption of rice, Niger has a very low consumption (< 30 kg per capita and per annum). Those figures are given at the national level and are still high if looking at the same indicators in urban area.

Looking to the Niger case, the situation is different because the rice calorie supply as percentage of total calories supply is very low (see Figure 1) comparing to Senegal and Mali. In 2005, it approaches 10 kg/capita/annum on average and the proportion of rice calorie in the total calories supply is below the West-Africa average since 1970 to 2010 and it represents less than 5%.

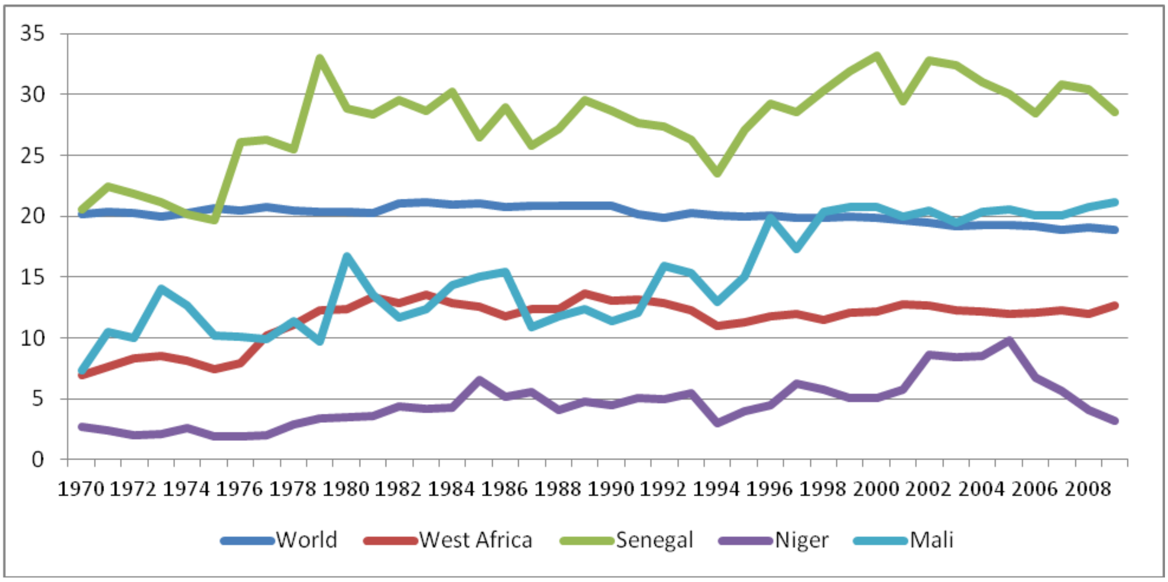
Map 1. West Africa rice consumption, February 2012 (*White circles=countries selected*)



Source: Authors, from GIEWS/FAO, February 2012.

◯: Countries selected for the study.

Figure 1. Proportion of rice calorie in total calorie supply (%)



Source : Authors, data from FAO-USDA Estimation.

Considering the rice calorie supply as percentage of total calorie supply estimated by FAO and USDA, we notice that Senegal has a very high value comparatively to two countries (Mali and Niger) and as well to West-Africa average which is bellow 15%. Mali was closed to the West-Africa average from the 70's to the beginning of the 90's. After this period, rice was becoming most important in terms of calorie supply and repsents about 20% with an increase trend. Niger has the lowest level of rice calorie supply as percentage of total calorie supply. It is more less than the West-Africa average but there is an increase trend from 2007 as showed by the figure 1. For all countries it is important to notice the decrease of the rice calorie supply in 1994-1995. This period correponds to the beginning of the liberalisation process in food markets and rice as well. After this period, all of the three countries show a positive trend in increasing of the proportion of rice calorie in the total calories supply at the national level.

Although rice market is considered as stable for various reasons, it is important to notice that these last years, it is victim of volatility as other agricultural products. When between January and April 2008, world rice prices tripled, in Senegal rice prices doubled.

Given this situation and the contrasted context in three countries chosen in Western Africa, this study aims to answer three main questions:

i) Does price volatility in rice market occurs at the same degree in different countries?

ii) Is there any relationship between International and domestic markets for rice?
iv) If there is any transmission, what is the speed of adjustment to long-run equilibrium?

The structure of the paper consists of seven major sections. From a selected literature review, the second section presents the trend in the world cereal prices, including a brief discussion on the causes of the recent spikes. Section 3 presents the back ground of local rice markets in the three selected countries. The data used are presented in Section 4 followed by the Section 5 where modeling approach and methodology are detailed. In the Section 6, this paper presents the empirical analysis and results discussions while the Section 7 draws some conluding remarks and policy implications.

2. Selected literature review

According to OECD (2009), agriculture remains exposed to many risks like production, market, institutional, personal and financial risks. Uncertainty about the prices that farmers will obtain for their products or pay for inputs is amongst the most important. For example, farmers in some countries face a number of risks that were formerly absorbed by market and price support policies (Matthews, 2010).

Due to the recent food price spikes, a number of studies have discussed the factors which may explain the evolution of recent price changes (Abbott and Borot de Battisti, 2009; Gilbert; 2010; Gilbert and Morgan, 2010). The most often causes involved are changes in supply/demand factors. On the demand side, the fast economic growth in Asian economies and particularly in China is often cited. On the supply side, the underinvestment in agriculture as well as low commodity inventory levels of recent years are often cited as contributing factors. Some recent studies have mentioned a new factor relate to the change in the use of food crops with the increasing production of bio-fuels. Other macroeconomic and financial factors apart from specific commodity market fundamentals are considered to influence agricultural commodity price volatility including: changes in oil prices, changes in world money supply, changes in the value of the dollar since many agricultural commodity prices are denominated in terms of the US dollar (OECD, 2011). Other factors which are often also quoted include climate change, trade policies in exporting and importing countries, and the feedback between price expectation and market responses. Gilbert and Morgan (2010) and De Schutter (2010) highlight the role of speculation in futures and options trading on food commodity markets, while some others do not support this view (Irwin and Sanders, 2010).

Some economists argue also that there are links between volatility and crises, higher volatility leading to an economic crisis (Aizenman and Pinto, 2005; Acemoglu *et al*., 2003). It is thus important to know the evolution of price volatility to help in the design of appropriate policies and to help market participants to better accommodate these phenomena. Some papers have thus investigated the impact of government attempts to insulate their population from the harmful effects of food price variability. For further details, a closer look should be devoted to the contributions of Galtier (2009), OECD (2009) and Matthews (2010). These studies review policies that can help to mitigate the risk of price volatility and which can help farmers to better cope with income instability.

