CENTRE D'ETUDES
ET DE RECHERCHES
SUR LE DEVELOPPEMENT
INTERNATIONAL

Document de travail de la série

Etudes et Documents

E 2011.28

Are grain markets in Niger driven by speculation?

Catherine ARAUJO BONJEAN

Catherine SIMONET

Septembre 2011

CERDI
65 BD. F. MITTERRAND
63000 CLERMONT FERRAND - FRANCE
TEL. 04 73 17 74 00
FAX 04 73 17 74 28
www.cerdi.org

Les auteurs

Catherine Araujo Bonjean
CNRS Researcher, Clermont Université, Université d'Auvergne, CNRS, UMR 6587, Centre d'Etudes et de Recherches sur le Développement International (CERDI), F-63009 Clermont-Ferrand, France
Email : C.Araujo-Bonjean@u-clermont1.fr

Catherine Simonet
PhD student, Clermont Université, Université d'Auvergne, CNRS, UMR 6587, Centre d'Etudes et de Recherches sur le Développement International (CERDI), F-63009 Clermont-Ferrand, France
Email : cat.simonet@gmail.com

Corresponding author: C.Araujo-Bonjean@u-clermont1.fr

La série des *Etudes et Documents* du CERDI est consultable sur le site :
http://www.cerdi.org/ed

Directeur de la publication : Patrick Plane

Directeur de la rédaction : Catherine Araujo Bonjean

Responsable d'édition : Annie Cohade

ISSN : 2114-7957

Avertissement :

Les commentaires et analyses développés n'engagent que leurs auteurs qui restent seuls responsables des erreurs et insuffisances.

Abstract

Over the last two decades, millet prices in Niger have enjoyed periods of spectacular growth followed by rapid reversals. During these periods of boom, millet prices seem to deviate from fundamental values. These deviations may be attributed to the presence of rational speculative bubbles. Considering millet as a “food asset” we develop a millet pricing model and test for the presence of periodically and partially collapsing bubbles for 15 millet markets of Niger. The test strategy consists in estimating price deviations from fundamental values and exploiting the theoretical properties of bubbles. The residual augmented least squares (RALS) Dickey-Fuller tests do not rule out the presence of bubbles in millet prices. Moreover, the estimation results from a M-TAR model that captures the asymmetries in the adjustment process of prices to fundamentals, do not reject the presence of rational bubbles for most of the sample markets. Lastly, an attempt is made to identify the origin and collapse date of bubbles using recursive and rolling ADF tests. Results show that small markets, located in deficit and remote areas are more prone to speculation than larger markets of the main producing and consuming regions.

JEL Classification: Q18, C22, D40, G14, O18

Key Words: periodically collapsing bubbles, M-TAR, Residual Augmented Least Square, Recursive ADF test, millet market, Niger

Introduction

Over the past 20 years, grain markets in Niger have experienced numerous large positive price shocks followed by rapid reversals. These shocks, whose duration is typically less than one year, are transitory but constitute a threat for poor households dependent on markets for food security. These periods of price spikes sometimes lead to a severe food crisis, as was the case in Niger in 2005.

These recurrent episodes of high local foodgrain prices are mostly related to a rainfall shock and a deficit in domestic production. The episodes of price increase recorded in 2008 are an exception; they are the consequence of the international food crisis. However the correlation between the extent of the food deficit and the price increase is difficult to establish. This may be due to the difficulty in measuring grain production. Millet is produced by numerous small farms scattered throughout the country and production is poorly recorded. As a matter of fact, production data are revised several times during the growing season and corrected several months after the harvest. Measurement errors may therefore explain the low correlation between prices and production.

Non competitive markets may also explain the apparent discrepancies between prices and food availability. In developing countries, traders are often considered as responsible for grain price increases. They are blamed for taking advantage of their monopsony power and for speculative stockholding. However, another explanation can be found in Sen's work on the origin of famines when there is no decline in food availability. For instance, Ravallion (1985) showed that the 1974 famine in Bangladesh cannot be imputed to a rice production deficit but to stockholders over optimistic price expectations. Such market "irrational exuberance" has been evidenced on equity markets but few works aim at studying this phenomenon on commodity markets of developing countries.

Yet the presence of rational speculative bubbles can explain the dramatic price increases followed by a sudden reversal that have been observed at different periods of time in the grain markets of Niger. It can also explain why the early warning system for preventing food crises, which is mainly based on the monitoring of crop growth, has been poorly effective in anticipating steep rises in prices despite technological advances that allow a more accurate monitoring of harvests (for instance through satellite observations).

Rational speculative bubble results from a self-fulfilling belief based on intrinsically irrelevant information that is not related to market fundamentals (Diba and Grossman, 1988). For instance, if agents anticipate an increase in grain price whereas these expectations are not based on changes in the fundamentals, the grain demand will increase moving the price away from its intrinsic value. Rational bubble is consistent with the efficient market hypothesis and the no arbitrage condition. It can be derived from a basic asset pricing model assuming competitive markets and rational expectations with no informational asymmetries. Agents know that the asset is overvalued but they are ready to pay more for the asset than its intrinsic value if they expect to sell it at an even higher price. Bubbles increase at the required rate of return and bursts when agent's expectations return.

In Niger investors in grain market operate in a highly uncertain environment that is likely to favour self-fulfilling beliefs. Information on the climatic and agronomic conditions of crops but also on economic variables is generally very poor. For instance, the intervention of government and external aid agencies, and their modalities, in case of food risk are all the more uncertain. Incompleteness of information as well as agents' lack of confidence in the information given by public authorities may fuel rational bubbles.

Rational bubbles are difficult to detect. There is now an abundant and continually renewed literature aiming at testing for the existence of rational bubbles on stock markets. Paradoxically while commodity markets are generally considered as highly speculative few works aim at testing for speculative bubbles on these markets.

In this paper, we consider millet as a food asset that can be held for long periods. Using a model for a storable good we show that, like other financial assets, the millet price depends on a fundamental component and a potential rational bubble. Following on Evans (1991) we consider a specific class of rational bubbles *i.e.* periodically and partially collapsing speculative bubbles (PCB). PCB are non linear processes that are explosive during the phase of bubble eruption but may be stationary on the whole period. To test for the presence of such bubbles the empirical strategy consists first in estimating the bubble component of prices as the difference between the millet market price and its fundamental value. Then, we explore the statistical properties of bubbles using three approaches. First we use the residual augmented least squares Dickey-Fuller tests to correct for skewness and kurtosis. Second, a M-TAR model is estimated that allows to test for asymmetry in bubble's process. Third, forward recursive and rolling *ADF* tests are conducted to detect explosiveness in bubble's dynamic. The results do no reject the presence of rational bubbles on nine markets under the 15 markets under study but reject the presence of bubbles on the main markets of Niger.

The paper is organized in the following manner. Section 1 displays the main characteristics of millet prices on the last two decades. Section 2 presents the rational bubble model for millet and the theoretical characteristics of bubbles. Section 3 is devoted to the empirical test strategy. The last section concludes.

1. Millet price fluctuations in Niger since 1990

Millet is the staple diet of the population and the main food crop in Niger. Millet covers 65 % of cultivated land and represents about ¾ of the cereal production (IRD, 2009). It is the best adapted crop to arid and semi-arid areas of Niger. Millet is grown in the part of the Sudano-Sahelian region where annual rainfall varies between 500 and 700 mm. It is a rainfed crop cultivated by small traditional farmers using low input agricultural pratices. As a consequence, millet production is highly vulnerable to pest attacks and weather conditions.

