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Are grain markets in Niger driven by speculation?

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Abstract[1]

Over the last two decades, millet prices in Niger have experienced several periods of spectacular increase during which they seemed to go well above their fundamental value. The presence of rational speculative bubbles might explain these episodes of price bursts followed by rapid reversals. Considering millet as a food asset we test for the presence of periodically and partially collapsing bubbles for 24 millet markets of Niger. The test strategy consists of testing for non-linearity in the price process corresponding to regime switching between an explosive regime and a stationary one. Two tests are implemented: the Markov switching ADF unit root test and the recursive unit root test of Phillips, Shi and Yu (2012). The results show that most of the time price movements do not exhibit the specific characteristics of rational bubbles. A noticeable exception is 2005. The great food crisis that hit the Niger that year may partly be explained by speculative bubbles.

Key word: periodically collapsing bubbles, Markov switching model, Recursive ADF test, millet, Niger

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

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Introduction

Over the past 20 years, grain prices in Niger have experienced numerous large positive shocks followed by rapid reversals. These shocks, whose duration is typically less than one year, are transitory but constitute a threat to poor households who are dependent on markets for food security. Indeed, these periods of price spikes sometimes lead to severe food crises, as was the case in Niger in 2005 and more recently in 2012 and 2013.

A straightforward explanation for price run-ups in local food grain prices relates to the occurrence of large negative supply shocks. Indeed, millet price spikes are generally recorded after a rainfall deficit and a drop in domestic supply. Large climate fluctuations that are common in this country located in the Sahel part of West Africa generates intrinsic volatility in fundamentals that result in wide price fluctuations.

However, data show that production and price fluctuations are not closely related which leads to question the functioning of markets. Non-competitive markets may 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. Another explanation to price upsurge might be found in Sen's work on the origin of famines when there is no decline in food availability. In this stream of work Ravallion (1985) showed that the 1974 famine in Bangladesh cannot be explained by a rice production deficit, but by stockholders' over-optimistic price expectations.

Such market "irrational exuberance" coming from exaggerated expectations has been evidenced on stock markets. Speculative bubbles are usually blamed for large and persistent price deviations relative to their fundamental value. Speculative bubbles might have multiple origins. They can be irrational originating from noise traders who trade irrationally on the basis of irrelevant information. They may also have social or psychological origin resulting in fads or fashions in asset markets (Schiller, 1984). But bubbles can also be rational resulting from self-fulfilling beliefs based on irrelevant information that is not related to market fundamentals (Diba and Grossman, 1988). For instance, if the economic actors 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. A 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 prepared to pay more for the asset than its intrinsic value if they expect to sell it at an even higher price. The bubble increases at the required rate of return and bursts when agents' expectations return to normal.

The presence of rational speculative bubbles might 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. Bubbles might also explain why the early warning system for preventing food crises, which is mainly based on the monitoring of crop growth, has not been effective in anticipating steep rises in prices despite technological advances that allow more accurate monitoring of harvests.

In Niger, investors in the 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 as well as on economic variables is generally very poor. Moreover interventions of the government and external aid agencies in case of food risk are often unpredictable (Cornia and Deotti, 2008). Therefore incomplete or unreliable information provided by the public authorities may fuel speculative bubbles.

The aim of this paper is to test for the presence of speculative bubbles in millet markets of Niger. There is a growing empirical literature aiming at detecting explosive behaviour in financial and commodity future markets (see for instance, Phillips and Yu 2011, Prakash and Stigler 2011, Figuerola-Ferreti *et al*. 2014) but it is to our knowledge the first time that such an analysis is implemented in a developing country.

We focus on a specific class of rational bubbles the so called periodically and partially collapsing speculative bubbles (PCB) originally defined by Evans (1991). PCBs are nonlinear processes; they are explosive during the phase of bubble eruption, but they may be stationary over the whole sample period. To test for the presence of PCBs we look for explosive behaviour in millet price taking into account the evolution of observable fundamentals. Looking for nonlinearities resulting from regime switching and explosiveness in price processes we implement two types of tests: the Markov switching unit root test and the recursive ADF unit root test. Most of the time, price movements do not exhibit the specific characteristics of bubbles. However results show that the 2005 food crisis may partly be explained by speculative bubbles that are detected in some large urban markets of Niger.

The paper is organized in the following manner. Section 1 outlines the main characteristics of millet price evolution over the last two decades. Section 2 exposes the theoretical properties of periodically and partially collapsing bubbles. The Markov-switching unit root test is implemented in section 3. Section 4 is devoted to the recursive unit root test. Robustness tests based on estimates of the fundamental value of millet are conducted in section 5. Section 6 discusses the results and concludes.

1. Millet price evolution on the past two decades

Niger is a landlocked country belonging to the category of Least Developed Countries and ranking at 182th position (of 185) in Gross Domestic Product per capita ranking[2]. Millet is the most suitable crop for the arid and semi-arid areas of Niger. Millet covers 65 % of cultivated land and represents about 3/4 of cereal production (IRD, 2009)[3]. Millet is also the staple diet of the local population representing almost 40% of total food supply. Therefore population is highly dependent on millet production for food security. As illustrated below, millet supply and prices have been highly volatile during the past decades leading to chronic food insecurity and recurrent food crisis.

1.1. The data base

A market information system (SIMA) has been implemented in Niger at the end of the 1980s within the framework of structural adjustment programs. The SIMA has been collecting prices for major agricultural products and livestock on an expanding number of markets and on a decadal basis. Unfortunately, price collection has been irregular and only a few number of price series can be exploited for time series analysis. For instance, some markets have been dropped from the sample after a few years while others have been included recently. Moreover missing values in price series are common, especially at the decadal frequency, so that numerous price series can hardly be used for econometric analysis.

Given these difficulties we restrict our working sample to 24 millet markets for which price information is available on a regular monthly basis from January 1990 to February 2012

[2] TheWorld Bank database for 2012. http://data.worldbank.org/indicator/

[3] Niger is the second largest producer of millet in West Africa, behind Nigeria. Nevertheless Niger regularly imports millet from neighboring countries.

or April 2013. For these markets the number of missing data is lower than 10% of total observations.

The sample markets are disseminated in 21 of the 36 departments of Niger. The data set includes markets of the main cities of Niger (*Chefs-lieu de department*) but also markets of few numbers of rural municipalities. Most markets are located in the most populated south part of Niger (below the 15th parallel) where climatic conditions are more favorable to agriculture (see table A2 and map 1 in the appendix). Population density decreases quickly from about 162 pop. per km² in the extreme south to less than one people per km² in the northern department of Bilma. Thus we can confidently consider that price movements in the 24 markets of our sample are representative of price evolution in the main markets of Niger. However, Niger's population is predominantly rural with about 80% of people living in rural areas in 2010. Past studies tend to show that the main grain markets of Niger are fairly well integrated. But we do not know to what extent prices behavior in rural areas differs or not from that of prices in the main department cities.

1.2. Price evolution

As can be seen from figure 1, millet prices are subject to large variations from one year to the next and to large seasonal fluctuations within the year. Actually, millet is a rain fed crop cultivated by small traditional farmers using low input agricultural practices. As a consequence, millet production is highly vulnerable to pest attacks and weather conditions. Moreover, trade does not play a regulating role on prices. Millet is the subject of intensive cross-border trade between Niger and neighbouring countries (in particular Nigeria) but it is not traded on international markets. Because weather conditions are broadly the same in neighbouring countries which belong to the same regional production area, the dampening effect of trans-border trade on prices is weak.

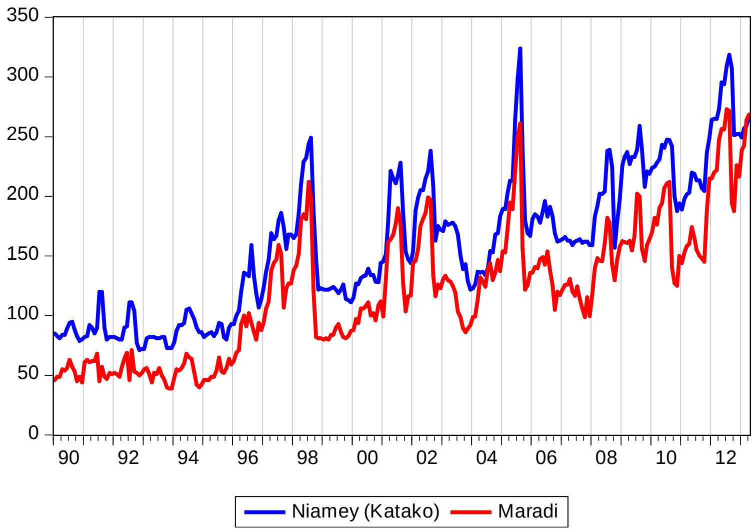
As a consequence, millet price fluctuates widely from year to year according to natural conditions and within the year according to the production cycle. Millet prices are lower during the harvest and post-harvest season from September to January. Then they gradually go up and reach their peak at the end of the lean season[4] from July to August. The large seasonal fluctuations in millet price – price increase by about 40% on average between

[4] The lean season is the period that precedes the harvest during which granaries are depleted.

December and August – reflect the importance of storage costs. These costs include physical losses and above all the opportunity cost of capital which can be as high as 4% per month.

Millet is usually stored over the crop year but can be held for more than one year. Typically three categories of agents hold stocks: farmers, wholesalers and the public authorities. Most grain is stored at the farm level, but these stocks are difficult to assess. As a general rule, stocks are built up immediately after the harvest and held until the beginning of the new crop season. According to their expectations regarding the state of the future harvest, farmers may start selling their stocks in June. However, most of the time stocks are not liquidated before August-September. Stocks at the farm gate level are intended to cover the household's food needs until the next harvest, and meet the farm's demand for seeds. However, many small farmers whose production is not sufficient to cover their food needs are net buyers of grain. Others are forced to sell millet early in the crop marketing season to meet their cash needs and to buy back grains later in the season.