Volatility of agricultural commodity prices is important for several reasons. First, price volatility is one of the main sources of risk in international agricultural trade. Second, production decisions are taken well in advance of product sales by anticipating prices. Third, food price volatility can damage food security in many developing countries where a high proportion of the revenue is used in purchasing food.

3. Background of rice production and market

Despite a significant potential for rice production, West Africa region only meets about 60% of its needs in rice. Comparatively to the imports of 1.7 million tons in the early 1990s, in the recent past, West Africa imported 5.2 million tons of rice (2011). This situation is expected to continue in the coming years due to population growth, urbanization and changing food habits. According to several sources, rice is expected to become a staple food in urban areas of the region in the coming years.

When world rice prices soared in 2008 following export restriction by the main suppliers to the world market, the impact varied from country to country, depending on their degree of import dependency and exposure to the world market: for example between January and April 2008, prices tripled at the world level, doubled in Senegal, and increased by a factor of 1.5 in Mali. In Senegal, one of the policy measures taken by the government was to reduce imports by 16%. This had the consequence in increasing food insecurity sharply in urban areas.

3.1. Senegal

According to the public statistics, a 60 percent jump in milled rice production to 443,000 tons for 2012/13 compared to 276,000 tons in 2011/12. Moreover, 2012/13 estimates exceed

2010/11 levels (411,000 tons) by 8 percent. With its 13.102.000 habitants on 30 April 2013, Senegal has expectations to produce 388.000 tons of rice while it was looking for 750.000 tons of importation to cover the national needs (Pregec, November 2012). The goal to increase milled rice production to 1 million tons by 2015 for self-sufficiency was extended to 2018. Recently, improvements in infrastructure have focused on rice production in the Delta region with public upgrading canals and pumping/water-distribution infrastructure.

Senegal imports about 70 percent of its rice for domestic consumption. During 2011/2012, the milled rice imports were 1.2 million tons, which was a 55 percent increase from the previous year, but just 200,000 tons will be saved for stock to cover three months of consumption (USDA-Post). As rice dishes are less expensive than millet-based ones and due to intensive urbanization rice consumption is increasing.

Thirteen private companies share Senegal’s import market with the largest controlling 24 percent. Importers buy shiploads of rice through a cluster of twelve brokers located in Switzerland rather than directly from exporting countries, which they then store in their own warehouses in Dakar compared to smaller importers that deal with container-sized transactions. In Senegal, tariffs on rice vary according to grade and customs duties are set at 10 percent for all grades. There is no sur-tax on broken rice which fixes its maximum tariff at 12.7 percent compared to 27.7 percent for brown rice and 32.7 percent for semi-milled rice.

3.2. Niger

Rice demand is increasing in Niger, and domestic production represents about 34 percent of total rice supply. According to the USAID report (2011), domestic needs for rice are estimated at 250,000 MT per year. Niger's rice imports come primarily from Thailand (31%), Pakistan (27%) and India (13%). An annual average of 190,000 MT of rice was imported during the past five years, with annual volumes ranging from 149,074 MT to 246,840 MT (FAOSTAT).

The importation and commercialization of rice is somewhat liberalized in Niger, with occasional intervention to control prices in certain markets. There is a network of marketing facilities in Niamey and the regional capitals. Transportation to some places during the rainy season may limit transactions on rural markets. There are at least four large importers of rice, and at least ten large wholesalers, which together suggest there is some competition in the imported rice industry in Niger.

3.3. Mali

Mali is a land-locked country with 70% of its population being rural and agricultural and rice is more important in urban areas, accounting for half of cereals consumed (Moseley, 2010). Mali produces 80% of its own rice and although it is not a net food importer in most years (World Bank, 2008). Carney (2001); Moseley *et al*., (2010) further attributes this situation to the fact that Mali's inland Niger Delta is one of the oldest rice production site in the world, the zone where African rice was likely domesticated coupled with the fact that much of the rice traditionally grown in southern Mali's seasonal wetland are for home consumption. Three others reason could explain this situation: i) the fact that Mali has a landlocked status made imported rice relatively more expansive in favor of domestic rice producers; ii) In addition, Mali has improved internal road network in recent years which reduces the cost of getting local rice to the market (Koenig, 2005); and iii) the fact that local rice producers get benefit from urban consumers who prefer local to imported rice, even when local rice cost more.

In 2011/12, Mali imported about 13 percent of its needs (180,000 tons) using a few rice importers. Imports arrive mainly from Cote d'Ivoire by train or truck and from Dakar by train. In 2012/13, imports are estimated to decrease by 44 percent or by 80,000 tons. Mali custom duties for imported rice are set at ten percent.