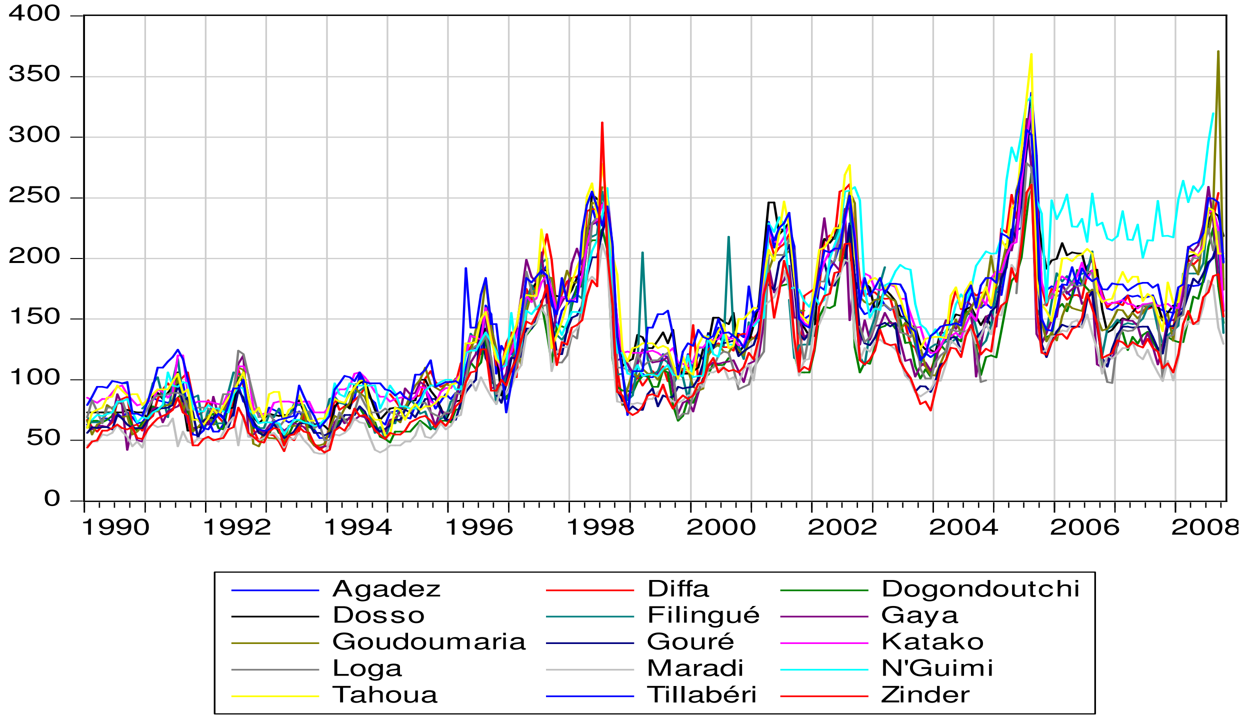
Millet has a short growing cycle of about 90 days. The crop calendar varies depending on the beginning of the rainy season, which generally starts in May and ends in October. Land preparation and planting are progressing with the arrival of the monsoon rains. Sowing takes place from May to August, harvests start in September and last until December. The success of the campaign mainly depends on the level of precipitations as well as their temporal and spatial distribution during the rainy season.

Millet can be stored for several months, over more than one year. Three categories of agents hold stocks: farmers, wholesalers and the public authorities. Most grains are stored at the farm level but these stocks are difficult to assess. As a general rule, stocks are built during the harvest season and held for at least one year. They are intended to cover the households' food needs until the next harvest and meet the farm demand for seeds. However, many farmers with low production level are net buyers of grain. Their production is not sufficient to cover their food needs or they may be forced to sell millet early in the crop marketing season to meet their cash needs. Wholesalers hold stocks over short periods generally not exceeding two months with the result that the rate of stock turnover is high (Aker, 2010). Public safety stocks are renewed by tender during the first months of the year[1].

The production cycle generates large seasonal price fluctuations. Millet prices are lower during the harvest and post-harvest season from September to January. Then they gradually go up and culminate at the end of the lean season[2] from July to September. The amplitude of the seasonal movement in prices is particularly important in Niger where prices rise on average by 40% between January and August.

Millet is the subject of intensive cross-border trade in West Africa but it is not traded on international markets. Niger is structurally importer of millet. Its main source of imports is Nigeria but imports from Mali and Burkina Faso have been expanding during the last decade. Because of the strong correlation of climate shocks within the sub-region, trans-border trade does not really play a regulating role. Trade dampening effect on prices is weak and millet prices are the subject of large variations from one year to another in relation with climate fluctuations.

Figure 1. Millet prices in Niger, Fcfa/kg, January, 1990- October, 2008



Source: SIMA

A market information system (SIMA) has been implemented in Niger at the end of the 80s that collects market prices for major agricultural products. Market price information is disseminated to producers, consumers and traders through the media. SIMA has now

[1] Unfortunately, information on the level of public stocks and dates of operation is not available.
[2] The "lean season" is the period that precedes the harvest during which granaries are depleted.

accumulated a large amount of data and can trace the evolution of food prices in a large geographical area and for a wide range of commodities.

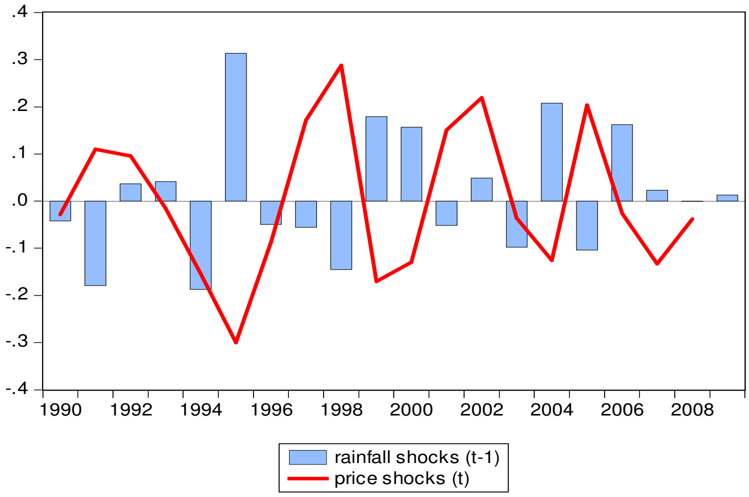
We selected a sample of 15 millet markets from the markets covered by the SIMA. Market selection has been based on the quality of available information: markets for which too many data are missing have been dropped from our sample. The selected sample includes a variety of markets that differ according to their location: remote area, border proximity, production or urban area. The observation period starts in January 1990 and ends in October 2008.

Figure 1 depicts the evolution of millet prices on the past two decades. Except for N'Guimi during the end of the period, prices follow a common trend punctuated by large positive shocks. Figure 2 focuses on the evolution of real millet price in the capital city – Niamey – in relation with the cumulated rainfall during the preceding year[3]. Considering that rainfall is the main component of the fundamental value of millet, Figure 2 evidences periods during which prices deviate from their fundamental value.

Except for the 2008 shock that corresponded to the international food crisis, most of the episodes of price boom have been recorded after a rainfall deficit. This was the case in 1996-1998 and 2005. The price increase during 1996-1998 corresponded to three consecutive years of rainfall deficit, the larger one being registered in 1997. Prices reached again high levels in 2005 after the 2004 drought. Note that the more severe drought registered during the 1990 rainy season did not resulted in a sharp price increase in 1991.

A more puzzling situation occurred in 2001-2002. After two consecutive years of excess rainfall, a small rainfall deficit during the rainy reason generated a sharp price increase in 2001. Moreover, price kept increasing in 2002 whereas the rainfall level was above its mean. In 1992 also, millet prices registered a positive shock that was not related to a negative rainfall shock. These abnormal price evolutions relative to rainfall may reflect the presence of speculative bubbles.

Figure 2. Real millet price in Niamey and rainfall shocks[4]



Source: SIMA and author's calculations

[3] The rainfall variable is delayed to take into account the production cycle.

[4] Shocks are calculated on an annual basis as the difference between the price (or cumulated rainfall) level at year *t* and the mean (cumulated rainfall) for the 1990-2008 period. They are expressed in percentage of the mean price (cumulated rainfall).

The outlandish price evolution in 1994 is partly the consequence of the Franc CFA devaluation. The severe rainfall deficit recorded during the 1993 rainy season - the most important deficit of the period - was not followed by a sharp increase in current millet price (Figure 1). In real value millet price fall down due to the high level of inflation generated by the 1994 devaluation (Figure 2).

2. A rational bubble model for millet

According to the preceding observations, speculative behaviour on millet markets may have exacerbated climate shock effects, leading to price spikes and increased food insecurity. Before proceeding to econometric tests for the existence of price bubbles, we develop a simple asset-pricing model assuming rational expectations. We then focus a specific class of rational bubbles and highlight their statistical properties. A short literature survey illustrates the main difficulties in testing for the presence of speculative bubbles and exposes the main test strategies.

The millet pricing model

We consider a simple model for millet price with linear supply and demand[5]. Market equilibrium is given by the set of equations (1) to (3).

Net supply (Q) in period t is positively related to the current price of millet:

$$Q_t = a_t + bP_t + \varepsilon_t \qquad b > 0 \qquad (1)$$

P_t is the millet price level in period t
a_t is an index that depends on current and lagged values of y_t a vector of exogenous supply and demand variables.

Farmers and traders withhold supply if they expect future price to be sufficiently high to compensate for storage costs and losses. Assuming risk-neutral stockholders, demand for stocks in period t (S_t) is positively related to the price spread between the future expected price and the current price:

$$S_t = c(E_t P_{t+1} - P_t) + d_t + w_t \qquad c > 0 \qquad (2)$$

d_t is an index that depends on a vector of variables reflecting the opportunity cost of holding millet.
$E_t P_{t+1}$ is the expected price of millet in period t+1
E_t is the conditional expectations operator
ε_t and w_t are zero-mean, finite variance, serially uncorrelated disturbance terms. They are for unaccounted variables on the demand and supply side.