Figure 1. Millet price in Niamey and Maradi, Fcfa/kg, January 1990 - April 2013

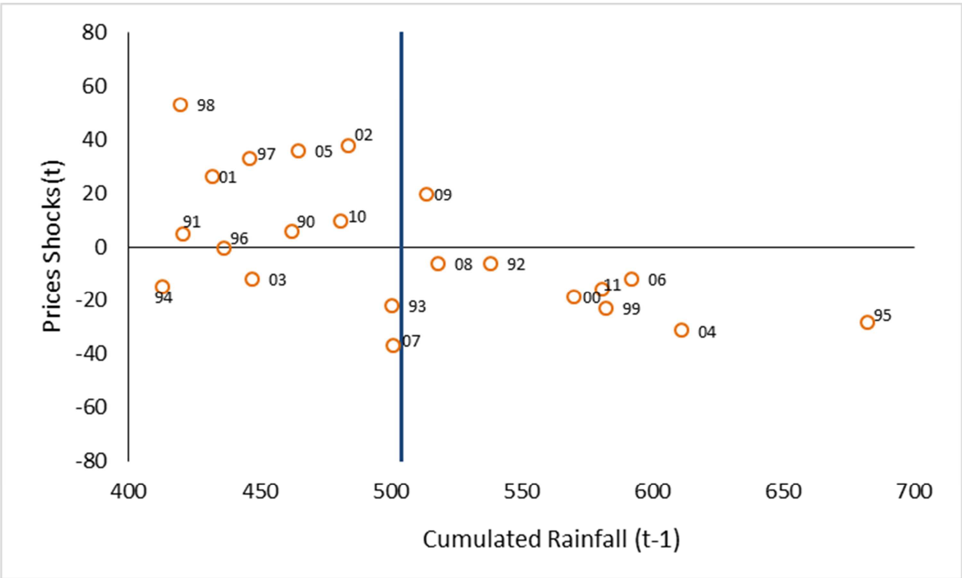


Source: SIMA

Wholesalers hold stocks over short periods, generally not exceeding two months, with the result that the rate of stock turnover is high (Aker, 2010, WFP, 2005). High risk and high capital cost are the main reasons for the rapid rotation of stocks. Traders collect millet during the 3-4 months following the harvest (from September to December). They start importing millet from neighbouring countries (Nigeria, Mali and Burkina Faso) later in the marketing year. Public safety stocks have been considerably reduced during the structural adjustment era. They fall from 150 00 tons in 1983 to less than 20 000 in the mid-2000 representing less than 1% of production (Deatti and Cornia, 2008). Public stocks are renewed by tender during the first months of the year[5].

Figure 1 depicts the evolution of millet price in the main market of the capital city (Katako) and the major market of the main producing region (Maradi). Prices follow a common ascendant trend punctuated by large positive shocks. Most of the episodes of price boom have been recorded after a rainfall deficit. This was particularly the case in 1997, 1998 and 2001. However Figure 2 evidences puzzling situations. For instance the most severe rainfall deficit of the period that occurred in 1993 did not result in significant price increase in 1994. In the same way, prices did not rise after the drought registered during the 2002 and 1989 rainy season. By contrast, the moderate rainfall deficits recorded in 2001 and 2004 resulted in large price increases in 2002 and 2005.

Figure 2. Millet price shocks in Niamey (Fcga/kg) and cumulated rainfall (mm)



Price shock is the price deviation from trend at year t. Cumulated rainfall is the cumulated level of precipitation over the rainy season of year t-1 in the main agricultural areas (see below). Mean cumulated rainfall on the 1989-2012 period equals 509 mm.

[5] Unfortunately, information on the level of public stocks and dates of operation is not available.

2. The rational bubbles model and test strategy

Considering millet as an asset we focus on a specific class of rational bubbles, the periodically and partially collapsing bubbles and expose our test strategy.

2.1. Periodically and partially collapsing bubbles

In the standard asset pricing model assuming risk neutral stockholders and positive stocks, the equilibrium price is given by a model of the form (Diba and Grossman, 1987):

$$E_t P_{t+1} = \lambda P_t + x_t \qquad \text{with} \quad \lambda > 1 \qquad (1)$$

where P_t is the millet price level in period *t;* E_t is the conditional expectations operator. $E_t P_{t+1}$ is the expected price of millet in period t+1. x_t is a forcing variable; it is an index that depends on a vector of variables reflecting market fundamentals.

Equation (1) relates the current millet price to the next period's expected price, variables determining fundamentals. 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 (1) for *P* involves two components: F_t the market-fundamentals component and B_t a potential rational-bubbles component (Blanchard, 1979; Blanchard and Watson, 1982; Diba and Grossman, 1987, 1988).

$$P_t = B_t + F_t \qquad (2)$$

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

$$F_t = E_t \sum_{i=0}^{\infty} (\lambda^{-(i+1)} x_{t+i}) \qquad (3)$$

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 expectational difference equation:

$$E_t B_{t+1} - \lambda B_t = 0 \qquad (4)$$

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

$$E_t B_{t+j} = \lambda^j B_t \quad \text{for all } j > 0 \tag{5}$$

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.

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 (6a) and (6b):

$$B_{t+1} = \lambda B_t u_{t+1} \qquad \text{if } B_t \leq c \tag{6a}$$

$$B_{t+1} = \left[\delta + \frac{\lambda}{\pi}\theta_{t+1}\left(B_t - \lambda^{-1}\delta\right)\right]u_{t+1} \qquad \text{if } B_t > c \tag{6b}$$

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 (4) 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, its growth rate falls to a mean value of δ, and the process begins again (Evans, 1991).

Thus, the advantage of this type of bubble is to account not only for occasional asset price crashes but also for rapid run-ups in prices before a crash.

2.2. Test strategy

According to equations (2) and (4), the asset price is expected to manifest explosive behavior in the presence of bubbles. In the absence of bubbles the asset price is expected to be I(0) or I(1) depending on the properties of the fundamentals. Most empirical tests for bubbles are based on the exploitation of these theoretical properties of the asset price and fundamental.

Following the seminal work of Diba and Grossman (1984, 1988) many authors have attempted to establish the presence of rational bubbles by conducting right-sided unit root tests on the asset price and the observable fundamental or by testing cointegration between these two variables (see Gurkaynak 2008 for a survey). However as shown by Evans (1991), Charemza and Deadman (1995) and Waters (2008), linear unit root tests are not able to detect periodically collapsing bubbles that only exhibit characteristic bubbles properties during their expansion phase. Standard tests for unit root and cointegration tend to reject the presence of bubbles even when such bubbles are present (van Norden and Vigfusson, 1996).

The failure of this so called "conventional" testing procedure has led to the development of two main alternative approaches that have higher power in identifying the existence of bubbles. The first approach developed by Hall, Psaradakis and Sola (1999) relies on Markov-switching unit root test. This test is based on a Markov switching model allowing for two regimes in the price process corresponding to the expanding and collapsing phase of bubbles. The second approach recently proposed by Phillips, Wu and Yu (2009) and Phillips, Shi and Yu (2012, 2013a and 2013b) relies on recursive ADF unit root tests. This test procedure aims at detecting periods of explosive behaviour in the asset price and allows for consistent dating of the beginning and end of the explosive phase.

3. Testing for regime switching: the Markov-Switching unit root test

The conventional unit root ADF test clearly rejects the null of a unit root to the benefit of the stationary alternative for all millet price series (see table A1 in the Appendix). This result which is consistent with a stationary fundamental value does not preclude the existence of periodically collapsing bubbles. Indeed standard unit root tests have little power to detect bubbles of the PCB type that typically appear as stationary processes to standard unit root tests.

In the presence of PCB, prices are expected to switch between two regimes: a non-stationary regime corresponding to the expanding phase of the bubble and a stationary regime corresponding to the collapsing phase of the bubble. To test for this type of nonlinearity in the price process we implement the Markov-switching Augmented Dickey Fuller (MS-ADF) test developed by Hall, Psaradakis and Sola (1999) which is based on a two state Markov-switching model. The test equation is given by:

$$\Delta P_t = \mu_0(1-S_t) + \mu_1 S_t + [\beta_0(1-S_t) + \beta_1 S_t]P_{t-1} + \sum_{k=1}^{p}[\psi_{0k}(1-S_t) + \psi_{1k}S_t]\Delta P_{t-k} + [\sigma_0(1-S_t) + \sigma_1 S_t]e_t$$

$$\text{with} \quad e_t \sim N(0,1) \tag{7}$$

where S_t is a discrete-valued random variable that can take two values (0 or 1). If $S_t = 0$, the process is in regime 0; if $S_t = 1$, the process is in regime 1. The random sequence $\{S_t\}$ is specified as a homogeneous Markov chain (see Hamilton, 1994) with transition probabilities:

$$\Pr\{ S_t = 1|S_{t-1} = 1\} = p \ ; \Pr\{ S_t = 0|S_{t-1} = 1\} = 1- p \ ;$$

$$\Pr\{ S_t = 0|S_{t-1} = 0\} = q \ ; \Pr\{ S_t = 1|S_{t-1} = 0\} = 1- q \qquad (8)$$

This specification allows all parameters, including the variance of the residual term, to vary according to the regime. The Markov-switching ADF test is based on the t-ratios associated with the maximum likelihood estimates of β_0 and β_1.