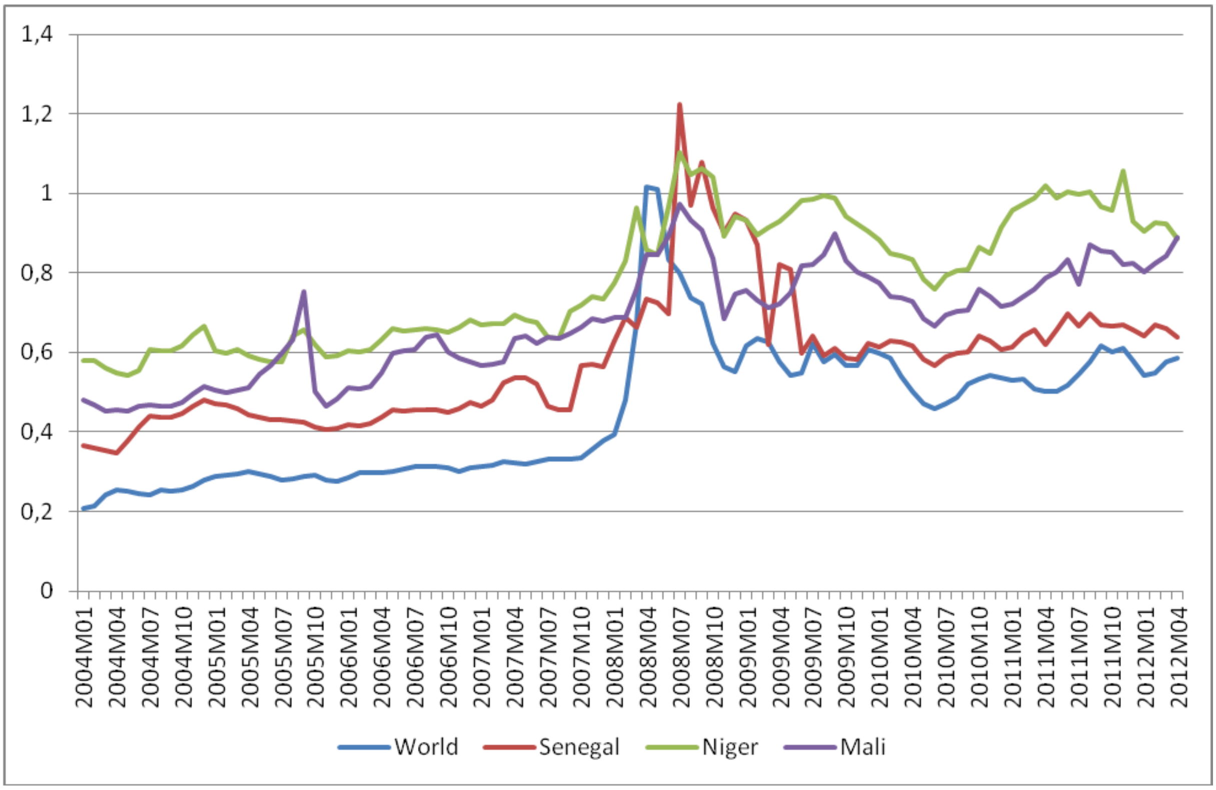
Rice consumption is estimated to reach 1.4 million tons in 2012/13. In Bamako, more than half of consumption is satisfied by imports. According to Government sources, the Malian crisis may have decreased availability of rice for vulnerable populations with cereal price spikes of 54 percent in Gao, and 16-29 percent in Segou and Timbuktu compared to Bamako. In its recent report, USDA (2013) considers that despite French and African forces fighting Islamic extremists in the North Mali, rice production has managed to increase. Government of Mali estimates a 16 percent bump in milled rice production for 2012/2013 at 1.3 million tons. However, production is still 13 percent below 2010/11 levels, falling short of its national target of 2.7 million tons by 2013 using rain-fed, total water control, and floating rice production systems.

4. Data

The analysis is based on monthly retail prices of rice from January 2004 to April 2012. The price series used are expressed in US dollars per kilo. The world price serie is from International Monetary Fund (IMF) and it represents 5 percent broken milled white rice(Thailand nominal price quote) while the price sries for the three selected countries concern the imported rice in Dakar (Senegal), Niamey (Niger) and Bamako (Mali).

The sample used in the analysis contains four monthly prices of rice: Word market rice prices (world-International market), Rice price in Senegal (sen), Rice price in Niger (nig) and Rice price in Mali (mal). Data were from Fews Net collection tool and are completed in some cases by FAO/GIEWS.

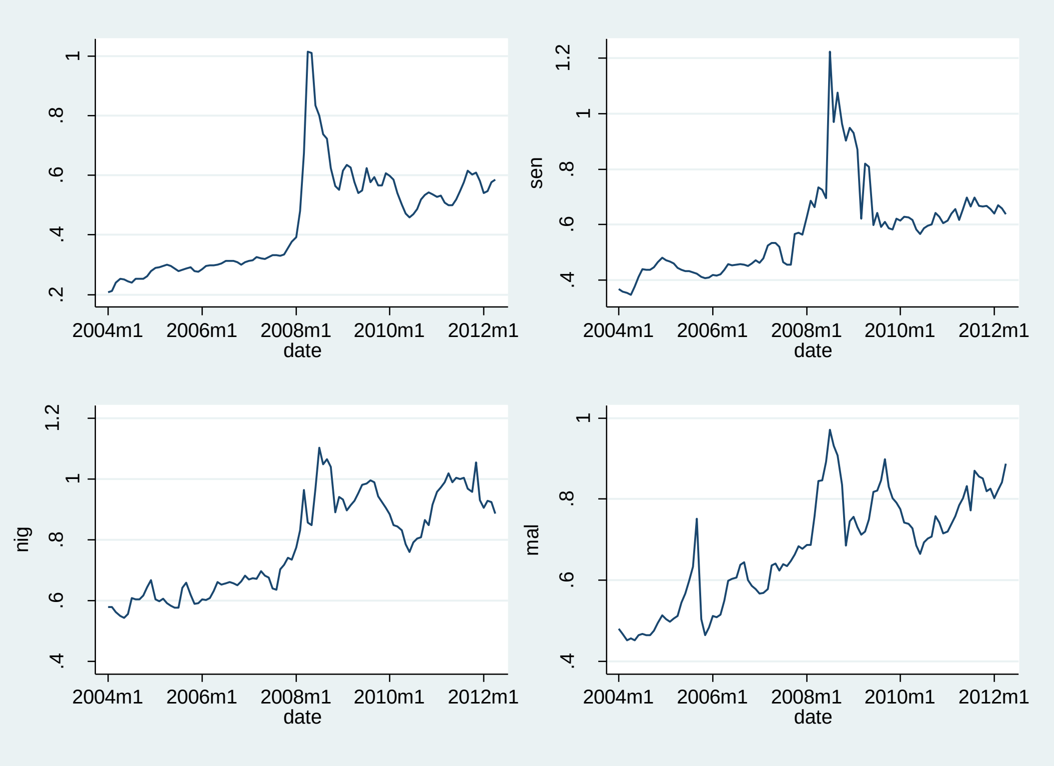
Figure 2. Rice prices (US per kg) in the World and in selected



Source: Authors, from rice price series at the international market and in the selected countries.

Comparatively to Niger and Mali, retail rice prices in Senegal are very closely track international prices (figured 2 and 3). Other than the early extreme peak of April 2008, retail prices have been close to global trade prices. After only two months, the shock was transmitted in Senegal (Dakar). In Niger (Niamey) and Mali (Bamako) the shock was transmitted with different magnitude. This situation is expected so that the global price volatility has been violently reflected in a country like Senegal that is a net importer. Due to their geographic position, Mali and Niger have very high levels of prices before and after the period of spike in 2008. Looking to the Mali retail prices, it seems that the transmission of volatility is lower compare to the Niger rice market.