The millet market equilibrium is given by:

$$S_t = Q_t + S_{t-1} \qquad (3)$$

[5] This model draws on Ravallion (1985), Hwa (1979), Pindyck and Rotemberg (1990), Quddus et Becker (2000).

S_{t-1} is the initial stock.

The market clearing price solves (3) at each point in time so that:

$$E_t P_{t+1} = \lambda P_t + x_t + \mu_t \quad (4)$$

where: $\lambda = \dfrac{b+c}{c} > 1$ and $x_t = a_t - d_t \;\; \mu_t = \varepsilon_t - w_t + S_{t-1}$

x_t is a forcing variable; it is an index that depends on a vector of variables reflecting the market fundamentals.

μ_t is an error term including the initial stocks, which accounts for unobserved variables to the researcher.

Equation (4) relates the current millet price to the next period expected price, variables determining fundamentals and to an unobserved variable (μ). It is a first order difference equation in P. Given that the eigenvalue of the system (λ) is greater than unity, the forward-looking solution of equation (4) for P involves two components:

$$P_t = B_t + F_t \quad (5)$$

F_t is the market-fundamentals component and B_t is a potential rational-bubbles component (Blanchard, 1979, Blanchard and Watson 1982, Diba and Grossman, 1987, 1988).

Under the assumption that $E_t(x_{t+j}+\mu_{t+j})$ does not grow at a geometric rate equal or greater than λ, F_t is a convergent sum (Diba and Grossman, 1987):

$$F_t = E_t \sum_{i=0}^{\infty} (\lambda^{-(i+1)} x_{t+i} + \mu_{t+i}) \quad (6)$$

The market-fundamentals component of the millet price relates to the expected value of the exogenous variables determining supply and demand.

In contrast to the fundamental component, the bubble part, B_t, is not stationary. B_t is the solution to the homogenous expectationnal difference equation:

$$E_t B_{t+1} - \lambda B_t = 0 \quad (7)$$

If B_t is different from zero there exists a rational bubble that is self-fulfilling. The conditional expectations of the bubble are explosive:

$$E_t B_{t+j} = \lambda^j B_t \;\; \text{for all } j > 0 \quad (8)$$

The presence of a self-fulfilling rational bubble does not violate the no arbitrage condition. The bubble is expected to grow at the required rate of return.

Periodically and partially collapsing bubbles

Following Blanchard and Watson (1982) and Evans (1991) we focus on a class of rational stochastic bubbles that periodically collapse and regenerate: the so called Periodically Collapsing Bubble (PCB) given by (9a) and (9b):

$$B_{t+1} = \lambda B_t u_{t+1} \qquad \text{if } B_t \le c \qquad (9a)$$

$$B_{t+1} = \left[\delta + \frac{\lambda}{\pi}\theta_{t+1}\left(B_t - \lambda^{-1}\delta\right)\right]u_{t+1} \qquad \text{if } B_t > c \qquad (9b)$$

δ and θ are positive parameters. u_{t+1} is an exogenous independently and identically distributed positive random variable with $E_t u_{t+1} = 1$. θ_{t+1} takes the value 1 with probability π and 0 with probability 1- π, where $0 < \pi < 1$.

The PCB process switches between two regimes depending on the bubble being above or below the threshold value c.

This bubble process satisfies equation (7) since the expected growth rate of the bubble is always λ. For $B_t < c$ the bubble increases slowly at mean rate λ; if B_t rises above the threshold it expands faster at the mean rate $\lambda\pi^{-1}$ but may collapse with probability 1- π. The bubble grows at a higher rate during expanding phases to compensate the investor for the possibility of collapse. When the bubble collapses, it falls to a mean value of δ, and the process begins again (Evans, 1991).

As a consequence periodically collapsing bubbles not only account for occasional asset price crashes but also for rapid run-ups in asset prices before a crash.

Testing for periodically and partially collapsing bubbles

Most of empirical tests for rational speculative bubbles are indirect tests that exploit the theoretical properties of bubbles. Bubbles are explosive process that should be detected through stationarity tests (Diba and Grossman, 1984, 1988). Thus many authors have aimed at establishing the presence of rational bubbles by testing asset price stationarity and cointegration between the asset price and observable fundamentals (see Gurkaynak, 2008 for a survey). However as shown by Evans (1991), Charemza and Deadman (1995), Waters (2008), linear unit root tests are not able to detect collapsing bubbles that only exhibit characteristic bubbles properties during the expansion phase. Standard tests for unit root and cointegration reject the presence of bubbles even when such bubbles are present (van Norden and Vigfusson, 1996).

Taylor and Peel (1998) proposed a unit root test, namely the residuals-augmented Dickey–Fuller (RADF) test, with smaller size distortion when data exhibit strong skew and kurtosis, which is typically the case of PCB processes. For their part, Hall and Sola (1993) and Hall et al. (1999) proposed a switching ADF test allowing for the possibility of two regimes in the data generating process: the data are non-stationary in one regime and stationary in the other one, collapsing back towards the fundamental solution. The probability of observing the collapsing regime is assumed to follow a first order Markov process.

Evidence that one regime is non-stationary while the other is stationary indicates the presence of a bubble.

Alternatively, Bohl (2003), Bohl and Siklos (2004), Payne and Waters (2007) proposed to test the periodically collapsing bubbles model of Evans, using the momentum threshold autoregressive (M-TAR) model that is a generalization of the Dickey-Fuller test developed by Enders and Granger (1998) and Enders and Siklos (2001). The M-TAR adjustment model is able to capture the asymmetrically sharp adjustments towards the long run equilibrium that is typical for periodically collapsing bubbles (Bohl 2003).

Van Norden and Schaller (1993, 1996) and van Norden (1996) proposed an additional test to detect PCB, which is based on a two-state switching model. In the surviving state, the expected excess return is an increasing function of the relative size of the bubble whereas it is a negative function in the collapsing state. The probability of being in the surviving regime decreases as the relative size of the bubble grows. More recently, Phillips, Wu and Yu (2009) developed an approach related to the Markov switching model of Hall et al. (1999) based on a recursive test procedure. Their method allows both to detect explosiveness in the bubble process to locate the starting and ending date of the bubble. Their method consists in implementing right-tailed unit root tests in a recursive way.

Following on this empirical literature we explore in the next part of the paper the statistical properties of the deviation of millet prices from observed fundamentals.

3. Empirical strategy

Our test strategy aims at detecting periodically collapsing bubbles (PCB) such of the Evans' type. First we estimate the fundamental component of the millet price and the potential bubble term before investigating the dynamic properties of the bubbles. Second, we implement the residual ADF test of Taylor and Peel (1998). Then we estimate an M-TAR model to test for asymmetry in the bubble process. Lastly we implement the recursive and rolling ADF test of Phillips et al. (2009) to test for explosiveness in the bubble process and to identify the origin and collapse date of bubbles.

3.1. Measurement of potential bubbles

To measure bubbles we need an empirical model for the fundamental value of millet. Following Pindyck and Rottemberg (1990), we assume that forecasts of x_t in Eq (6) are based on its current and past values. x_t includes observable exogenous variables that determine millet supply and demand and all relevant information about future net supply.

Most previous studies have shown that millet markets in Niger are fairly well spatially integrated (Araujo et al., 2010). As a consequence the fundamental value of millet in Niger is assumed to be determined at the national level by aggregate supply and demand. The fundamental value is only allowed to vary between markets by a constant term. These market specific effects catch differences in price level that are related to the geographical location of markets. In other words, specific effects measure fixed transaction costs associated to the location of markets.

The fundamental value of millet is therefore estimated using panel data for the 15 millet markets on the period 1990-2008. The estimated equation is given by (10):

$$P_{it} = \alpha_1 Rainfall_t + \alpha_2 CumulRainfall_t + \alpha_3 CPI_t + \alpha_4 .Gasoline_t + \sum_{s=1}^{12} \varphi_s M_{st} + \varepsilon_i + \nu_{it} \qquad (10)$$

P_{it} is the millet price on market *i* at time *t*.

$Rainfall_t$ is the monthly rainfall level. This is an information variable that is useful to predict the future harvest.

Cumul rainfall$_t$ is the cumulated level of rainfall over the rainy season (from May to October) in the main production area[6]. It takes a constant value from October *t-1* to September *t* (the crop year). This is an exogenous variable that aims at capturing the state of millet availability for the current period.

$Gasoline_t$ is the price of gasoline in Niger. This variable is a proxy for production and trade costs that vary with the oil price.

CPI_t is the consumer price index in Niger

M_s are monthly dummies that capture seasonal price variations

ε_i are market specific fixed effects

ν_{it} is the error term. It includes all factors not explained by right-hand variables.