By convenience, the regime with the largest ADF coefficient is set to be regime 1 and the regime with the lowest coefficient is set to be regime 0. The millet price is expected to be non-stationary with an explosive root in regime 1 ($\beta_1 \geq 0$) and stationary in regime 0 ($\beta_0 < 0$). Therefore, the null hypotheses $\beta_0 = 0$ and $\beta_1 = 0$ are tested against, respectively, the one-sided alternative $\beta_0 < 0$ and $\beta_1 > 0$. Since the null distribution of the test statistics is unknown, simulated critical values are obtained by parametrically bootstrapping the null model (corresponding to $\beta_0 = \beta_1 = 0$) using the estimates of μ_0, μ_1, ψ_{0k}, ψ_{1k}, σ_0 and σ_{1t}.

The results summarized in Table 1 evidence two distinct regimes - a stationary (regime 0) and a non-stationary possibly explosive regime (regime 1). In the non-stationary regime the coefficient β_1 is positive in the majority of cases with t-stats well above standard values. Comparing the test statistics to bootstrap critical values, the unit root null hypothesis is rejected in favour of the explosive root alternative for nine markets at the five percent level and for one more market (Loga) at the 10% percent level. These markets include Maradi and Zinder the most important markets of the main producing area of millet. Regime 0 captures the collapsing phase of bubbles. In this regime the unit root null hypothesis is rejected against the stationary alternative for all markets except one (Goudoumaria). The coefficient β_0 is generally large in absolute value, indicating a sharp correction in the millet price.

According to the transition probabilities, the stationary state tends to be less persistent than the non-stationary one. The expected duration of the explosive regime is 9.5 months while the expected duration of the collapsing regime is shorter, equal to 4.1 months on average. The stationary regime is also characterised by higher volatility than the explosive one meaning that sharp price corrections involve high volatility.

Table 1. Results from the Markov-switching ADF test

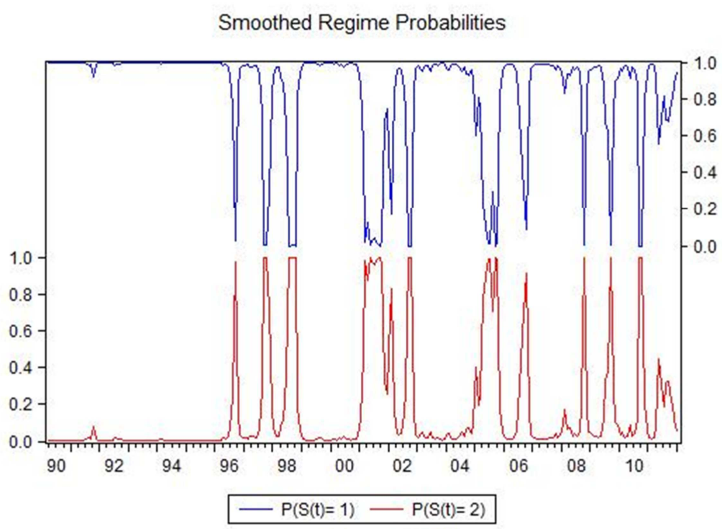
		Agadez	Arlit	Bakin	Birni	Danissa	Diffa	Dogon.	Dosso	Dungas	Filingue	Gaya	Gothey.	Goud.	Goure	Katako	Loga	Maradi	Nguimi	Tahoua	Tchinta	Tessa.	Tillabe.	Zinder
Regime 0	β0	-0.151	-0.064	-0.235	-0.281	-0.65	-0.211	-0.539	-0.133	-0.327	-0.573	-0.265	-0.260	-0.205	-0.513	-0.180	-0.250	-0.268	-0.128	-0.396	-0.213	-0.259	-0.112	-0.519
		(-2.00)	(-2.29)	(-3.22)	(-2.53)	(-6.37)	(-2.34)	(-5.76)	(-3.32)	(-3.92)	(-3.60)	(-2.40)	(-2.90)	(-1.51)	(-5.91)	(-2.92)	(-3.21)	(-2.62)	(-2.17)	(-4.07)	(-2.80)	(-4.04)	(-2.99)	(-2.99)
	σ0	3.388	18.146	29.37	34.638	17.43	31.31	15.713	22.324	30.021	39.435	42.258	38.537	46.576	15.300	24.19	27.099	26.55	29.76	31.398	29.698	22.928	25.395	36.035
		(29.15)	(47.10)	(40.61)	(29.03)	(9.11)	(35.01)	(9.87)	(39.30)	(40.68)	(26.34)	(32.70)	(39.46)	(27.83)	(18.34)	(30.89)	(35.52)	(30.18)	(40.05)	(33.16)	(35.59)	(37.82)	(52.55)	(28.33)
	Ed0	3.58	5.96	3.66	2.04	1.20	4.80	1.37	2.16	5.70	1.89	2.30	7.47	1.61	2.20	2.65	2.65	2.96	3.29	11.23	2.76	14.78	4.15	3.10
	$\overline{P}$	197	186	144	158	119	201	123	168	134	161	176	206	169	143	188	145	152	226	180	192	146	169	164
	obs	53	80	86	42	7	77	18	81	90	24	39	80	28	29	56	77	51	77	138	72	106	143	33
Regime 1	β1	0.008	-0.001	0.056	0.010	0.045	-0.002	0.033	0.016	0.005	0.033	0.021	-0.062	-0.004	0.069	0.016	0.030	0.045	0.018	-0.027	0.013	-0.020	-0.014	0.028
		(1.30)	(-0.11)	(3.41)	(0.52)	(1.92)	(-0.31)	(2.36)	(1.98)	(0.49)	(2.22)	(1.10)	(-2.35)	(-0.33)	(4.75)	(1.81)	(1.70)	(3.78)	(1.51)	(-1.37)	(1.96)	(-0.90)	(-1.79)	(2.30)
	σ1	2.03	1.083	6.71	6.783	11.75	9.58	10.205	4.688	6.920	12.828	10.384	10.611	8.589	9.145	5.86	6.691	7.46	6.72	10.058	8.170	6.731	3.268	8.744
		(11.84)	(0.32)	(18.49)	(14.91)	(40.29)	(21.14)	(34.04)	(14.83)	(22.32)	(35.05)	(30.11)	(27.95)	(23.14)	(37.85)	(18.89)	(20.95)	(20.04)	(11.07)	(31.09)	(16.23)	(23.67)	(10.26)	(33.56)
	Ed1	8.62	2.97	6.42	6.80	15.92	10.38	10.59	3.06	8.84	10.00	8.30	14.64	7.45	11.76	7.52	5.14	9.82	4.71	23.33	4.93	19.32	2.75	15.49
	$\overline{P}$	133	137	96	110	111	137	120	143	94	137	127	118	127	124	153	122	114	144	147	144	78	142	112
	obs	210	154	192	182	225	195	218	182	161	202	213	159	172	222	222	153	227	86	137	158	133	120	230
	p11	0.721	0.832	0.727	0.510	0.165	0.785	0.272	0.537	0.825	0.471	0.566	0.866	0.380	0.545	0.623	0.622	0.662	0.696	0.911	0.638	0.932	0.759	0.677
	p22	0.884	0.664	0.844	0.853	0.937	0.898	0.906	0.673	0.887	0.900	0.880	0.932	0.866	0.915	0.867	0.805	0.898	0.788	0.957	0.797	0.948	0.636	0.935
LL		-1123	-880	-1141	-884	-935	-1150	-934	-1031	-1040	-978	-1075	-1043	-849	-980	-1050	-932	-1088	-986	-1058	-970	-956	-1099	-1050
LR		*136.37*	170.49	*156.36*	177.50		*106.85*	163.00	130.30	158.19	133.05	151.39	121.69	182.67	159.30	*158.32*	119.53	140.41	113.30	132.98	90.94	123.62	161.80	216.74
nb obs		278	234	278	224	232	272	236	263	251	226	252	239	207	251	278	230	278	263	251	230	239	263	263
Bootstrap critical values for ADF tests																								
β0	1%	-2.484	-2.672	-3.113	-2.657	-2.672	-2.535	-3.039	-2.810	-2.643	-2.928	-2.467	-2.821	-2.787	-2.866	-2.590	-2.567	-3.185	-2.876	-2.498	-3.036	-2.527	-2.788	-2.686
	5%	-1.919	-2.166	-2.101	-1.858	-2.166	-1.969	-2.306	-2.013	-2.121	-2.234	-2.046	-1.921	-2.027	-1.910	-2.126	-1.916	-2.314	-1.884	-1.866	-2.227	-1.931	-2.031	-2.002
	10%	-1.593	-1.775	-1.801	-1.516	-1.775	-1.555	-1.967	-1.718	-1.780	-1.842	-1.784	-1.614	-1.750	-1.607	-1.825	-1.638	-1.986	-1.608	-1.567	-1.894	-1.641	-1.693	-1.687
β1	1%	2.602	2.449	2.703	2.677	2.449	2.504	2.216	2.316	2.487	2.694	2.693	2.936	2.793	2.418	2.766	2.407	2.197	2.815	2.836	2.053	2.427	2.640	2.603
	5%	1.822	1.758	1.900	2.104	1.758	1.928	1.536	1.854	1.865	1.714	1.980	1.901	1.958	1.845	2.106	1.913	1.793	2.031	1.883	1.571	1.911	1.784	1.840
	10%	1.576	1.407	1.593	1.762	1.407	1.604	1.331	1.513	1.480	1.435	1.593	1.447	1.371	1.468	1.857	1.582	1.425	1.767	1.647	1.232	1.615	1.445	1.487

t-ratio are in parenthesis. Ed_i : expected duration of regime i. LL: log likelihood
Critical values are obtained from parametric bootstrapping with 500 replications.
The lag lengh *p* is set to one. The intercept and the autoregressive parameter vary according to the regime.
LR: Test for regime switching. H_0: the intercept, the variance and the autoregressive parameter are equal across regimes (Standard ADF). Alternative: the intercept, the variance and the autoregressive parameter differ across regimes (MS-ADF)

As a by-product the MSM gives estimates of regime probabilities. As an illustration, Figure 3 depicts the inferred probabilities of being in each regime for the millet price in Zinder. We consider that an observation belongs to the explosive regime if the smoothed probability for this observation to be in the explosive regime is greater than or equal to 0.5. According to this criterion we can locate each regime and calculate corresponding mean prices. We thus detect 11 explosive episodes in the millet price in Zinder, occurring between 1996 and 2010. The periods of explosive behaviour are roughly the same in other markets. The number of observations in the collapsing regime is quite low so that coefficients might not be accurately estimated. Most of collapsing episodes are recorded from August to November.