Figure 3. Rice prices (US per kg) in the World and in selected countries.



Source: Authors, computed from rice price series at the international market and in the selected countries.

In response to global price movements, Senegal rice prices rose dramatically and over-passed the international level. As global prices fell down in the second half of 2008, Senegal and Mali follow the same path after two months and almost eight months later for Niger. Further prices have continued to rise, especially in Niger even as rice prices have stabilized in the global market.

Table 1. Correlation coefficients between rice prices

	WORLD	SENEGAL	NIGER	MALI
WORLD	1.0000			
SENEGAL	0.8068	1.0000		
NIGER	0.8565	0.8354	1.0000	
MALI	0.8763	0.7811	0.9230	1.0000

Source: Authors

The table above shows high correlation between international rice prices and imported retail rice prices in the capital cities of three West African countries: Dakar (Senegal), Niamey (Niger) and Bamako (Mali).

Lookinig to the correlation matrix among the four time series reported in Table 1, the rice prices on the world market seem to be positively correlated with the ones on the domestic market. This is expected as we consider the imported rice. A high positive correlation is observed also between different domestic markets. Average correlations between international and the domestic prices of imported rice in Senegal, Niger, and Mali are respectively 0.81, 0.86, and 0.88.

Considering the infomations reported in Figure 4 and Table 1, it seems that there is a close co-movement of the different price series of rice in the world market and in the three domestic ones. But at this stage, there is no evidence to suggest any conclusion about the cross market innfluences that will be tested later with some econometric modes like cointegrationa and Granger-Causality.

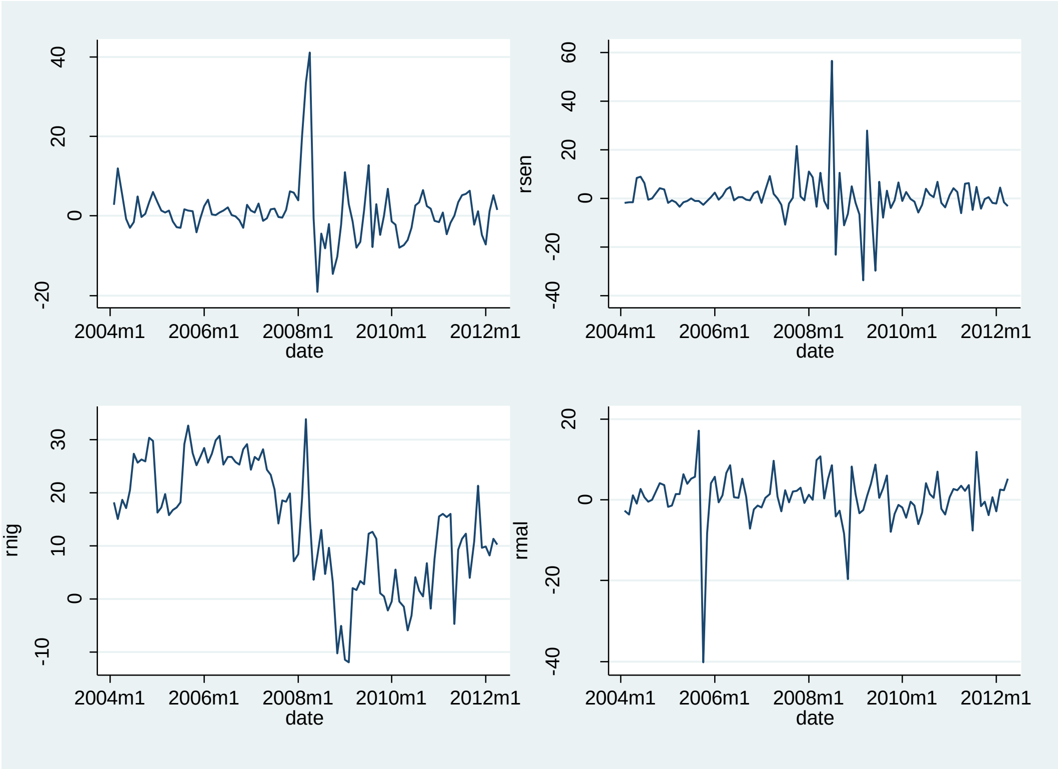
Table 2. Descriptive statistics of different price series (2004M01-2012M04)

	WORLD	SENEGAL	NIGER	MALI
Observations	100	100	100	100
Mean	0.446	0.580	0.784	0.676
Std.Dev.	0.172	0.164	0.162	1.137
Minimum	0.207	0.348	0.543	0.452
Maximum	1.015	1.225	1.103	0.971
Skewness	0.808	1.296	0.147	-0.036
Kurtosis	3.567	5.194	1.551	1.932

Source: Authors's calculations

Descriptive statistics of the observed rice price series (see Table 2), suggest that the standard deviation is quite similar in the world market and in Senegal and Niger. The measure of the spread of the distribution is high in the Mali case comparatively to the other price series.

Figure 4. Returns of rice prices in the World and in selected countries



Source: Authors, computed from rice price series in their levels at the international market and in the selected countries.

In this research returns prices are computed as follow: $R_t = 100 \times [\ln(P_t) - \ln(P_{t-1})]$. As shown by the Figure 4, the returns series are caracterized by random, rapid changes and are technically said volatile. In all series, volatility seems to change over time. For instance the word market and the rice markets of Senegal and World experienced a relatively sedate period from 2004 to 2007. Then the price returns become much more volatile until early 2010, excepted the rice market in Senegal. At the international market (world), high volatility is observed in 2008. In Senegal high volatility seems to be between 2008 and 2010 while in Niger, from 2008 till the end of 2012, retuns in rice prices seem to be more volatile. Rice market in Mali follow its one path: before 2006, there is no high variability in returns but at the end of 2006 there is high volatility followed by an other one at the beginning of 2009. In the returns graphs, it is clearly visible that there is evidence of volatility clustering for the return series of world and for all individual countries. This could be a good indication to mobilize ARCH and GARCH models to handle this kind of volatility.

5. Modeling approach and methodology

In order to handle volatility in different rice price series, the generalized autoregressive conditional heteroskedasticity (GARCH) developed by Bollerslev's (1986) as extension from ARCH model (Engle, 1982) is used. In this paper the variant of GARCH model like exponential form specified by Nelson (1991) is mobilized to model the asymmetric effects of price shocks on the conditional variance between the world rice prices and the domestic markets.