The fitted value of P_{it} that derives from Eq(10) is taken as a measure of the fundamental value of millet and ν_{it} is the apparent deviation of the price in the *i* market from its fundamental value[7] at time *t*. Of course, the fundamental value may be misspecified leading to measurement errors in the bubble term. However, the tests are invariant to linear transformation of B_t. Therefore a misspecification of the level of the bubble will have no effect on the unit root and TAR tests for bubbles (van Norden, 1997).

Estimation results are given in Table 1. As expected, gasoline price enters positively in the fundamental equation. The current rainfall level and the cumulated rainfall level, which represent, respectively, the future harvest and the current millet availability, negatively affect the fundamental value of millet. Mean prices in Maradi, Zinder, Dogondoutchi, Gouré, which are located in the main producing region of Niger close to the Nigerian border, are below the average price level. Mean price in N'Guimi is the highest; N'Guimi is located in a remote area close to the Tchadian border. Prices are also higher in Niamey the main consumption market of Niger.

[6]Rainfall data come from *Global Air Temperature and Precipitation: Gridded Monthly and Annual Time Series (Version2.01)* interpolated and documented by Cort J. Willmott and Kenji Matsuura (with support from IGES and NASA), University of Deleware. For more information see Legates et al. (1990a 1990b) and Willmott and Matsuura (1995). The data base gives monthly precipitation for the 1900-2008 period, interpolated to a 0.5 by 0.5 degree grid resolution. The variables *Rainfall* and *Cumulated rainfall* are respectively the mean rainfall level and the mean cumulated rainfall level calculated on observations below 14 degrees latitude (considered as the limit of the production area in Niger).

[7] Measuring bubbles as the residuals of a price regression on fundamental value generates positive and negative apparent bubbles although there are theoretical arguments against negative bubbles (Diba and Grossman, 1988). Following Schaller and van Norden, (1997), we consider that ruling out negative bubbles would imply an extreme form of rationality that is not convincing (Blanchard and Fisher, 1989). In what follows we only consider positive bubbles.

Table 1. Estimation of the fundamental value of millet

Dependent variable: current millet price			Fixed effects
Gasoline	0.039	Agadez	4.683
	(0.000)	Diffa	7.436
CPI	1.995	Dosso	9.441
	(0.000)	Gaya	-5.337
Cumulated Rainfall	-0.225	Katako (Niamey)	11.846
	(0.000)	Maradi	-25.684
Rainfall	-0.202	Tahoua	14.119
	(0.000)	Zinder	-20.859
Monthly fixed effetcs	yes	Goudoumaria	1.702
Cross-section fixed effect	yes	Nguimi	19.625
Adjusted R-squared	0.753	Dogondoutchi	-15.798
Nb of obs	3331	Loga	-5.704
		Filingue	0.484
		Goure	-11.427
		Tillaberi	15.567

P-value in parenthesis. Stationarity tests are given in the appendix.

As an illustration, Figure 3 shows the estimated fundamental component of the millet price in Niamey (Katako market). The deviation between the current price and the fundamental component represents the bubble part.

Figure 3. Fundamental component of the millet price in Katako (Niamey) (Fcfa/kg)

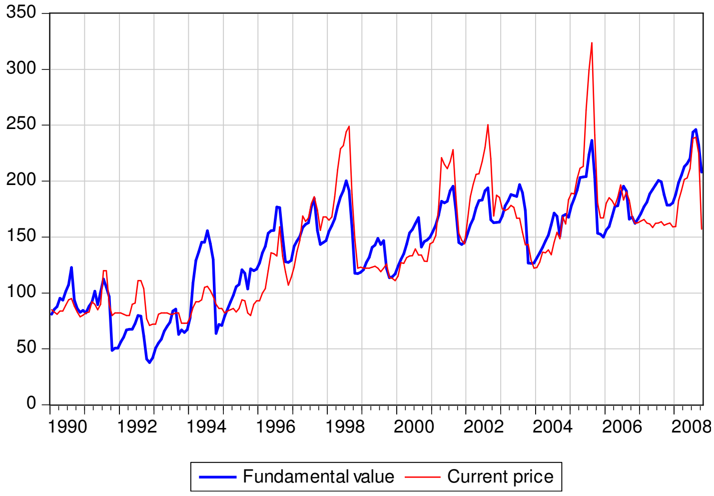


Figure 3 highlights four periods during which the millet price in Katako rose dramatically beyond its fundamental value: 1998, 2001, 2002 and 2005. A deeper analysis shows that apparent bubbles break out at the beginning of the lean season and end with the arrival of the new harvest (Araujo et al. 2010) In other words, prices increase exponentially from March/April to July/August; they then crash to their initial level within one month.

3.2. Testing for unit root in the bubble process

Following the seminal work of Diba and Grossman (1984) and (1988), we investigate the stationary properties of millet price deviation from fundamental value.

Residuals from Eq. (10), which represent the bubble component of millet prices, exhibit both skewness and excess kurtosis (Table 2). The Jarque Bera test rejects normality for all markets except Maradi and Loga, at the 5 % confidence level. Note that non normality is consistent with the presence of periodically collapsing bubbles (Taylor and Peel, 1998, Payne and Waters 2007).

The standard ADF test which equation is given by (11) rejects the unit root null hypothesis in all cases. However this test is not very informative. As shown by many authors it fails to reject stationarity in presence of PCB which may be stationary on the whole period but are locally explosive.

$$\Delta B_t = \theta B_{t-1} + u_t \tag{11}$$

We thus implement the Residual Augmented Least Squares (RALS) Dickey-Fuller test developed by Taylor and Peel (1998) (see also Im and Schmidt, 2008). The RADF test is robust to skewness and kurtosis in the distribution of the residual term and is more powerful in detecting periodically collapsing bubbles. The RADF test equation is given by:

$$\Delta B_t = \theta B_{t-1} + \gamma \hat{w}_t + \xi_t \tag{12}$$

Where: $\hat{w}_t = [(\hat{u}_t^3 - 3\hat{\sigma}^2 \hat{u}_t), (\hat{u}_t^2 - \hat{\sigma}^2)]$. The vector $\hat{w}_t$ corrects the estimate of θ for skewness and excess kurtosis of the residuals. $\hat{u}_t$ are the residuals of equation (11) and $\hat{\sigma}^2$ the estimated variance ; ξ_t is white noise.

The test statistic is $\tau_A = \hat{\theta} / \sqrt{Var(\hat{\theta})}$

$\hat{\theta}$ is the estimated coefficient in Eq. (12); var($\hat{\theta}$) is the variance-covariance matrix of $\hat{\theta}$. It is given by Im and Schmidt (2008). Critical values are given by Sarno and Taylor (2003).

t-tests in the RADF equation confirm the presence of skewness and kurtosis in the potential bubbles. The RADF tests that correct for excess skewness and kurtosis do not reject the unit root hypothesis for four markets among the 15 markets under study: Dogondoutchi, Gouré, Katako and N'Guimi. However these tests alone do not provide sufficient evidence for the presence of bubbles.

Table 2. Bubbles' characteristics

	Agadez	Diffa	Dogondoutchi	Dosso	Filingué	Gaya	Goudoumaria	Gouré	Katako	Loga	Maradi	N'Guimi	Tahoua	Tillabéri	Zinder
Obs.	226	221	217	226	210	226	215	226	226	216	226	218	226	226	226
Skewness	0.736	0.611	0.326	0.571	0.700	0.433	1.354	0.405	0.501	0.315	-0.027	0.710	1.065	0.504	0.864
Kurtosis	4.307	3.123	2.600	3.350	3.788	3.324	6.371	3.979	3.435	2.777	2.668	3.107	5.518	3.705	7.038
Jarque Bera	36.509	13.872	5.289	13.412	22.589	8.042	167.527	15.223	11.215	4.028	1.067	18.405	102.420	14.257	181.679
Prob	*0.000*	*0.001*	*0.071*	*0.001*	*0.000*	*0.018*	*0.000*	*0.000*	*0.004*	*0.133*	*0.587*	*0.000*	*0.000*	*0.001*	*0.000*
ADF test (1)															
ρ	-0.166	-0.161	-0.200	-0.150	-0.319	-0.237	-0.276	-0.153	-0.142	-0.160	-0.149	-0.169	-0.213	-0.255	-0.223
t-stat	-4.509	-4.288	-4.760	-4.265	-6.139	-5.487	-5.618	-4.259	-3.975	-4.036	-4.136	-4.346	-5.190	-5.705	-5.280
RADF test															
θ	-0.172	-0.135	-0.101	-0.133	-0.210	-0.181	-0.151	-0.094	-0.099			-0.123	-0.166	-0.215	-0.159
$CR\tau_A$	-5.092	-3.973	-2.715	-4.248	-4.444	-4.541	-3.699	-2.767	-3.151			-3.391	-4.539	-5.210	-4.386
t-stat : Kurtosis	4.223	7.569	8.746	4.787	9.169	6.969	12.666	7.277	7.751			7.139	8.725	4.116	8.703
t-stat : Skewness	2.426	2.640	0.252	1.398	1.107	2.021	-1.221	1.678	0.609			-0.004	4.858	1.032	-4.281