To sum up, according to the MS ADF test, nine to ten price series present the two main characteristics of periodically collapsing bubbles i.e. alternative periods of explosiveness and collapse. By contrast, three price series, Diffa, Gotheye and Tillaberi which are stationary in both regimes, do not present any bubble characteristics. This is also the case for Goudoumaria which appears to be a random walk with a break in variance (non-stationary process in both regimes). Results for the remaining nine markets are not conclusive. They show strong evidence of a collapsing regime but in the non-stationary regime prices are not significantly explosive.

Figure 3. Probabilities of expanding and collapsing regimes in Zinder



As shown by Shy (2010) the MS-ADF test is susceptible to false detection of explosive behaviour in periods of high variance when imposing a constant error variance in the MS-ADF. But when the error variance is allowed to be regime dependent the algorithm may not converge well or converge to a local maximum (Phillips, Shi and Yu, 2012). To overcome these limits we use an alternative approach to bubble detection recently developed by Phillips, Wu, Yu and Shi in a series of recent papers. Their approach is based on a recursive implementation of right-tailed ADF unit root tests.

4. Testing for explosiveness: the generalized sup ADF test

4.1. The test procedure

Phillips, Shi and Yu (2012), PSY hereafter, have developed a new method to test for explosive behavior and date the origin and collapse of bubbles. This method allows detection of multiple bubbles of the PCB type in a sample data. The test procedure consists in implementing recursive right-tailed ADF unit root tests on sample regression with varying starting and ending points. Inference is based on the generalized sup ADF (GSADF) test.

PSY (2012) testing procedure is an extension of the Phillips, Wu and Yu (2011) approach which relies on a sup ADF test (SADF). The SADF test is based on the implementation of right-side ADF tests on a forward expanding sample sequence. The sup ADF test has proved to have more power than conventional unit root test in detecting explosive behaviour but can be inconsistent when the sample period includes multiple bubble episodes (PSY, 2012). To overcome this drawback, the PSY test procedure extends the sample regression sequence to cover more subsamples of the data with flexible window widths. When the data include one or more bubble episodes, the PSY dating algorithm gives consistent estimates of the starting and ending points.

In the PSY testing procedure the null specification is a random walk with asymptotically negligible drift given by:

$$y_t = dT^{-\eta} + \theta y_{t-i} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^2), \qquad \theta = 1 \qquad (9)$$

d is a constant, T is the sample size and $\eta > 1/2$. The test regression is given by:

$$\Delta y_t = \alpha_{r_1 r_2} + \beta_{r_1 r_2} y_{t-i} + \sum_{i=1}^{k} \psi^{i}_{r_1 r_2} \Delta y_{t-i} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma^2_{r_1 r_2}) \qquad (10)$$

k is the lag order. $ADF_{r_1}^{r_2}$ is the t-ratio statistic associated to regression (10). The sample regression starts from the r_1th fraction of the total sample and ends at the r_2th fraction of the sample; $r_w = r_2 - r_1$ is the fractional window size of the regression. The number of observations in the sample regression is $T_w = [Tr_w]$, where [.] is the integer part of the argument. The ADF test regression is run repeatedly on a sample sequence. In this sample sequence, r_1, the starting point of the sample regression varies from 0 to $r_2 - r_0$ and r_2, the end point of the regression varies from r_0 to 1. r_o is chosen according to the total number of observations to insure that there are sufficient observations in the initial regression.

The GSADF statistic, denoted GSADF(r_0), is the largest ADF statistic over the sample sequence:

$$\text{GSADF}(r_0) = \sup_{\substack{r2\in[r0,1] \\ r1\in[0,r2-r0]}} \{ADF_{r1}^{r2}\} \tag{11}$$

The asymptotic critical values of the GSADF statistics under (9) are given by PSY (2013, Table 1) for $d = \eta = 1$. They depend on r_0, the size of the smallest window.

When implementing the GSADF test on the millet price series we set the smallest window size r_0 to 27 observations corresponding to about 12% of total observations. The lag order k is determined using the Schwarz information criterion. Following PSY (2012) we calculate the finite sample critical value of the GSADF statistic from 5,000 Monte Carlo replications.

To locate the bubble periods the date-stamping algorithm developed by PSY (2012) consists in implementing a sup ADF test on a backward expanding sample sequence. In this sample sequence the end point of the sample is fixed at r_2 and the starting point varies from 0 to $r_2 - r_0$. The backward ADF statistic is labeled $BADF_{r_1}^{r_2}$. Inference is based on the backward sup ADF statistic which is the sup value of $BADF_{r_1}^{r_2}$ on the sample sequence:

$$\text{BSADF}_{r2}(r_0) = \sup_{r1\in[0,r2-r0]}\{BADF_{r1}^{r2}\} \tag{12}$$

According to PSY (2012), the origination date of a bubble $[T\hat{r}_e]$ is the first observation with BSADF statistic exceeding the BSADF critical value. Therefore, the termination date of the bubble $[T\hat{r}_f]$ is the first observation after $[T\hat{r}_e]$ + δ log(T) with BSADF statistic below the BSADF critical value. The minimum duration of the bubble is given by δ log(T). It depends on the parameter δ which is set up by the analyst according to the data frequency. The fractional origination and termination points of a bubble are given by:

$$\hat{r}_e = \inf_{r2\in[r0,1]}\{r_2 : BSADFr_2(r_0) > scv_{r2}^{\beta_T}\} \tag{13a}$$

$$\hat{r}_f = \inf_{r2\in[re+\delta\log(T),1]}\{r_2 : BSADFr_2(r_0) < scv_{r2}^{\beta_T}\} \tag{13b}$$

$scv_{r_2}^{\beta_T}$ is the 100(1 - β_T) % critical value of the sup ADF statistic based on [Tr_2] observations[6].

4.2. Test results

Implementing the GSADF test to the 24 millet price series we find strong evidence of explosive episodes in all markets except four: Diffa, Dogondoutchi, Gaya and Tillaberi (Table 2, column 1 and 2). Results are robust to different lag specifications in the test regression. To locate the explosive periods we compare the backward SADF statistic sequence with the 95% BSADF critical value sequence (Figures are given in the appendix). The sequence of critical values is obtained from Monte Carlo simulations with 5000 replications. Results are synthetized in Table 3.

Five periods of explosiveness in millet prices are identified in 1996, 1997, 1998, 2001 and 2005. In 1996 almost all price series of the sample experienced an explosive episode during the hunger season. Most of these episodes are of short duration, less than 3 months.

In 1997, 1998 and 2001 respectively 5, 8 and 9 markets out of 24 have experienced explosive episodes whose duration is greater or equal to 3 months. These episodes generally started in April and lasted until the arrival of the new harvest in September. The longest periods of explosiveness occurred in 2005 which is the year of the great food crisis in Niger. During that year prices in all markets except Dungass increased explosively. The explosive phase started in March or April in Agadez, N'Guimi, Dan Issa and Filingue and lasted for 5 months. In Maradi also, the third city of Niger in the centre of the millet growing area, millet price started increasing explosively in March but for a shorter period (3 month).

Prices also increased explosively in Katako, the main market of the capital city, in June and July 2005. In July 2008, Katako experienced another short episode of price explosiveness. This price spike episode which is circumscribed to Katako, may be the manifestation of the transmission of the price boom on world food markets to the capital city. We note that the new price upsurge that occurred in 2012 cannot be classified as explosive.

Over the whole period some markets appear to be more prone to exuberance than others. This is especially the case for N'Guigmi that recorded 21 months of explosiveness during the 1990-2012 period. N'Guigmi has also experienced the longer spells of explosive behaviour (6 months in 1997, 7 months in 1998 and 5 months in 2005). The geographical

[6] The significance level β_T depends on the sample size T and goes to zero as the sample size goes to infinity.

situation of N'Guigmi may explain atypical behaviour. N'Guigmi which is the capital of the eponymous department is located in a remote area in eastern Niger close to the border of Chad and Nigeria and about 1500 km from Niamey. Goudoumaria a rural municipality in the same region than N'Guigmi also experienced long episodes of explosiveness during the 1998 – 2000 period. Dan Issa another rural municipality, 560 km East of Niamey, have known a long period of explosiveness in 1996-1997[7].

The markets of Agadez, Arlit, Maradi, Zinder and Katako that are among the largest urban markets of Niger also experienced frequent and relatively long episodes of explosiveness with cumulated duration over the sample period equal to 15 to 11 months (Table 3). Agadez and Arlit are the most important cities of Northern Niger. Agadez is 900 km distant from Niamey at the border of the Sahara and Arlit is about 200 km north of Agadez, 170 km from the Algerian border. By contrast, Zinder and Maradi respectively the second and third largest city are located in the surplus southern region. Maradi and Zinder regions account for approximately 40% of the domestic millet production (WFP, 2005).