5.1. ARCH model specification

Traditionally, heteroskedasticity and autocorrelation have been considered as major problems in time series. Working on financial markets, Engler (1982) showed that large and small errors tended to occur in clusters such as exchange rates and stock market returns. To look at time heteroskedasticity in time series data, Engler propose the Autoregressive Conditional Heteroskedasticity (ARCH). The ARCH specification helps to focus on the mean and the variance of time series; which are useful when we want to understand the magnitude of volatility in time series data.

Considering the following model:

$$Y_t = \rho Y_{t-1} + \beta X + \varepsilon_t \quad (1)$$

The variance of ε_t is typically treated as a constant ($\varepsilon_t = \sigma^2$) and in the same time, the variance of the disturbance can change over time, which means that the conditional variance would be σ_t^2. Engle postulated that the conditional disturbance variance should be modeled as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots . + \alpha_p \varepsilon_{t-p}^2 \quad (2)$$

The lagged ε^2 terms are called ARCH terms and it denotes an AR process. The equation (2) specifies an ARCH model of order p and it is written ARCH (p). The conditional disturbance variance is the variance of ε_t and is modeled as follow:

$$\sigma_t^2 = \mathrm{var}(\varepsilon_t \left| \varepsilon_{t-1}, \ldots . + \varepsilon_{t-p} \right. \quad (3)$$

$$= E(\varepsilon_t^2 \mid \varepsilon_{t-1}, \ldots + \varepsilon_{t-p}) \quad (4)$$

$$= E_{t-1}(\varepsilon_t^2) \quad (5)$$

In equation (5), E_{t-1} indicates that the model takes into account an expectation conditional on all information up to the end of period t-1. It helps to observe that recent disturbances influence the variance of the current disturbance. So, the ARCH terms can be therefore interpreted as news about volatility from prior periods. A conditional disturbance variance expressed in the equation (2) can be simply obtained by defining the disturbance as:

$$\varepsilon_t = \upsilon_t \sqrt{\sigma_t^2} = \upsilon_t \, \sigma_t \quad (6)$$

where ε_t is the error terms (return residuals, with respect to a mean process) and υ_t is distributed as a standard normal (mean-zero and variance-one) white noise process. σ_t^2 is the conditional disturbance variance. These ε_t are split into a stochastic piece υ_t and a time-dependent standard deviation σ_t . So, the ARCH model is often simplified as follow:

$$Y_t = \rho Y_{t-1} + \beta X + \varepsilon_t \quad (7)$$

$$\varepsilon_t \sim (0, \sigma_t^2) \quad \text{where} \quad \sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_p \varepsilon_{t-p}^2 \quad (8)$$

Equation (8) is equivalent to $\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2$ (9)

with $\alpha_0 \rangle 0$ and $\alpha_i \geq 0$ pour tout $i \rangle 0$.

An ARCH (p) model can be estimated using ordinary least squares. A methodology to test for the lag length of ARCH errors using the Lagrange multiplier test was proposed by Engle (1982). This procedure is set up in three steps as follows:

1. Estimate the best fitting autoregressive model AR (p) and obtain the residuals ε_t ;

2. Compute an OLS regression of the squared error $\hat{\varepsilon}_t^2$ on a constant and *p* lagged values;

3. Test the joint significance of parameters α_i where the null hypothesis is that, in the absence of ARCH components, we have $\alpha_i = 0$ for all $i = 1,.....p$ and the alternative hypothesis is that, in the presence of ARCH components, at least one of the estimated α_i coefficients must be significant.

5.2. GARCH model specification

The main constraint in using ARCH model is that the α_i parameters have to be positive. Most of the time, the estimation produce negative estimates of α_i. GARCH, Bollerslev (1986) solved this problem by proposing a Generalized Autoregressive Conditional Heteroskedasticity (GARCH). In this model, the AR process (ARCH model) is turning into an ARMA process by adding a moving average process. The GARCH (p, q) model, where p is the order of the GARCH terms σ^2 and q is the order of the ARCH terms ε^2 is given by:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + ... + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + ...\beta_p \sigma_{t-p}^2 \qquad (10)$$

$$\Rightarrow \sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 \qquad (11)$$

The equation (11) shows clearly that the value of the conditional disturbance variance depends on both the past values of the shocks and on the past values of itself. So, the simplest GARCH model with p = 1 and q = 1 is GARCH (1,1) and can be written as follow:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \qquad (12)$$

By developing the equation (12), we find that the current variance depends on all previous squared disturbances with an effect which declines exponentially over time. In the new GARCH specification, some parameter restrictions are needed to ensure the stationary in the variance of the time series: $\alpha_0 \rangle 0$, $\alpha_1 , \beta_1 \rangle 0$ and $\alpha_1 + \beta_1 < 1$.

5.3. Cointegration model specification

The concept of cointegration (Granger, 1981) and the methods for estimating a cointegrated relation or system (Engle and Granger, 1987; Johansen, 1988, 1991, 1995) provide a framework for estimating and testing for long run equilibrium relationships between non stationary integrated variables. If two prices in spatially separated markets (or different levels of the supply chain) p_{1t} and p_{2t} contain stochastic trends and are integrated of the same order, say I(*d*), the prices are said to be cointegrated if:

$$P_{1t} - \beta P_{2t} = \varepsilon_t \text{ is I(0)} \tag{13}$$

β is referred to as the cointegrating vector (in the case of two variables a scalar), whilst equation (13) is said to be the cointegrating regression. The above relationship can be estimated utilizing *inter alia* Ordinary Least Squares OLS (Engle and Granger, 1987), or a Full Information Maximum Likelihood method developed by Johansen (1988, 1991) that is most commonly encountered in the literature. More specifically, P_{1t} and P_{2t} are cointegrated, if there is a linear combination between them that does not have a stochastic trend even though the individual series contain stochastic trends (see Stock and Watson, 1988, for the stochastic trend representation of cointegrated systems). Cointegration implies that these prices move closely together in the long run, although in the short run they may drift apart, and thus is consistent with the concept of market integration. Engle and Granger test the null of no cointegration by applying unit root tests on the error term ε_t . Johansen derived the distribution of two test statistics for the null of no cointegration referred to as the Trace and the Eigenvalue tests.