(1): The test equation includes no intercept and no lagged difference terms. It is given by: $\Delta B_t = \rho B_{t-1} + u_t$

Critical value for $CR\tau_A$: -3.54 at the 5% level (Sarno and Taylor 2003 for a sample size equal to 156 observations)

Table 3. Results from the M-TAR model

	Agadez	Diffa	Dogondoutchi	Dosso	Filingué	Gaya	Goudoumaria	Gouré	Katako	Loga	Maradi	N'Guimi	Tahoua	Tillabéri	Zinder
ρ_1	-0.124	-0.190	-0.143	-0.093	-0.226	-0.167	-0.154	-0.040	-0.190	-0.169	-0.198	-0.124	-0.097	-0.286	-0.129
t-stat	-2.471	-4.362	-3.067	-1.951	-3.342	-2.805	-2.439	-0.816	-4.540	-3.684	-4.802	-2.698	-1.568	-4.562	-2.319
ρ_2	-0.218	-0.076	-0.404	-0.220	-0.479	-0.315	-0.461	-0.277	-0.016	-0.118	-0.003	-0.286	-0.303	-0.222	-0.350
t-stat	-4.003	-1.021	-4.463	-4.218	-5.934	-5.035	-6.141	-5.443	-0.240	-1.598	-0.040	-3.892	-5.580	-3.465	-5.470
R^2 adj	0.087	0.081	0.120	0.085	0.187	0.126	0.171	0.116	0.081	0.068	0.090	0.092	0.128	0.125	0.133
threshold	3.714	12.893	11.977	1.526	10.249	5.800	13.239	4.483	10.958	8.209	6.463	13.176	3.347	2.387	5.069
F-tests															
Φ	1.621	1.768	6.566	3.249	5.811	2.953	9.776	11.397	4.697	0.334	5.676	3.484	6.334	0.507	6.818
proba	0.204	0.185	**0.011**	**0.073**	**0.017**	**0.087**	**0.002**	**0.001**	**0.031**	0.564	**0.018**	**0.063**	**0.013**	0.477	**0.010**
$\rho_1=\rho_2=0$	11.067	10.033	14.663	10.802	23.193	16.611	21.829	15.147	10.335	8.062	11.529	11.213	16.800	16.411	17.647
obs	224	217	209	224	198	224	207	224	224.000	208	224	212	224	224	224

Critical values for H_0: $\rho_1 = \rho_2 = 0$: 5.58 (10 %); 6.62 (5%); 8.82 (1%) (Enders and Siklos, 2001).

3.3. Testing for asymmetry in the bubble process

PCB follow a non-linear process that can be detected using the momentum threshold autoregressive (M-TAR) model. This model is a generalization of the Dickey-Fuller test, proposed by Enders and Granger (1998) and Enders and Siklos (2001). As shown by Payne and Waters (2007) and Bohl (2003), the M-TAR model is well suited when the adjustment exhibit more momentum in one direction than the other. This is the case of PCB that increase exponentially until they reach a certain threshold level and suddenly collapse abruptly.

The M-TAR equation for the residuals from the price equation (10) is given by:

$$\Delta B_t = (1 - I_t)\rho_1 B_{t-1} + I_t \rho_2 B_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta B_{t-1} + \varepsilon_t \qquad (13)$$

I_t is an indicator function that depends on the level of ΔB_{t-1}:

$$I_t = \begin{cases} 1, & if \quad \Delta B_{t-1} \geq \tau \\ 0, & if \quad \Delta B_{t-1} < \tau \end{cases}$$

τ is the unknown threshold value. ε_t is an iid process with zero mean and constant variance.

The M-TAR model allows the speed and direction of adjustment, ρ_1 and ρ_2, to depend on the previous period's change in B_t. Following Payne and Waters (2007) our test strategy is based on the test of the null hypothesis of symmetry when the null of unit root is rejected. The rejection of the null hypothesis of symmetric adjustment with $|\rho_2|>|\rho_1|$ evidences the presence of periodically collapsing bubbles. Bohl (2003) demonstrated that this test has sufficient power to detect asymmetry when the DGP is given by the Evans' bubble model. If the estimated coefficient, ρ_2, is statistically significant and negative, and larger in absolute terms relative to ρ_1, there is evidence of a sharp correction when prices have risen above a certain threshold relative to fundamentals.

The threshold value τ is estimated using Chan (1993) procedure, searching over the potential threshold values so as to minimize the sum of squared errors from the fitted model. The lag length is selected according to the Akaike Information criterion.

Under the null hypothesis of a unit root in B_t, $\rho_1 = \rho_2 = 0$. The distribution for the test statistic is not standard; the critical values are provided by Enders and Granger (1998) and Enders and Siklos (2001). The null hypothesis of symmetry is tested by the restriction, $\rho_1 = \rho_2$ using the usual F-statistics (Φ).

The M-TAR estimation results (Table 3) lead to the rejection of the unit root hypothesis for all series. The *F* tests reject symmetry of adjustment at the 5% confidence level for six markets: Dogondoutchi, Filingué, Goudoumaria, Gouré, Tahoua and Zinder and at 10% for one market: N'Guimi. We thus do not reject the presence of speculative bubbles on these markets. We note that symmetry of adjustment is rejected at the 10% confidence level for three other markets: Dosso, Gaya and N-Guimi. Symmetry of adjustment is also rejected for Maradi and Katako but the coefficients ρ_1 and ρ_2 do not satisfy the condition: $|\rho_2|>|\rho_1|$. As a consequence, we the test results do not provide evidence for speculative bubbles on Maradi and Katako market.

Different sensitivity tests to alternative specifications of the fundamental value have been conducted. First, the international rice price has been introduced in the millet fundamental equation to take into account possible substitution effects at the consumption level between local and imported cereals. However this price is never significant. Second, the millet production has been introduced in the fundamental equation instead of the cumulated rainfall variable[8]. The results are unchanged except for N'Guimi that does not exhibit bubble characteristics anymore.

3.4. Testing for explosive behaviour in the bubble component

The forward recursive ADF test and the rolling ADF test implemented by Phillips, Wu and Yu (2009) allow testing for explosive behaviour, which is another characteristic of bubbles, and to estimate the origination and collapse date of bubbles.

Both procedures consist in testing iteratively the unit root null hypothesis against the right-tailed alternative hypothesis of explosive process. The test equation is given by (14):

$$x_t = \mu_x + \delta x_{t-1} + \sum_{j=1}^{J} \phi_j \Delta x_{t-j} + \varepsilon_{x,t} \qquad \varepsilon_{x,t} \sim \text{NID}(0, \sigma^2_x) \qquad (14)$$

The unit root null hypothesis is H_0: $\delta = 1$; the right-tailed alternative hypothesis is H_1: $\delta > 1$.

The lag order J is determined using significant tests of Campbell and Perron (1991). Starting with a maximum lag length $J_{\max}$, the optimal lag length is equal to $J_{\max}$ if the last included lag is significant at the 5 % level. Otherwise, the order of the autoregressive process is reduced by one until the coefficient of the last included lag is significant. The selection procedure of the optimal lag length is conducted for each sub-sample when applying the recursive and rolling tests. Following Schwert (1989), the upper bound of the lag length $J_{\max}$ is expressed as a function of the sample size[9]: $J_{\max} = [12*(T/100)^{1/4}]$. Other lag length criteria such as the Bayesian information criterion (BIC) and the Akaike information criterion (AIC) are used as robustness tests.

The forward recursive ADF test consists in estimating equation (14) repeatedly on subsamples incremented by one observation at each pass. The first subsample includes $\tau_0 = [nr_0]$ observations with r_0 a fraction of the total sample. The following subsamples encompass the first subset augmented successively by one observation so that the last subset corresponds to the full sample. The ADF_r statistic is computed for each recursive subsample, which includes $\tau = [nr]$ observations with $r \in [r_o, 1]$. Note that the recursive test encounters the same limit in detecting PCB than the conventional ADF test when the sample size becomes too large. The test can fail to detect PCB when observations that do not belong to an explosive process are included into the sample.

---

[8] Note that the correlation between rainfall level and production data is weak casting doubts on the reliability of production data. Indeed, production data are revised gradually during the crop year. Official and final data are published during the first trimester i.e. about 3 months after the end of the harvest season. Data are revised according to the state of the grain availability on markets during the main marketing season. These data may therefore suffer from endogeneity biais, food production deficit being revised upwards in case of price boom.