By contrast, some large municipalities such as Dungass, Dosso and Loga have experienced few explosive episodes and seem to have been less affected by speculation. This is also the case for Tillaberi, Kirtachi and Tchintabaraden which are municipalities of lesser importance. We note that except Niamey, the municipalities which have experienced the lowest number of episodes of price explosiveness are mainly located in the South-West part of Niger while the most affected municipalities are in the northern and central part.

To sum up, periods of explosiveness in millet prices can be found in most markets of Niger. Interpreting explosive behaviour in prices as the manifestation of speculative bubbles depends on the properties of market fundamentals. The next section addresses the difficult issue of estimating the fundamental value of millet.

[7] Results for Goudoumaria and Dan Issa must interpreted with cautious because of missing observations during the period of apparent explosiveness that may have affected the test results.

Table 2. GSADF test results (t-stat)

	Current prices				Bubble component			
	(1)		(2)		(3)		(4)	
Agadez	3.540	***	3.539	***	2.434	**	2.332	**
Arlit	2.692	**	2.692	**	1.003		1.622	
Bakin	3.262	***	3.262	***	1.701		1.619	
Birni	2.833	***	2.833	***	1.262		1.054	
Danissa	4.663	***	4.663	***	2.676	**	2.724	**
Diffa	1.854		1.854		1.034		1.112	
Dogondoutchi	1.888		1.888		-0.297		-0.429	
Dosso	2.987	***	2.987	***	2.039	**	1.701	
Dungass	2.108	*	2.040	**	-0.151		0.869	
Filingue	3.815	***	3.815	***	2.300	**	2.181	**
Gaya	1.641		1.641		0.921		0.694	
Gotheye	2.272	**	2.676		1.638		1.865	
Goudoumaria	2.111	*	3.020	***	1.688		2.437	**
Goure	3.404	***	3.410	***	2.239	**	2.275	**
Katako	4.549	***	4.549	***	2.764	**	3.254	***
Kirtachi	1.736		1.736		1.207		3.865	***
Loga	2.515	**	2.512	**	1.693		1.115	
Maradi	2.426	**	2.426	**	1.595		0.951	
Nguimi	1.980	*	3.506	***	1.682		2.035	*
Tahoua	3.195	***	3.197	***	1.976	*	2.141	*
Tchinta	2.642	**	2.642	**	1.245		1.506	
Tessaoua	2.931	***	2.931	***	1.100		1.439	
Tillaberi	1.684		1.684		2.969	**	2.309	**
Zinder	2.215	**	2.215	**	0.918		1.315	

*: significant at the 10% level; **: significant at the 5% level; ***: significant at the 1% level;
(1) no lag in test regression
(2) (3) (4) (5) Lag length selection according to SIC, max 3 lags
(3): specific fundamental value
(4): fundamental value estimated on panel data with 3 markets; regressors: Trend, cumulated rainfall, rice price, exchange rate
Finite sample critical values of the GSADF test against an explosive alternative:
90%: 1.915; 95%: 2.188; 99%: 2.696
Monte Carlo simulated values with 5000 replications. Sample size: T = 265.
The random walk process under H_0 is given by: $y_t = T^{-1} + y_{t-1} + \varepsilon_t$
Test regressions include an intercept.

Table 3. Date-stamping explosive periods in the millet price: the BSADF monitoring procedure

Region	Department	Market	1996		1997		1998		2001		2005		2008		
			start	lengh	Start	lengh	start	lengh	Start	lengh	Start	lengh	Start	lengh	Total lengh
Agadez	Arlit	Arlit	na		May	3	May	1	March	5	July	2			11
Agadez	Tchirozérine	Agadez	August	1	July	1	May	3	April	3	April	5			13
Diffa	Diffa	Diffa	June	2	July	2	June	1			July	1			6
Diffa	Maïné-Soroa	Goudoumaria	July	1			July	38			May	3			42
Diffa	N'Guigmi	N'Guigmi	July	1	June	6	Jan	7	April	2	March	5			21
Dosso	Dogondoutchi	Dogondoutchi	May	2			April	3	na		July	1			6
Dosso	Dosso	Dosso									June	2			2
Dosso	Gaya	Gaya	July	1	April	1					July	2			4
Dosso	Loga	Loga	May	1					April	0	june	2			3
Maradi	Tessaoua	Tessaoua	July	1	April	4	April	3	March	3	May	3			14
Maradi	Madarounfa	Maradi	May	1	April	4	April	4	March	4	April	3			16
Maradi	Madarounfa	Dan Issa	May	16					August	1	April	5			22
Tahoua	Birni N'Konni	Birni N'Konni			July	2	April	3	April	1	June	3			9
Tahoua	Tahoua	Tahoua	August	1	July	1	April	2	April	4	June	2			10
Tahoua	Tchintaba	Tchintabaraden	August	1			April	1	June	1	July	2			5
Tillabéri	Filingué	Filingué	August	1					na		March	5			6
Tillabéri	Kollo	Kirtachi									August	1			1
Tillabéri	Tillabéri	Tillabéri									June	2			2
Tillabéri	Tillabéri	Gotheye	August	2					Feb	4	June	2			8
Zinder	Gouré	Gouré	July	1			July	1	June	2	April	3			7
Zinder	Magaria	Dungass	June	2			July	1							3
Zinder	Tanout	Bakin Birji			July	2			March	3	July	2			7
Zinder	Mirriah	Zinder	May	3	April	3	July	1	March	4	June	2			13
Niamey	C.U.Niamey	Katako	August	1	August	1	May	3	March	5	June	2	july	1	13

5. The fundamental value of millet

To take into account the evolution of market fundamentals we follow the approach commonly used to test for speculative bubbles on stock markets. According to the basic asset pricing model the fundamental component of stock price is the discounted value of expected future dividends. Therefore, tests for speculative bubbles are based on analysis of stationarity and cointegration of stock prices and dividends.

Transposed to the millet market we estimate the relationship between millet price and observable fundamentals and investigate the dynamic properties of the residual term which is taken a measure of the potential bubble component of the millet price. The estimated model includes all observable exogenous variables that determine millet supply and demand.

On the supply's side, the level of precipitations over the rainy season catches climate conditions which are the main determinant of millet harvest. The price of oil which is considered as a proxy for millet production costs has been introduced in the equation without success[8]. On the demand side, a trend variable takes into account population growth. The world price of rice catches possible substitution effects in consumption. Indeed, rice is the main substitute to millet in population diet and most of the rice consumed in Niger is imported from the international market.

The estimated equation is given by:

$$P_t = \alpha_1 + \alpha_2 CumulRainfall_t + \alpha_3 Rice_t + \alpha_4 ER_t + \alpha_5 Trend + \nu_t \tag{14}$$

P_{it} is the millet price on market i at time t. $Cumul\ rainfall_t$ is the mean cumulated level of precipitation from May to October. It is calculated on observations below 14 degrees latitude which is considered as the limit of the main production area in Niger[9]. $Rice_t$ is the export price of Thai rice[10]; it is quoted in US Dollars. ER_t is the Franc Cfa to dollar exchange rate. The fitted

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8 The domestic price of gasoline being unavailable we considered the crude oil price as a proxy (Oil price is given by the simple average of three spot prices; Dated Brent, West Texas Intermediate, and the Dubai Fateh, in US Dollars per Barrel. Source: IFS). It may explain the non-significance of this variable in the millet price regressions.

9 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.

10 Price of 5 percent broken milled white rice, Thailand nominal price quote, in US Dollars per Metric Ton.

value of P_t is taken as a measure of the fundamental value of millet; the error term v_t is the apparent deviation of the millet price from its fundamental value at time *t*.

Equation (14) is first estimated for each market separately. However the main drawback of this approach that consists in measuring the potential bubble as the residual of the regression of the asset price on observable fundamentals is that the fundamental value is driven by the price process. Therefore explosive millet price may lead to an estimated fundamental value artificially explosive (Figuerola-Ferreti *et al*. 2014). As a consequence, in highly explosive markets, the fundamental value may catch part of price explosiveness and biases results toward low detection of bubbles.

To reduce this potential source of bias, equation (14) is, in a second stage, estimated using a fixed effects panel data model. The market sample is then restricted to markets that do not evidence non-linear behaviour according to the Markov-Switching ADF test results. These markets are: Diffa, Gaya and Tillaberi. We thus consider that the fundamental value for millet is the same throughout the country up to a constant term. Estimation results for the panel data model are given in Table 4. As expected, the cumulated rainfall level catching the millet supply negatively affects the millet price while the price of rice and the exchange rate have expected positive impact[11].

Table 4. Estimation of the fundamental value of millet

Dependent variable: millet price	
Cumulated Rainfall	-0.194 (0.000)
Rice price	0.070 (0.000)
Exchange rate	0.100 (0.000)
Trend	0.504 (0.000)
Cross-section fixed effect	yes
Adjusted R-squared	0.683
No. of obs	795

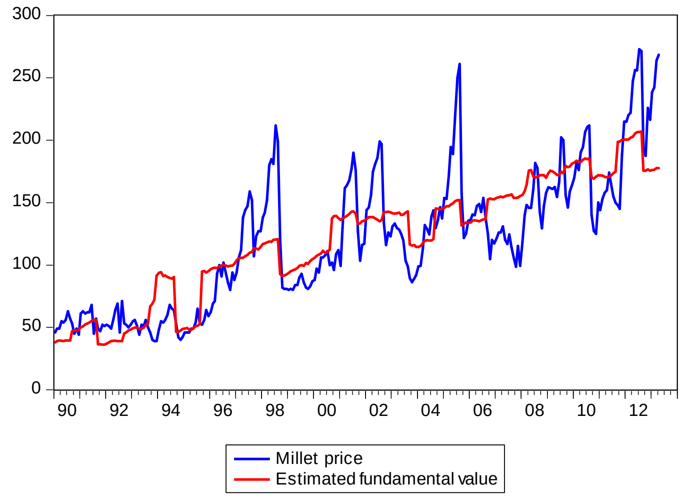
Cluster robust standard errors. P-value in parenthesis.