To measure the price transmission model, the vector error correction model (VECM) developed by Engle and Granger (1987) is used in order to establish any relationship (long-run equilibrium, short-run dynamics) between prices from the World and the domestic cereal markets in different countries. The time series properties of each of the price variables will be examined by using the Augmented Dickey-Fuller (ADF) test (Fuller, 1976). The order of integration of each of the selected cereal prices is determined. Regarding the orders of integration, VECMs or vector auto-regressions (VARs) are specified and estimated. As developed in scientific literature on time series analysis, several criteria like Akaike Information Criterion (AIC) for lag lengths are verified before the VECM and VAR models.

In the case that prices from two spatially separated markets, P_{1t} and P_{2t}, are cointegrated, the Vector Error Correction (or VECM) representation is as follows:

$$\begin{pmatrix} \Delta p_{1t} \\ \Delta p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} (P_{1t-1} - \beta P_{2t-1}) + \mathrm{A}_2 \begin{pmatrix} \Delta p_{1t-1} \\ \Delta p_{2t-1} \end{pmatrix} + \ldots + \mathrm{A}_\mathrm{k} \begin{pmatrix} \Delta p_{1t-k} \\ \Delta p_{2t-k} \end{pmatrix} + \begin{pmatrix} \upsilon_{1t} \\ \upsilon_{2t} \end{pmatrix} \tag{14}$$

where υ_{1t} and υ_{2t} are independent and identically distributed (iid) disturbances with zero mean and constant finite variance, whilst the operator Δ denotes that the I(1) variables have been differenced in order to achieve stationary.

The estimated coefficient of $(P_{1t-1}$ - $\beta P_{2t-1})$ reflects the errors or any divergence from this equilibrium, and correspond to the lagged error term of equation (13). The vector $\begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix}$ contains parameters, usually, $0 < |\alpha_i| < 1$ *I* = 1, 2, commonly called error correction coefficients, that measure the extent of corrections of the errors that the market initiates by adjusting P_{1t} and P_{2t} towards restoring the long run equilibrium relationship. In our case, P_{1t} represents the domestic price and P_{2t}, the international market price. If the error correction coefficient approaches the value -1, it is recommended to assess the extent to which policies, transaction costs and other distortions delay full adjustment to the long run equilibrium.

6. Empirical analysis and results discussion

6.1. Unit root analysis

Checking for stationarity condition of price series is the first step of the analysis. The literature suggests different tests: Augmented Dickey-Fuller (ADF) unit root test (1979), Phillips and Perron (1988) test and the KPSS propsed by Kwiatkowsky et al. (1992) test. The Augmented Dickey-Fuller test is one of the most commonly use tests for stationarity. The null hypothesis is that the series has a unit root. In other words, the ADF tests for the null hypothesis of non-stationarity against the alternative hypothsis of stationarity condition. Rejecting the null hypothesis means that the stationary condition is achieved.

The Phillips and Perron is a non-parametric test to check for serial correlation. This method modifies the non-augmented DF test so that the serial correlation does not affect the asymptotic distribution of the test. For the KPSS, the null hypothesis is to test the stationarity.

Table 3. Unit root tests

		Levels			First diff.		
		ADF	PP	KPSS	ADF	PP	KPSS
constant	SEN_Rprices	-1.756	-2183	1.55	-6.016***	-15.233***	0.0816
	NIG_Rprices	-1.533	-1.532	3.91	-8.312***	-9.877***	0.0722
	MAL_Rprices	-1.642	-1.584	3.7	-7.277***	-9.793***	0.0302
	World_Rprices	-1.884	-1.979	1.48	-4.897***	-6.017***	0.0449
constant & trend	SEN_Rprices	-1.735	-2.549	0.338	-6.026***	-15.203***	0.0508
	NIG_Rprices	-2.255	-2.291	0.364	-8.301***	-9.845***	0.0536
	MAL_Rprices	-3.097	-3.082	0.399	-7.238***	-9.749***	0.031
	World_Rprices	-2.558	-2.554	0.232	-4.879***	-5.987***	0.0379

ADF: Dickey-Fuller Augmented, PP: Phillips-Perron, KPSS: Kwiatowski-Phillips-Schmidt-Shin.

***, **, *: denote statistical significance at 1%, 5% and 10%

Source: Authors, computed from rice price series.

Scientific literature on time series provide information criterio procedures to help come up with a proper number of lags. Three commonly used are Schwarz's Bayesian Information Criterion (SBIC), Akaike's Information Criterio (AIC), and Hannan and Quinn Information Criterio (HQIC).

According to results presented in Table 3, in levels, all the food price series appear non-stationary, however, they appear stationary in first differences, implying all series are integrated of order 1, denoted I (1). This suggests using the returns for estimating the GARCH models for examining conditional volatility over the time period selected.

6.2. Testing for ARCH and GARCH effect

ARCH fits models of autoregressive conditional heteroskedasticity using conditional maximum likelihood. "Conditional" means that the likelihood is computed based on an assumed or estimated set of priming values for the squared innovations and variances prior to the estimation sample. The original ARCH model proposed by Engle (1982) modeled the variance of a regression model's disturbances as a linear function of lagged values of the squared regression disturbances. We can write an ARCH (m) model as:

$$Y_t = X_t \beta + \varepsilon_t \qquad (15)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 + \alpha_3 \varepsilon_{t-1}^2 + ... + \alpha_m \varepsilon_{t-m}^2 \qquad (16)$$

The first equation (eq.15) represents the conditional mean and the second one (eq.16), the conditional variance.

The ARCH/GARCH framework proved to be very successful in predicting volatility changes. Empirically, a wide range of price series and economic phenomena exhibit the clustering of volatilities. These models describe the time evolution of the average size of squared errors, that is, the evolution of the magnitude of uncertainty. Despite the empirical success of ARCH/GARCH models, there is no real consensus on the economic reasons why uncertainty tends to cluster.

Table 4. ARCH-GARCH model estimation of rice price series

	Model 1	Model 2	Model 3	Model 4
Main_L.World	0.315***			
	(2.85)			
Constant	0.154	0.491	14.37***	1.078*
	(0.36)	(1.07)	(12.40)	(2.57)
ARCH effect	0.467*	0.627**	0.609*	0.814***
	(2.42)	(2.90)	(1.66)	(4.20)
GARCH effect	0.561***	0.701***	-0.000854	-0.0542
	(4.02)	(10.84)	(-0.00)	(-0.68)
Constant	1.790	-0.194	51.65*	13.76***
	(1.50)	(-0.25)	(2.29)	(4.25)
Number Obs.	98	99	99	99
AIC	586.7	677.9	753.9	601.7
BIC	599.7	688.2	764.2	612.0

t statistics in parentheses, * $p<0.05$, ** $p<0.01$, *** $p<0.001$. **Model1**= Volatility model for the world market rice, **Model 2**= Volatility model for Senegal market rice, **Model3**= Volatility model for Niger market rice, **Model 4**= Volatility model for Mali market rice.