[9] [] signifies the integer part of the argument

The rolling ADF test is expected to perform better than the recursive ADF test in detecting short-lived bubbles. Under the rolling ADF test procedure, equation (14) is estimated repeatedly on a rolling subsample of size N. The first subsample includes the first observation to the Nth observation. The second subsample includes the second observation to the (N+1)th observation. In order to detect short-lived bubbles the test is implemented for low values of the subsample size, being aware that coefficients may be poorly estimated when the sample size is too small.

Phillips et al. (2009) identify the origination date r_e and the collapse date r_f of the explosive process comparing the recursive ADF test statistics with the standard Dickey-Fuller *t*-statistics. The origination date corresponds to the smaller but significant test statistic and the ending date corresponds to the higher but non significant test statistic:

$$\hat{r}_e = \inf_{s \geq r_0} \left\{ s : ADF_s > cv(s) \right\} \quad \text{and} \quad \hat{r}_f = \inf_{s \geq \hat{r}_e} \left\{ s : ADF_s < cv(s) \right\} \qquad (15)$$

$cv(s)$ is the critical value that changes at each pass with the sample size[10].

The authors consider as a bubble phase the consecutive time intervals during which the ADF test statistic is significant. This definition of bubble period is questionable for two reasons. First, a significant test statistic implies that the bubble follows an explosive process on the whole corresponding sample. In this respect, rolling ADF test on small samples may allow to capture the origination date of bubble with more accuracy. Second, a significant but decreasing test statistics indicates that the bubble is collapsing (Huang, 2008).

As a consequence, when using the rolling ADF tests, we will consider that the ending date of bubble is given by the last observation of the sample corresponding to the most significant test statistic. The origination date of bubble will be the first observation of the sample corresponding to the smaller but significant test statistic. The critical values for each subsample size considered in the rolling ADF procedure have been computed using Monte Carlo simulations with 100 000 replications.

Results of the recursive ADF tests are given in table 4. The *sup*-ADF statistics are significant for all millet price series rejecting the null hypothesis of unit root in favour of the alternative hypothesis of explosive behaviour. On the contrary there is no evidence of explosive behaviour in the fundamental component of millet prices. These results, which suggest the presence of explosive bubbles, are not corroborated by recursive ADF test conducted on the bubble component of prices. These tests, which are not significant for any market, are not reported. As an illustration, Figure 4 plots the recursive ADF statistic for the current price and for the fundamental component of millet price in Maradi. The comparison of the test statistics for the current price and the fundamental value of millet highlights an explosive bubble period running from January 1997 to September 1998. However the test statistic for the residual term is not significant.

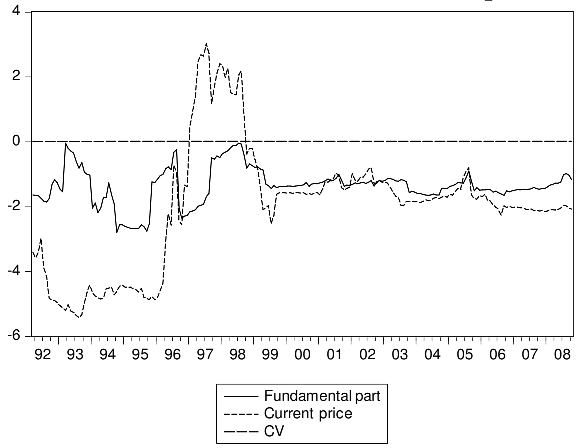
[10] Critical values are given by: $cv(s) = \log(\log(ns))/100$; they correspond to a significance level around 4% (Phillips et al., 2009).

Table 4. Sup ADF tests and origin and collapse date of bubbles

Millet price in:	sup ADF	AR(1) coef	Starting date	Ending date
Agadez	2.681	1.193	Apr-97	Oct-98
Diffa*	1.340	1.086	Jul-97	Sept-98
Dogondoutchi*	2.183	1.131	Aug-95	Sept-95
			Jul-97	Sept-98
Dosso	4.692	1.232	June-96	Dec-98
Filingué*	3.276	1.184	Sep-97	Oct-98
Gaya	3.706	1.230	Jul-97	Nov-98
Goure	4.590	1.213	Feb-97	Nov-98
Maradi	3.027	1.224	Janv-97	Sept-98
Niamey	4.024	1.162	Dec-96	Oct-98
N'Guimi*	2.623	1.105	June-96	Sept-98
Tahoua	3.148	1.251	March-98	Dec-98
Tillabéri	1.839	1.102	Aug-96	Oct-96
			March-97	Apr-97
			Jul-97	Nov-98
Zinder	4.762	1.271	Apr-96	Dec-98
Fundamental value	-0.026	0.999		

Critical value for sup ADF: 2.094 (1%), 1.468 (5%), 1.184 (10%) (Phillips et al., 2009)
The initial subset covers the period from January 1990 to April 1992 (corresponding to $r_0 = 12\%$)
The fundamental value only differs between markets by a constant that do not affect *ADF* tests.
*: some data are missing

Figure 4. Recursive ADF_r statistics for millet price in Maradi



The failure of recursive ADF tests to detect periods of explosive behaviour in bubble process can be due to the short-lived nature of bubbles on millet markets. To check the robustness of these results, rolling ADF tests, with the initialisation date rolling forward, are implemented for the potential bubble part of millet prices on subsamples of different size. Results are reported in table 5 and Figure 5 in the appendix.

Table 5. Most significant ADF statistics for bubble part

	AR(1) (tstat)	Bubble's period	Sub-sample size
Agadez	0.114 (0.831)	03.07 - 05.08	n = 25
	0.039 (0.409)	95.05 - 98.08	n = 40
Diffa	0.054 (0.513)	94.10 - 98.06	n = 45
Dogondoutchi	0.148 (0.934)	98.12 – 02.08	n = 45
Dosso	ns		
Filingué*	0.101 (0.816)	03.08 – 05.08	n = 25
Gaya	ns		
Goure	0.228 (2.193)	96.08 – 98.08	n = 25
Katako	ns		
Loga*	0.062 (0.586)	02.10 - 05.08	n = 35
Maradi	ns		
N'Guimi	0.055 (0.574)	03.07 – 05.07	n = 25
Tahoua	0.091 (0.968)	02.10 - 05.08	n = 35
	0.039 (0.445)	94.11 - 98.07	n = 45
Tillaberi	ns		
Zinder	0.115 (0.713)	94.12 - 98.08	n = 45

*: missing data

Lag length selection according to Schwartz information criterion. Negative bubbles are not considered.

ADF test with no constant and no trend. Simulated critical values on 100 000 replications:

	N=25	N=35	N=40
1 percent	1.164	1.108	1.099
5 percent	0.382	0.359	0.339
10 percent	-0.018	-0.0499	-0.061

Table 5 reports the AR(1) coefficient and the corresponding *t*-stat for the most significant ADF test and for different sub-sample size. Rolling ADF tests for N=25 do not reject the null of unit root in favour of the right-tailed alternative at the 5% significance level for 5 markets: Dosso, Gaya, Katako, Maradi and Tillaberi. According to these results there is no significant evidence of speculative bubbles in the main markets of Niger. Maradi, Dosso, and Gaya are indeed major markets located in the main producing region; Katako is the main market of the capital. Tillaberi is a smaller market, located in a producing region of the western part of Niger, not far from the border of Mali and Burkina Faso.

However three periods of speculative behaviour can be distinguished on the others markets:

- 2003-2005: Agadez, Filingué and N'Guimi experienced short-lived bubbles during this period while Loga and Tahoua experienced a more persistent bubble episode.
- 1994-1998: Agadez, Diffa, Tahoua and Zinder experienced persistent bubbles on the period running from October 1994 to August 1998. Gouré experienced a shorter episode of bubble from August 1996 to August 1998.

- 1999-2002: Dogondoutchi is the only market experiencing a long lasting bubble episode during this period.

Except for Agadez, Diffa and Loga, these results are consistent with the asymmetry test results. Remember that tests carried out from the M-TAR model reject asymmetry in the bubble process for these three markets.

4. Concluding remarks

Econometric results do not reject the existence of speculative bubbles of the PCB type for the majority of the markets under study. According to our results, the 2005 food crisis may be partly imputed to speculative behaviour in Agadez, Filingué, Loga, N'Guimi, Tahoua. However 1994-1998 should be considered as a more important period of speculation. Bubbles detected on five markets during this period tend to be more persistent.

Most of the markets that have experienced a bubble episode are located in deficit and remote areas with low income. This is particularly the case for N'Guimi and Diffa that are located in a poor region of the eastern part of the country, close to the Tchadian border. However, bubbles have also been detected in markets that are located in more favoured areas in terms of their geo-climatic and socio-economic conditions. This is the case of Dogondoutchi, Filingué, Loga and Zinder, an important urban centre in the southern part of Niger.