As an illustration, Figure 4 shows the estimated fundamental component and the millet price in Maradi. The deviation between the current price and the fundamental component represents the potential bubble part. This figure highlights five periods during which the millet

[11] Estimation results of time series models for equation (14) are not reported here.

price in Maradi has risen far beyond its fundamental value : 1997-1998, 2001, 2002, 2005 and 2012.

Figure 4. Millet price and fundamental component in Maradi (Fcfa/kg)

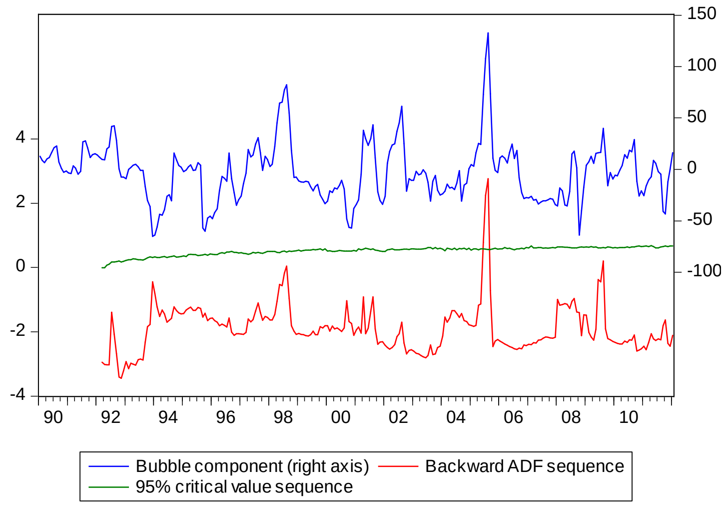


Then the recursive right-tailed ADF test is implemented on the estimated bubble component of millet prices. Results are given in table 3. When the relationship between the millet price and observable fundamentals is set specific to each market (time series models, table 3 column 3), evidence of speculative bubble is found in eight markets: Agadez, Dan Issa, Dosso, Filingue, Goure, Katajo, Tahoua and Tillaberi (table 3, column 3). The bubble episodes are recorded in 2005 at the end of the hunger season and do not exceed three months. As expected, when considering that the fundamental value is common to all markets (panel data model, table 3 column 4), the presence of bubble is detected on a larger number of markets (10 markets). As previously observed the BSADF tests detect the same bubble episodes in 2005. Test results are not presented here but an illustration is given in Figure 5 which depicts the BSADF test statistic and the bubble component of the millet price in Katako. The BSADF test also detects a bubble of longer duration in Goudoumaria – from July 2000 to March 2001 – as well as a bubble episode during the 1998 hunger season in N'Guigmi and a longer one from July 2002 to September 2002 in Kirtachi.

It must be noticed that this procedure can brings up negative bubbles corresponding to a sharp drop in the millet price under its fundamental value. This is the case in 1993-94 in Maradi, Bakin and Agadez at the time of the Fcfa devaluation. The millet price did not increase after the devaluation, but remained at a low level. Such episodes are not considered as speculative bubbles.

Paradoxically the estimated bubble component of two price series - Tillaberi and Kirtachi - that are not explosive in level manifests explosive behavior. In these two markets, prices have risen much faster than apparent fundamental values and the price spread increased in an explosive way.

Figure 5. Backward ADF test sequence: bubble component of millet price in Katako



6. Discussion and concluding remarks

We have found evidence of two types of nonlinearity in millet price: in a large number of markets millet price follow a two regimes process and manifested explosive behaviour in different periods of time. Periods of explosiveness were more frequent and larger in 2001 and 2005. However evidence for the presence of periodically collapsing bubbles is weak. Most of episodes of price explosiveness appear to be driven by fundamentals i.e. by large climate shocks. 2005 is the main exception. The great 2005 food crisis may partly be caused by abnormally high millet price relative to fundamentals during the hunger season in Agadez, Katako and Tahoua and five to eight other markets of lesser importance.

The origin of the 2005 food crisis has been the subject of a vast literature. According to Cornia and Deotti (2008) the crisis not only resulted from a decline in food supply, the failure of the institutions in charge of food aid management and the failure of household's entitlements but also from abnormal behaviour on grain markets. The authors registered during the 2004-2005 marketing year growing differences between producer and consumer prices and between prices in small and large collector markets that they take as evidence of the realisation of abnormal profit by wholesalers. Our econometric results that do not reject the existence of millet price bubbles in 2005 tend to confirm the speculative nature of the food crisis.

Of course our test strategy for speculative bubbles is subject to many limitations the main one relating to the estimation of market fundamentals. In our analysis fundamentals are mainly caught by weather conditions. The rejection of the presence of bubbles may result from omitted variables and misspecification of the relationship between prices and observable components of market fundamentals. Moreover the join determination of the fundamental value and the asset price biases result in favour of a low detection rate of bubbles.

Another limitation relates to the low frequency of our data. The PSY testing procedure requires a minimum number of observations in the sample regression. We set the minimum sample size to about 12% of total sample which allow estimating parameters with relative precision. But this minimum sample size might be too large to catch short lived intra annual explosive episodes.

Ruling out the presence of millet price bubbles, nonlinearity in price process may be interpreted as the standard result of the commodity storage model (see for instance Deaton and Laroque, 1992 and Ng 1996 for empirical tests). According to this model commodity prices follow a two-regime process depending on whether inventories are positive or null. In the stockholding regime prices are driven by net supply including demand for speculative storage. Inventories being costly, prices are expected to rise with an autoregressive coefficient greater than unity. Millet being generally held from one harvest to the other the stockholding regime should be the dominant one. In the stockout regime, there is no profitable arbitrage opportunity and the demand for inventories is null. The price level and the price volatility are expected to be higher because inventories no longer play any regulating role. In Niger, early stock liquidation might explain short episodes of price spikes during the hunger season.

The results of the Markov switching model showing higher price level and higher volatility in the non-explosive regime partly correspond to the predictions of the commodity storage model. However the high degree of price autocorrelation in this regime contradicts the theoretical predictions according to which prices should be serially independent in the stockout regime. Indeed it is a well-known weakness of the standard storage model of not being able to reproduce the high autocorrelation observed in most commodity prices. We note that Ng (1996) tested the storage model predictions using a similar approach - based on a SETAR model with two regimes. She also found high persistency in the stockout regime contradicting with the theoretical model.

Whether price exuberance is the consequence of self-fulfilling beliefs or the result of low inventories is a difficult issue. Discriminating between these alternative but nonexclusive models of price formation might be impossible without more precise price data and additional information on stocks. Results plead for further research to better understand intra annual price formation. They also plead for strengthening market information systems in developing countries such as Niger. In particular the collection of high frequency data for instance weekly data would be highly desirable.