Source: Atuthors' calculations.

For both models, ARCH effect is statistically significant at different levels while for GARCH effect only the world market and the Senegal market are statistically significant ($p<0.001$) .
For World market, we have estimated the ARCH (1) parameter to be 0.467 and the GARCH (1) parameter to be 0.561 and are statistically significant at 1%. The lag1 also for the return seem to be statistically significant at 1%. Econometric results highlight that rice price volatility are highly influenced by the volatility of the last month (57%) and by the errors squared of last month at 47%. According to the mean equation, the returns in rice prices are influenced at 32% by the previous returns (one month before).

For Senegal market, the estimation shows that rice price volatility is strongly influenced by the volatility of the last month (70%) and by the errors squared of last month at 63%. This shows that the country like Senegal is facing directly high volatility.

For Niger market, the ARCH effect is 0.609 (significant at p=10%) while the GARCH is not statistically significant. The econometric model says that rice price volatility is highly influenced by the errors squared of last month at 61%.
For Mali market, the econometric model shows that rice price volatility faces high volatility caused by the errors squared of last month at 81%.

6.3. Testing for cointegration world and domestic markets

Cointegration focuses on the long-run relationships between price series. It means that among non-stationary prices, a linear combination of the series is stationary and prices therefore tend to move towards the long-run equilibrium relationship. Given prices for two spatial markets, the long-run price relationship can be obtained by running the following regression.

$$P_t^i = \alpha + \beta \mathrm{P}_t^j + \varepsilon_t \qquad (17)$$

Globally, cointegration refers to the fact that two or more series share a stochastic trend. Engle and Granger (1987) suggested a two step process to test for cointegration. The first step consist to run an OLS regression forward by a unit root test. This is the EG-ADF test.

Table 5. Long-term relationship between world and domestic markets

	Model 1	Model 2	Model 3
α	0.237***	0.424***	0.365***
	(0.039)	(0.044)	(0.029)
β	0.77***	0.81***	0.70***
	(0.057)	(0.112)	(0.070)
Number of obs	100	100	100
F(1, 98)	53,77	52,16	100.03
Prob > F	0.000	0.000	0.000
R-squared	0.65	0.73	0.77

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001. **Model 1**= Cointegration model for Senegal market rice, **Model2**= Cointegration model for Niger market rice, **Model 3**= Cointegration model for Mali market rice.

Source: Atuthors' calculations.

The results reveals that both the two series are cointegrated, that means world prices do granger-cause rice prices in Senegal. Using var models to estimate Granger causality, we find that in both cases (two directions), we can reject the null hypothesis that each variable (price series in Senegal and in world market) does Granger-cause the other.

The results from VAR models to estimate Granger causality are indicated in the table 6. The null hypothesis is that ‘var1 does not Granger-cause var2’. Using the Wald test, the results show that for Niger and Senegal, we cannot reject the null hypothesis that the world rice market does not Granger-cause the domestic rice market. For the Mali case, this is not demonstrated. This confirms our expectation as Mali is not directly dependent to imported rice due to its productions and the behavior of the Malian consumers.

Table 6. Granger causality Wald tests

Equation	**chi2**	**df**	**Prob > chi2**
World price does not Granger-cause Senegal price	42.899	1	0.000
World price does not Granger-cause Niger price	24.225	1	0.000
World price does not Granger-cause Mali price	15.183	1	0.244

Source: Atuthors’ calculations.

6.4. **VCEM modelling for testing the transmission**

The vector error-correction model (VECM) is an extension the VAR models, where there is evidence of cointegration among two or more series. The model is fit to the first differences of the non stationary variables, but a lagged error-correction term is added to the relationship. In the case of two variables, this term is the lagged residual from the cointegrating regression, of one of the series on the other in levels. It expresses the prior disequilibrium from the long-run relationship, in which that residual would be zero.

Table 7. Engle and Granger Two-Step ECM estimation (*using equation 16*)

	Model 1	Model 2	Model 3
World	-0.287*	-0.132*	0.0462
	(-2.41)	(-2.05)	(0.54)
α_1	-0.349***		
	(-4.83)		
α_2		-0.210***	
		(-3.54)	
α_3			-0.254***
			(-3.44)
Constant	0.00913	0.00563	0.00565
	(1.05)	(1.19)	(0.90)
Number obs.	98	98	98
AIC	-201.2	-321.4	-266.2
BIC	-193.4	-313.6	-258.4

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001. **Model 1**= ECM model for Senegal market rice, **Model2**= ECM model for Niger market rice, **Model 3**= ECM model for Mali market rice.

Source: Atuthors' calculations.

The results in the table 7 show that the error correction mechanism is negative and significant for both the pairs of domestic markets and the world market. This suggests, that deviations from long-run equilibrium are corrected at about 35%, 21% and 25% per month respectively in Senegal, Niger and Mali rice domestic markets. This confirms our expectation as Senegal is a coastal country which relies easily to the world market of rice comparatively to the two other countries. Mali reacts very quickly to the deviations from the equilibrium because this country is one among West African countries which have high production of rice.

For Senegal and Niger, the coefficients of the world market are statistically significant at 5%. This result implies short term effects on the domestic markets in those two countries. It represents the percentage adjustment of domestic prices one period (one month) after a one percent shock in international market. However, in the case of Mali, the world market coefficient does not appear to have significant short term effects on the domestic market.

Table 8. VECM model results

	Model1	Model2	Model3
α	-0.31 ***	-0.21 ***	-0.26 ***
	(0.0091)	(0.059)	(0.076)
β	-0.65 ***	-0.57 ***	-0.56 ***
	(0.061)	(0.033)	(0.046)
∂	-0.17	0.14	0.11
	(0.171)	(0.101)	(0.106)
Number Obs.	98	98	98
AIC	-5.433	-6.236	-5.432
HQIC	-5.337	-6.140	-5.337
SBIC	-5.195	-5.999	-5.195

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001. **Model 1**= VECM for Senegal market rice, **Model2**= VECM for Niger market rice, **Model 3**= VECM for Mali market rice.