The most important findings concern the main millet markets of Niger which are: Niamey, Maradi, Gaya and Dosso. The tests for asymmetry and for explosiveness in bubble process converge to reject the presence of rational speculative bubbles on these markets at the usual confidence level. As a consequence, speculative behaviour should not be considered as a widespread phenomenon in Niger nor responsible for major food crises.

The results are of particular importance for the definition of a food security policy in Niger. Actions targeted at markets in deficit and low income areas, which are more prone to speculation, should be taken. In that purpose, a trade expansion program aiming at reducing barriers to trade within the country should be a priority.

The limits of this type of analysis are well-known. The tests for speculative bubbles are joint hypothesis tests of an asset price model and of the presence of bubbles. As a consequence, apparent evidence for bubbles can indicate a misspecification of the market fundamental. At the opposite, rejection of the presence of partially collapsing rational bubbles does not rule out the possibility for other types of speculative bubbles.

References

Aker, J. (2010), « Chocs pluviométriques, marchés et crises alimentaires : l'effet de la sécheresse sur les marchés céréaliers au Niger », *Revue d'Economie du Développement*, 1, 2010, p. 71-108.

Anderson K., C. Brooks, A. Katsaris (2010), "Speculative bubbles in the S&P 500: Was the tech bubble confined to the tech sector?", *Journal of Empirical Finance*, (forthcoming).

Araujo C., Araujo Bonjean C. and S. Brunelin (2010), "Alert at Maradi: preventing food crises by using price signals", *Etudes et Document*, CERDI.

Bhargava A. (1986), "On the theory of testing for unit roots in observed time series", *Review of Economic Studies*, LIII, p.369-384.

Blanchard, O.J., 1979. "Speculative bubbles, crashes and rational expectations". *Economics Letters* 3 (4), p.387–389.

Blanchard, O.J., Watson, M.W., 1982. "Bubbles, rational expectations and financial markets". *NBER Working Paper* no. 945. National Bureau of Economic Research, Cambridge, Mass.

Bohl, M. T. (2003). "Periodically collapsing bubbles in the US stock market?", *International Review of Economics and Finance*, 12, p.385–397.

Campbell J.Y. and P. Perron (1991). "Pitfalls and opportunities: what macroeconomists should know about unit roots", National Bureau of Economic Research, *Macroeconomics Annual*, 141-201, Cambridge: MIT Press.

Charemza, W. W., & Deadman, D. F. (1995). Speculative bubbles with stochastic explosive roots: The failure of unit root testing". *Journal of Empirical Finance*, 2, p.153–163.

Diba B.T. and H. I. Grossman (1987), "On the Inception of Rational Bubbles", *The Quarterly Journal of Economics*, Vol. 102, No. 3, p. 697-700.

Diba B.T. and H. I. Grossman (1988), "Explosive Rational Bubbles in Stock Prices?", *The American Economic Review*, Vol. 78, No. 3, p. 520-530.

Enders, W., & Granger, C. W. J. (1998). "Unit root tests and asymmetric adjustment with an example using the term structure of interest rates". *Journal of Business and Economic Statistics*, 16(3), p.304–311.

Enders, W., & Siklos, P. (2001). "Cointegration and threshold adjustment", *Journal of Business and Economic Statistics*, 19(2), p.166–176.

Evans, G. W. (1991). "Pitfalls in testing for explosive bubbles in asset prices", *American Economic Review*, 81, p.922–930.

Funke M., S. hall and M. Sola (1994), "Rational bubbles during Poland's hyperinflation. Implications and empirical evidence", *European Economic Review*, 38, p.1257-1276.

Gürkaynak R.S. (2008), "Econometric tests of asset price bubbles: taking stock", *Journal of Economic Surveys*, 22(1), p.166-186.

Hall, S.G., Psaradakis, Z., Sola, M., 1999. "Detecting periodically collapsing bubbles: a Markov-switching unit root test", *Journal of Applied Econometrics* 14, p. 143–154.

Im K. S. and P. Schmidt (2008), "More efficient estimation under non-normality when higher moments do not depend on the regressors, using residual augmented least squares", *Journal of Econometrics*, 144, p.219–233

IRD (2009), *Actualité scientifque*, Fiche n°325, juillet.

Legates, D. R. and C. J. Willmott (1990a). "Mean Seasonal and Spatial Variability Global Surface Air Temperature", *Theoretical and Applied Climatology* , 41, p.11-21.

Legates, D. R. and C. J. Willmott (1990b). "Mean Seasonal and Spatial Variability in Gauge-Corrected, Global Precipitation", *International Journal of Climatology*, 10, p.111-127.

Payne, J. E., & Waters, G. A. (2005). "REIT Markets: Periodically collapsing negative bubbles?", *Applied Financial Economics Letters*, 1(2), p.65–69.

Phillips P., Y. Wu and J. Yu (2009), "Explosive behaviour in the 1990s Nasdaq: when did exuberance escalate asset values?" *Cowles Foundation discussion Paper,* n°1699, Cowles Foundation for Research in Economics, Yale University.

Pindyck R. et J. Rotemberg (1990), "The excess Co-Movement of Commodity Prices", *The Economic Journal*, Vol. 100, n°403, p.1173-1189.

Quddus M. and C. Becker (2000), "Speculative Price Bubbles in the Rice Market and the 1974 Bangladesh Famine ", *Journal of Economic Development*, Vol. 25, No. 2, December, pp. 155-175.

Ravallion M. (1985), "The performance of Rice price Markets in Bangladesh During the 1974 Famine ", *The Economic Journal*, Vol. 95, n° 377, p.15-29.

Sarno, L. and Taylor, M. P.(2003) "An empirical investigation of asset price bubbles in Latin American emerging financial markets", Applied Financial Economics, 13: 9, p. 635-643

Schwert G.W. (1989). "Tests for unit roots: a Monte Carlo investigation, *Journal of Business and Economic Statistics* 7, p.147-159.

Sen A. (1981). *Poverty and famines. An Essay on Entitlements and Deprivation*, Clarendon Press, Oxford.

Taylor, M. P., & Peel, D. A. (1998). "Periodically collapsing stock price bubbles: A robust test". *Economics Letters*, 61, p.221–228.

Van Norden S. (1996). "Regime Switching as a Test for Exchange Rate Bubbles", *Journal of Applied Econometrics*, Vol. 11, No. 3, May - Jun., p. 219-251.

Van Norden S. and H. Schaller (1993). "The Predictability of Stock Market Regime: Evidence from the Toronto Stock Exchange", *The Review of Economics and Statistics*, Vol. 75, No. 3, p. 505-510.

Waters G.A. (2008), "Unit root testing for bubbles: a resurrection?", *Economics Letters*, 101, p. 279-281

APPENDIX

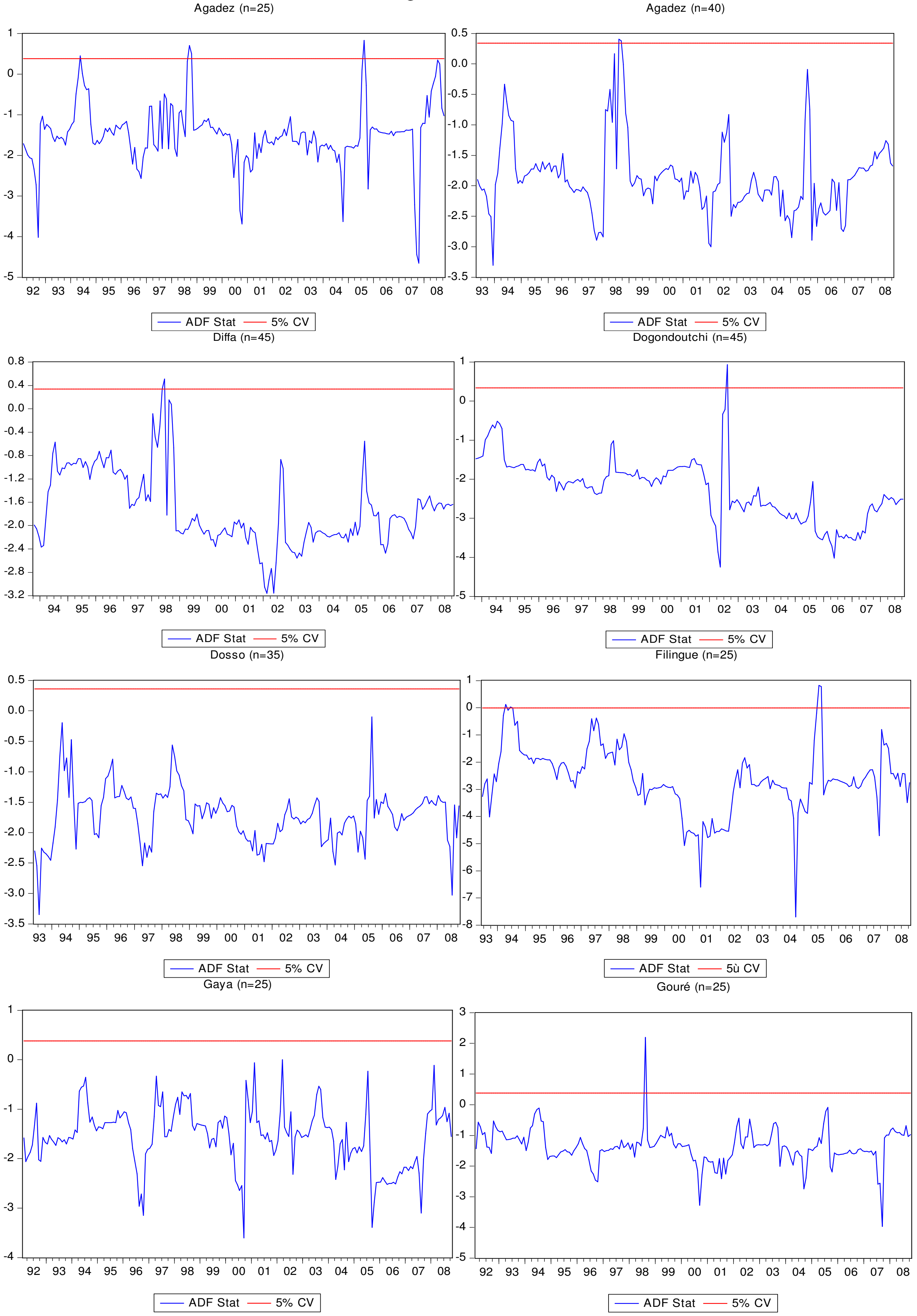
Table A1. Unit root tests**.** Sample period: January 1990 – October 2008