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APPENDIX

Map 1. Market sample

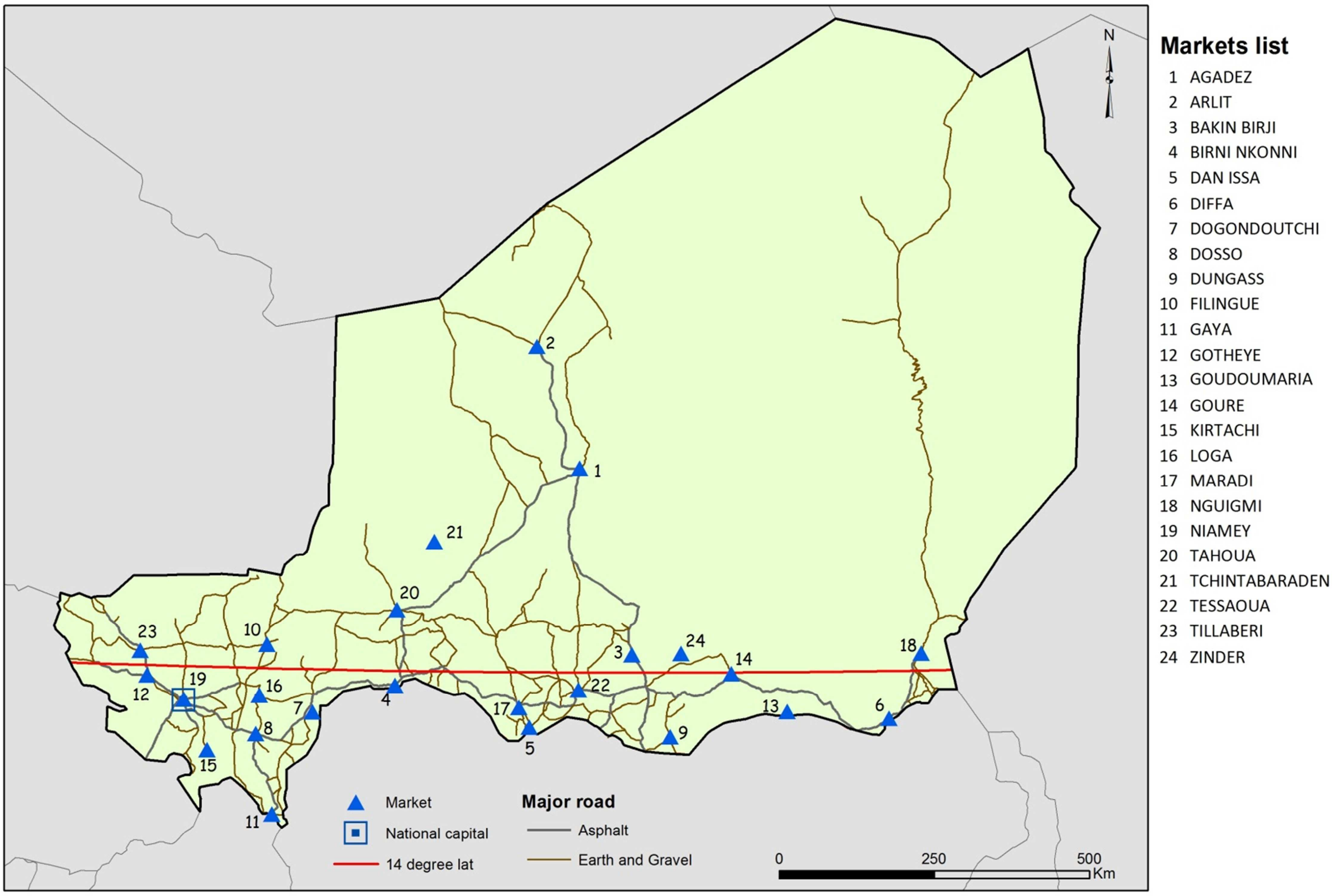


Table A1. Millet price. Sample characteristics and unit root tests

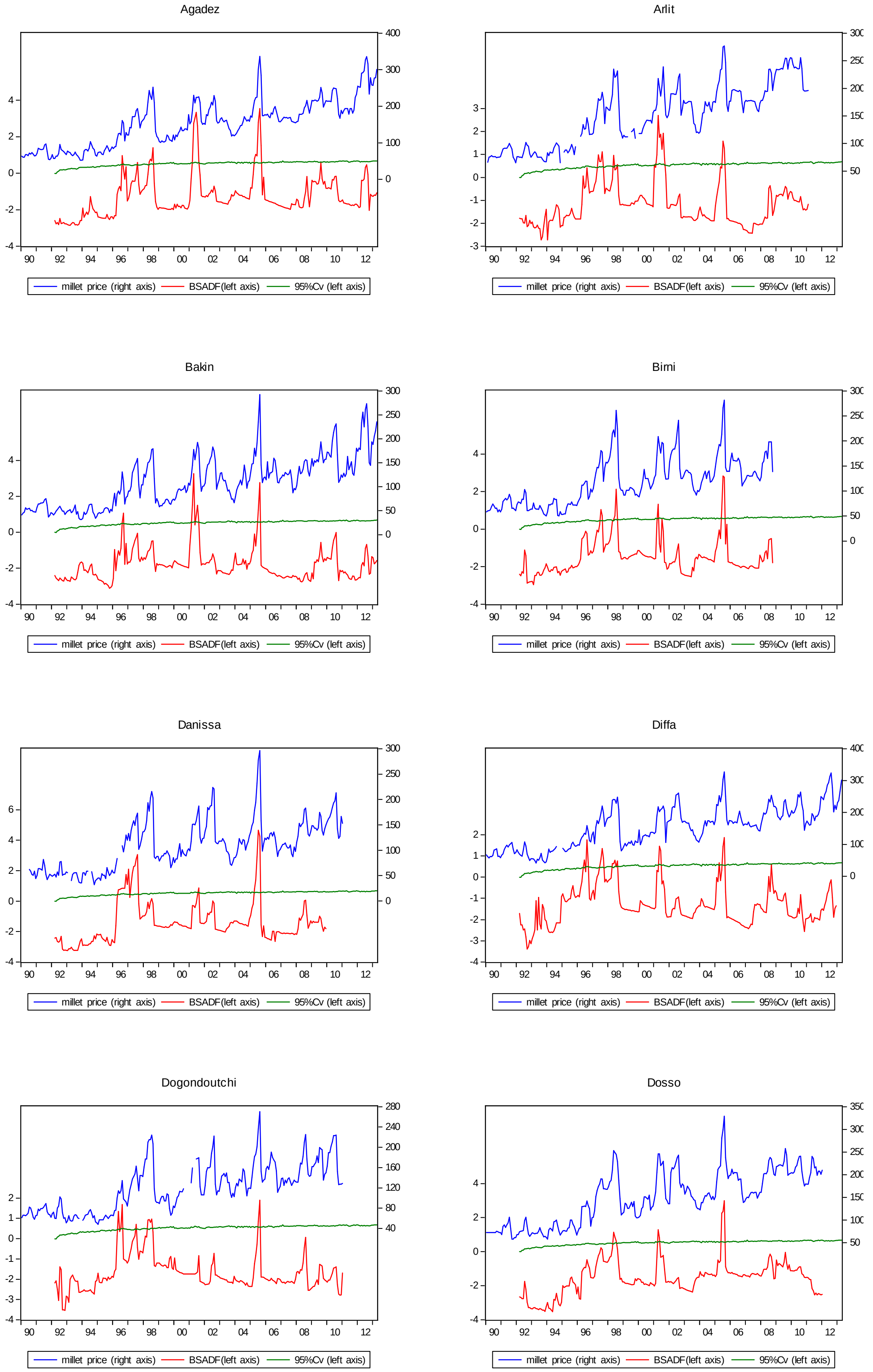
Market	Mean	Nb		Period of observation		ADF test [lag]	
	Fcfa/kg	Obs.	na*	start	end	t-stat	[p]
Arlit	152	244	9	1990.02	2011.02	-4.744	[1]
Agadez	145	280	0	1990.01	2013.04	-4.964	[1]
Diffa	146	249	4	1990.01	2013.04	-5.104	[1]
Goudoumaria	131	215	11	1990.01	2008.10	-3.805	[0]
N'Guigmi	158	271	8	1990.02	2013.04	-4.513	[0]
Dogondoutchi	120	244	7	1990.01	2011.01	-5.740	[1]
Dosso	150	265	0	1990.01	2012.01	-5.143	[1]
Gaya	134	254	0	1990.01	2011.02	-5.002	[0]
Loga	130	242	12	1990.01	2011.02	-5.791	[1]
Tessaoua	108	245	9	1990.05	2011.02	-5.632	[1]
Maradi	113	280	0	1990.01	2013.04	-5.243	[1]
Dan Issa	110	240	13	1990.07	2011.01	-5.213	[1]
Birni N'Konni	118	226	0	1990.01	2008.10	-4.979	[1]
Tahoua	152	279	1	1990.01	2013.04	-4.953	[0]
Tchintabaraden	156	239	14	1990.01	2011.01	-4.912	[1]
Filingué	139	238	16	1990.01	2011.02	-5.537	[0]
Kirtachi	133	235	19	1990.01	2011.02	-5.791	[1]
Tillabéri	156	265	0	1990.01	2012.01	-5.667	[1]
Gotheye	147	247	6	1990.01	2011.01	-5.131	[1]
Gouré	125	253	0	1990.01	2011.01	-5.706	[1]
Dungass	108	253	0	1990.02	2011.02	-5.942	[1]
Bakin birji	103	280	0	1990.01	2013.04	-4.304	[12]
Zinder	118	265	0	1990.01	2012.01	-5.571	[1]
Katako	154	280	0	1990.01	2013.04	-5.687	[1]

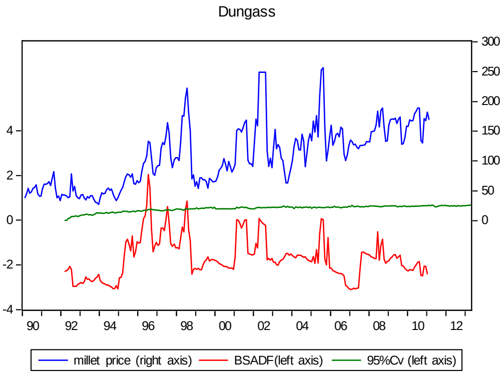
Source: SIMA and authors' calculations.
na: number of missing values.
ADF test: H_0: I(1) ; intercept and trend in test equation. Lag length selection: Schwarz Information Criterion within the range [0, 12].

Table A2. Main characteristics of markets

Region	Department	Market	Type of municipality	Inhabitants (in 2011)	Distance from Niamey
Agadez	Arlit	Arlit	Urban, capital of Dpt.	107 180	806 km
Agadez	Tchirozérine	Agadez	Urban, capital of Region	118 519	740 km
Diffa	Diffa	Diffa	Urban, capital of Dpt.	46 439	1138 km
Diffa	Maïné-Soroa	Goudoumaria	Rural	99 448	974 km
Diffa	N’Guigmi	N’Guigmi	Urban, capital of Dpt.	41 105	1192 km
Dosso	Dogondoutchi	Dogondoutchi	Urban, capital of Dpt.	77 035	208 km
Dosso	Dosso	Dosso	Urban, capital of Region	87 721	128 km
Dosso	Gaya	Gaya	Urban, capital of Dpt.	54 865	233 km
Dosso	Loga	Loga	Urban, capital of Dpt.	84 624	122 km
Maradi	Tessaoua	Tessaoua	Urban, capital of Dpt.	119 599	636 km
Maradi	Madarounfa	Maradi	Urban, capital of Region	200 015	540 km
Maradi	Madarounfa	Dan Issa	Rural	73 362	559 km
Tahoua	Birni N'Konni	Birni N'Konni	Urban, capital of Dpt.	139 142	342 km
Tahoua	Tahoua	Tahoua	Urban, capital of Region	119 599	373 km
Tahoua	Tchintabaraden	Tchintabaraden	Urban, capital of Dpt.	29 934	478 km
Tillabéri	Filingué	Filingué	Urban, capital of Dpt.	69 342	161 km
Tillabéri	Kollo	Kirtachi	Rural	33 955	89 km
Tillabéri	Tillabéri	Tillabéri	Urban, capital of Region	50 005	106 km
Tillabéri	Tillabéri	Gotheye	Rural	na	72 km
Zinder	Gouré	Gouré	Urban, capital of Dpt.	65 987	884 km
Zinder	Magaria	Dungass	Rural	97 247	786 km
Zinder	Tanout	Bakin birji	Rural	na	726 km
Zinder	Mirriah	Zinder	Urban, capital of Region	265 828	805 km
C.U.Niamey	C.U.Niamey	Katako	Urban, capital of Niger	1 222 066	