Source: Authors's calculations.

As hilighted in the table 8, in the three price series, there is a significant long-run relationship between the world market and the domestic ones. About 65%, 57% and 56%, respectively for Senegal, Niger and Mali represent the variation in the world rice price transmitted. Both coefficients (β) are statistically significant at 1%. Even Mali which is an occasional importer due to its rice production, the value of β parameter is comparable to the one of Niger where the rice is becoming an important staple food in urban area. As the estimation is done in logarithms, the percentages above can also be interpreted as the long-run elasticities of the domestic price with respect to the international price.

The parameter α represents the error correction coefficient as the speed of adjustment. Taking this coefficient in absolute value, it is important to point out that Senegal (31%) has a high speed of adjustment regarding the long-run equilibrium. It is followed by Mali (26%) and Niger (21%). Those results are similar with the ECM ones (table 7) and are realistic accordingly to the fact that we worked with imported rice prices in Dakar, Niamey and Bamako.

According to Sharma (2002) in his paper on market integration analysis between several Asian wheat markets and the world market, the conclusion was that the countries where government intervenes in the domestic market through various policy instruments, the error correction coefficients were estimated to lie between -0.01 and -0.07 indicating a slow adjustment to the long run relationship. In this research it was the case of Pakistan, India, Sri Lanka and Indonesia.

In Senegal, Niger and Mali with respectively a correction error term of -0.31, -021 and -0.26, we can assume that since the beginning of the 1990 (1994-1995), the market rice was liberalized with some competition even they remain some oligopsonic behavior during the crisis.

7. Conclundig remarks and policy implications

In this paper we decide to work on rice market in countries with different patterns in West Africa where rice is becoming an important staple food due to population growth, rapid urbanization, increasing incomes and urban consumer's preferences in terms of cost and ease of cooking.

Senegal is located in the Western Basin while Mali and Niger are respectively located in Central and Eastern Basins. Those countries have different pattern in rice consumption. Senegal has a high rate of consumption (around 73 kg/person/year) and Mali is in the Intermediate class with about 52 kg/person/year as rate of consumption. Niger, the third country chosen is in the last class of the lowest level of rice consumption (environ 15 kg/person/year).

Using monthly retail prices of imported rice from January 2004 to April 2012, this paper worked on returns to handle rice price volatility at the world market and in three selected countries in West Africa (Senegal, Niger and Mali). By using the ARCH/GARCH model, this research measure and compare the conditional volatilities of rice prices in the three countries. In terms of main findings, the econometric model ARCH-GARCH shows that at the world market level, volatility of return rice prices is highly influenced by the volatility of the last month (57%) and by the errors squared of last month at 47%. According to the mean equation, we find that the returns in rice prices are influenced at 32% by the previous returns (one month before).

At the domestic markets level, econometric results on the Senegal rice market show that volatility of rice price returns is strongly influenced by the volatility of the last month (70%) and by the errors squared of last month at 63%. This shows that the country like Senegal is facing directly high volatility. In the Niger rice market, the econometric model says that volatility of returns in rice price is highly influenced by the volatility the errors squared of last month at 61%. In the Mali rice market, the econometric model shows that rice price volatility faces high volatility caused by the errors squared of last month at 81%.

The second component of this research was to mobilize econometric tools like the Vector Error Correction Model (VECM), the Error Correction Model (ECM) to estimate short-term and long-run transmission rice price between the world market and the domestic ones. These kinds of tools allow also appreciating the speed of adjustment to long-run equilibrium by estimating the Error Correction coefficient. The main findings highlight that there is a significant long-run relationship between the world market and the domestic ones. About 65%, 57% and 56%, respectively for Senegal, Niger and Mali represent the variation in the world rice price transmitted. Both coefficients (β) are statistically significant at 1%. Even Mali which is an occasional importer due to its rice production, we have the same percentage as Niger where the rice is becoming an important staple food in urban area. As we worked with logarithms, the percentages below can also be interpreted as the long-run elasticities of the domestic price with respect to the international price.

The parameter α represents the error correction coefficient as the speed of adjustment. Taking this coefficient in absolute value, it is important to point out that Senegal (31-35%) has a high speed of adjustment regarding the long-run equilibrium. It is followed by Mali (26%) and Niger (21%). Those results are similar with the ECM ones and are realistic accordingly to the fact that we worked with imported rice prices in Dakar, Niamey and Bamako.

In terms of **policy implications**, this paper points out two elements:

-Looking at the descriptive statistics relate to the price series used in this research, we have seen that during the recent price spikes, in two countries out of three analyzed (Senegal and Niger), rice prices increased more than the world market price level. With that, we can assume that instead world prices, other elements could explain the high volatility in domestic markets like: supply shortages and policy intervenes. To avoid that developing countries and especially West-African countries could take advantage in strategies that aim to increase self-sufficiency. Mali is one example in this research. Politicians could also learn from the recent spikes experiences and evaluate some interventions which have bad implications in reducing volatility.

-In the recent past, most of the West-African countries have put huge means in infrastructures like irrigation to develop self-sufficiency and then improve accessibility to rice as it is becoming a staple food (Urban area). To reduce vulnerability of the rice market, Politicians/developers would assess the needs in the whole value chain of rice sub-sector. If processing, marketing and purchase capacity (incomes) of people are not improved, availability does not mean accessibility.

In terms of **applied research**, also two elements are highlighted in this research:

-Economic theory often suggests that certain subset of variables should be linked by a long-run equilibrium relationship but the variables under consideration may drift away from equilibrium for a while. When using long time series, it would be useful to assess the break points in the trends. This is important for an accurate evaluation of any program or policy intended to capture some structural changes using some cointegration tests of structural breaks like Zivot and Andrews test (1992).

-As Minot (2011) raised the question relate to the thresholds in world market to allow a co-movement in the domestic markets, this research points out the same question. It seems that there is a kind of threshold price difference between world and domestic market of rice below which co-movement in prices ceases. According to the reality assessed in the three different countries (status of net importers,…), we can assume that this threshold could be different regarding to the dependency on the world market. And then, how the changes transmitted from the world market to the urban markets (Dakar, Niamey and Bamako in our case study) are transmitted in small towns located in rural area?

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