Region	Market	Min	Max	Mean	Nb of observations	ADF P.value	KPSS LM-Stat
Millet price (Fcfa/kg) in:							
Agadez	Agadez	52	337	134	226	0,00	0,12
Diffa	Diffa	41	328	138	221	0,00	0,09
Diffa	Goudoumaria	45	371	131	215	0,02	0,08
Diffa	Nguimi	55	333	148	218	0,01	0,06
Dosso	Dogondoutchi	48	270	114	217	0,00	0,08
Dosso	Dosso	58	329	139	226	0,00	0,11
Dosso	Gaya	42	315	124	226	0,00	0,10
Dosso	Loga	50	279	123	216	0,00	0,07
Maradi	Maradi	39	261	104	226	0,00	0,12
Tahoua	Tahoua	54	369	144	226	0,00	0,11
Tillaberi	Filingue	51	326	129	210	0,00	0,09
Tillaberi	Tillaberi	58	306	145	226	0,00	0,11
Zinder	Goure	52	319	118	226	0,00	0,08
Zinder	Zinder	40	312	109	226	0,00	0,12
Niamey	Katako	71	324	141	226	0,00	0,09

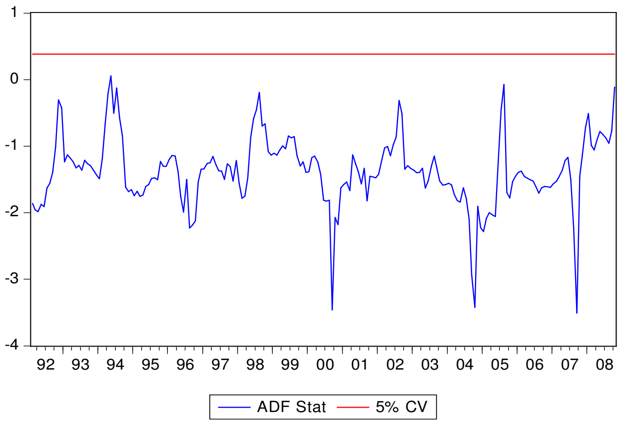
Source: SIMA and authors' calculations.

ADF test: H_0: I(1) ; KPSS : H_0: I(0). Tests implemented on current price values.

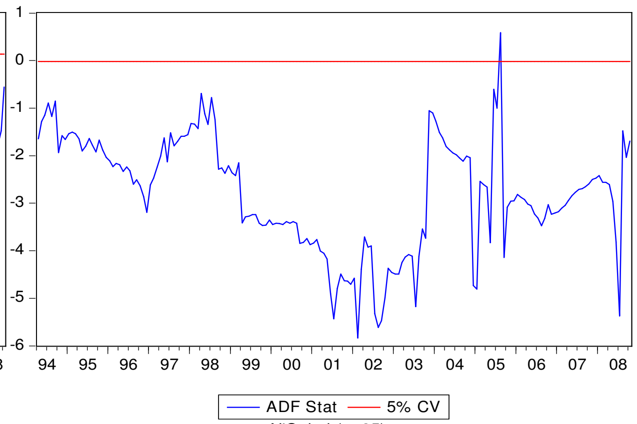
Rolling ADF test results



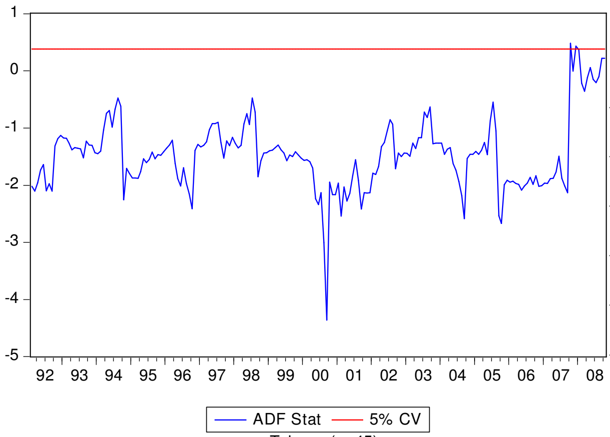
Katako (n=25)



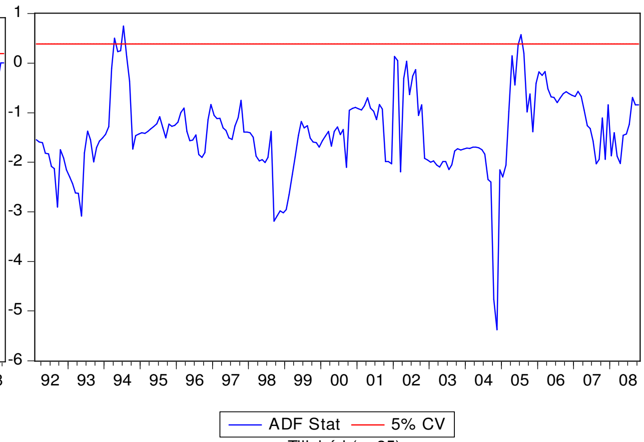
Loga (n=34)



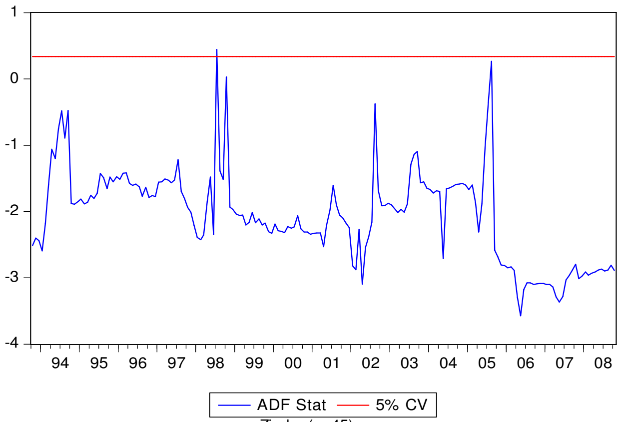
Maradi (n=25)



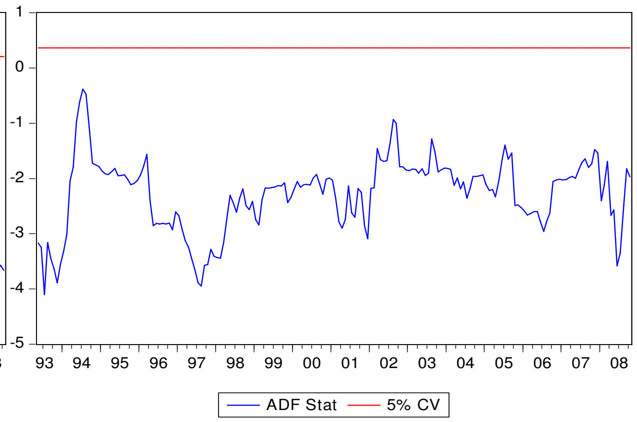
N'Guimi (n=25)



Tahoua (n=45)



Tillabéri (n=35)



Zinder (n=45)