Figure 1. Backward Sup-ADF test statistic




Dungass
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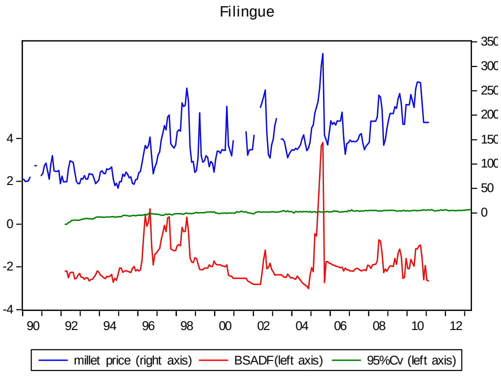
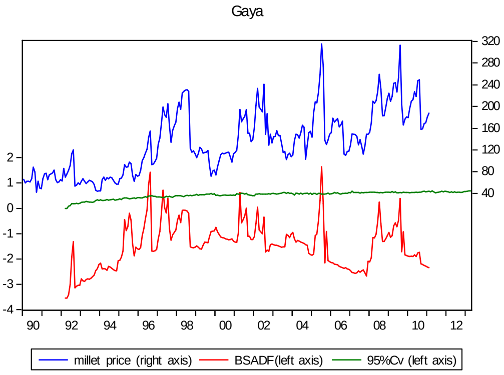
BSADF(left axis)
95%Cv (left axis)


Filingue
millet price (right axis)
BSADF(left axis)
95%Cv (left axis)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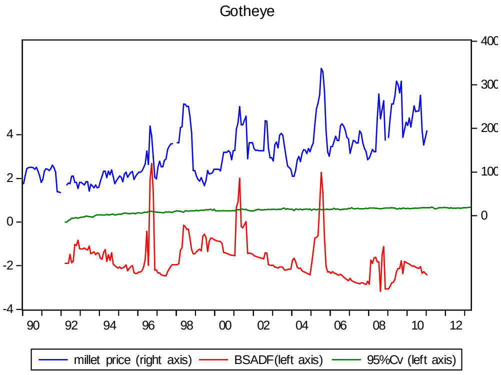
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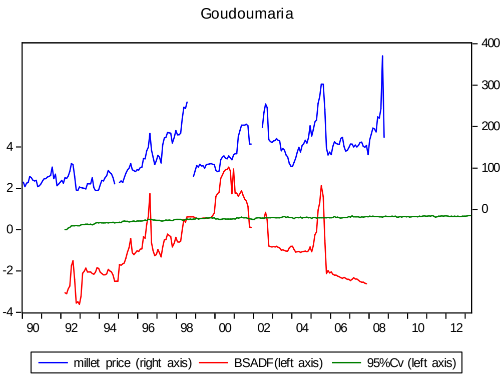
Goudoumaria
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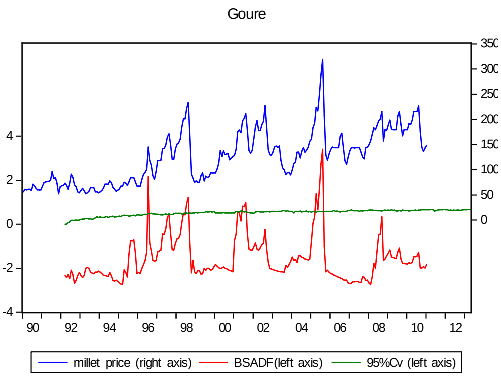
BSADF(left axis)
95%Cv (left axis)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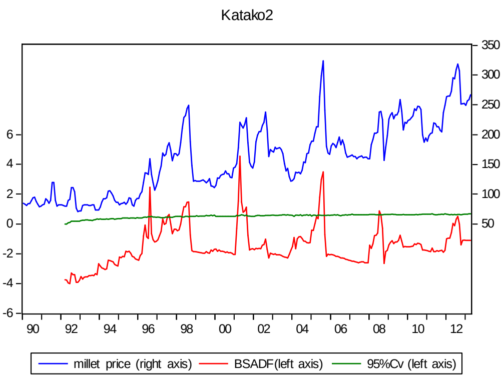
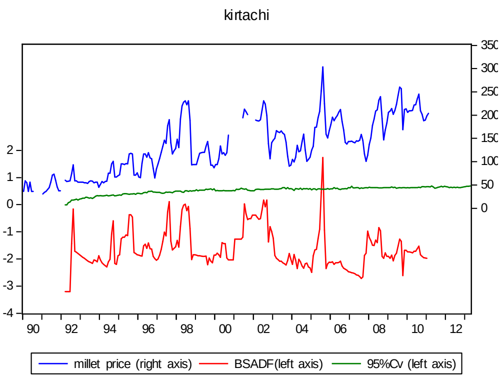
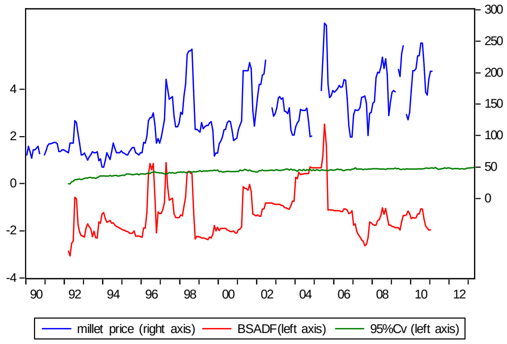
BSADF(left axis)
95%Cv (left axis)

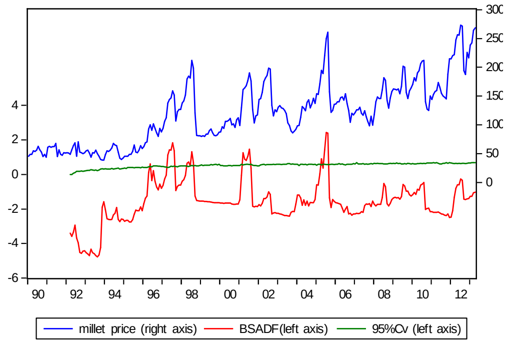

Katako2
millet price (right axis)
BSADF(left axis)
95%Cv (left axis)


kirtachi
millet price (right axis)
BSADF(left axis)
95%Cv (left axis)

loga



Maradi



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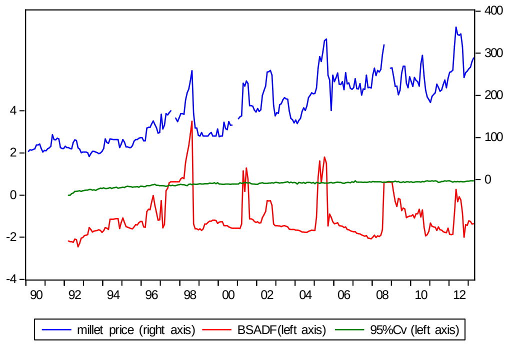

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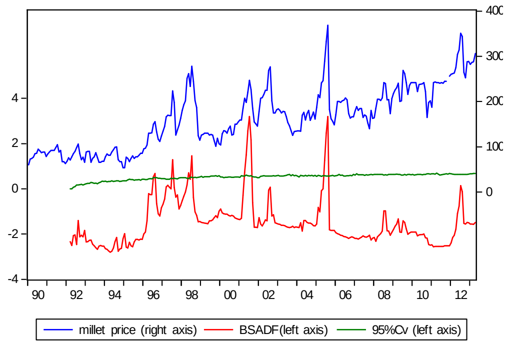
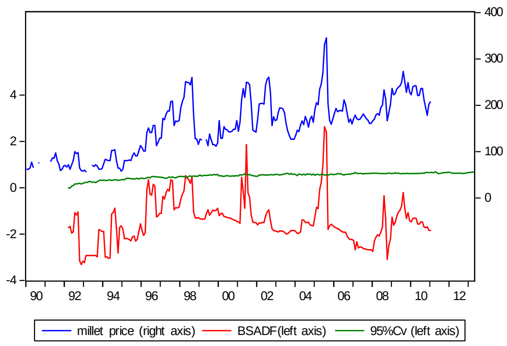


Tchinta



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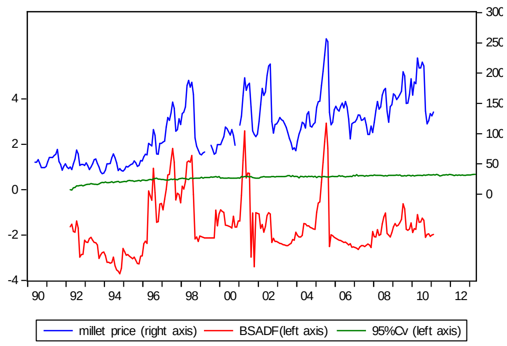

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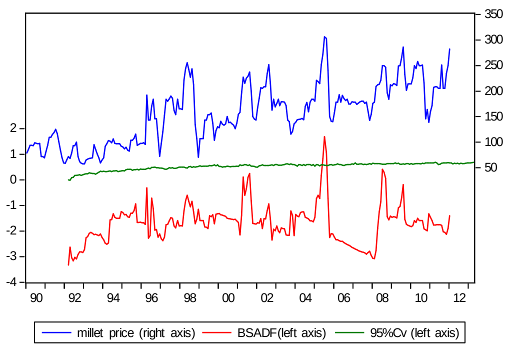

Zinder