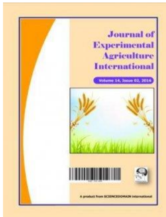

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Chronological Analysis of the Price of Tomato Fruit (*Solanum lycopersicum L.*) in Benin Main Markets from 2006 to 2015

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The fluctuation of the price of tomatoes during the year represents, for the Beninese population a real problem, both in terms of food and socio-economic. In this context, this work analyses the evolution of the selling prices of tomatoes in 11 Benin markets from 2006 to 2015. The tomatoes price experienced a high and strong fluctuation in most markets. The multiplicative model made it possible to isolate the trend and the seasonality. The trend has been adjusted by a 3rd order centered moving average model. Seasonality indices showed that the price is higher than the monthly average in most markets during the months from March to June. These fluctuations depend on the production system and rainfall conditions. The understanding of the evolution of the price of tomatoes is therefore necessary for the formulation of the market stabilization policies of this product.

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1. INTRODUCTION

The recent international crises in the prices of agricultural raw materials, especially that of 2007, have generated numerous disruptions in the national economies of developing countries such as the sub-Saharan region [1]. The negative consequences have been illustrated in various parts of the economy, especially in the prices of local products. For these countries, the price of food products is an important factor in the production and sales strategy of the producer, and in the household consumption strategy both in rural and urban areas. Hence, small scale rural producers sell and buy food products according to the time of year. Poor households in urban areas spend a large part of their income on food purchases so much so that the price of food products determines their standard of living. Fluctuations in these prices reinforce, either food insecurity situations for the poorest households [2] or the increase in malnutrition [3]. It is therefore necessary to understand the evolution of these prices for the formulation of food stabilisation policies. It is a structuring policy in the long-term agricultural development through the price movement control, known in research works as a factor that influences the technological investments of farmers [4]. Many factors can influence demand and supply which are the main factors that determine the price of products in the market. These factors can be exogenous as well as endogenous. Climatic factors are an example of exogenous factors because of the sensitivity of agricultural production to rainfall variables that exercise phytosanitary pressures that affect crops and their marketing. The behaviour of market players (producers and retailers in particular) is an example of an endogenous factor. Hence, because of the period between the time when the production decision is made and the date when it is sold, producers make price expectations that affect the level of their future production [4]. In literature, two forms of expectations are commonly made: Adaptive expectations [5] and rational expectations [6,7]. Adaptive expectations assume that only information about the past is taken into consideration by economic agents. The expected price is assumed equal to the weighted sum of past prices. This is the origin of the Nerlovian models [8] and the Cobweb models [9,10]. On the contrary, rational expectations use the prediction model endogenous variables, including prices, to make expectations. Instead of referring to past prices, the predictions are therefore based on the knowledge of a structural model of price determination, exogenous predictions of independent variables of the model, and expectations about the policy instruments of the model [11].

In underdeveloped countries in general, and particularly in Benin, the seasonality of food prices determines the farmers' storage and marketing strategy. The knowledge of producer prices and their role is therefore essential for understanding the economic environment of producers as well as the analysis and planning in the agricultural sector. In Africa prices in the markets of production and consumption are generally unstable. Contrary to what is commonly accepted, in reason of the diversity of products and sources of supply, prices in cities are also very unstable. While some of the variations are seasonal, linked to production schedules, they are far from entirely predictable: the cycles are not regular and there are significant fluctuations from one season to another, often attributed to climatic conditions but also the result of difficulties of access to transport and information [12]. It is interesting to note that the differences between prices in different markets are not constant, confirming, besides the market segmentation, the existence of variable transfer costs related to risk and stock changes [13].The purpose of this paper is to analyse the price of tomato fruit in 11 Benin main markets (consumer market and producer pooling market) from 2006 to 2015, using mathematical and statistical modelling approaches, in order to better understand the price variations and instabilities. Indeed, according to FAO [14], tomato fruit (*Solanum lycopersicum L.*), from the Solanaceae family, is one of the most important fruit crops produced in Benin in the year 2015, both in terms of area (39 030 ha) and in terms of production (303 893 tons). It is the most consumed fruit product used as an ingredient in the daily diet that is made of cereal and tuber foods. Given its importance in the socio-economic development of Beninese, its availability at an affordable price throughout the year is a problem for the populations of Benin [15]. This brings about the importation of fresh tomatoes from neighbouring countries, particularly Nigeria, Togo, Ghana and Burkina Faso, in order to supplement local production [16]. Most of the studies carried out on tomatoes in Africa in general and in Benin in particular, have focused on the evaluation of genetic potential, fertiliser doses and adaptability to tropical conditions [17]. However, few are the studies that base their analysis on the spatiotemporal information of the price of tomatoes. This study is therefore carried out in this regard in order to fill this gap in Benin.

2. METHODS

2.1 Data

The data source used is the monthly price series of tomatoes (per kg) in 11 Benin markets (Azové, Bohicon, Comé, Dantokpa, Djougou, Glazoué, Malanville, Natitingou, Parakou, Pobè and Tanguiéta) from 2006 to 2015. These markets concern both consumer and producer pooling markets. The database comes from the National Office for Food Security Support (ONASA). The criterion for the selection of the 11 markets is the existence of more or less complete series price data for the period. The missing data were estimated by considering the average of the indexed monthly prices of the four years that flank the missing data.

The rainfall data were obtained from the Agency for the Safety of Air Navigation (ASECNA). These data contain the monthly rainfall obtained from every one of the 11 towns where these markets are located from 2006 to 2015. Also, all the missing data were estimated considering the average indexed monthly data of the four years that flank the missing data.

2.2 Data Analysis

The methodological approach consisted firstly, in analysing the trend of every price series using a statistical modelling. The series decomposition for each market was then performed using multiplicative and additive mathematical models.

Thus, the trend for each series has been studied by adjusting the price data to the following models:

- linear trend : $P_t = b_0 + b_1 t$ (1)
- quadratic trend : $P_t = b_0 + b_1 t + b_2 t^2$ (2)
- exponential trend : $P_t = b_0 e^{b_1 t}$ (3)
- Moving averages of order 2, 3, 4, 5, 6 and 12
- Simple exponential smoothing
- Double exponential smoothing

In these relationships, t represents the time, b_0, b_1 and b_2 are constants to be estimated.

As for the decomposition model, the choice depends on the series to be decomposed. In this context, the additive and multiplicative models were analysed. Let's assume that the general price model is defined by the relationships:

$P_t = T_t + C_t + S_t + E_t$ for the additive model (1)

And

$P_t = T_t C_t S_t E_t$ for the multiplicative model (2)

In these relationships P_t represents the price of tomatoes at the time t, T_t is the overall trend component, C_t is the cyclical component, S_t is the seasonality component, and E_t is the irregular component. The long-term trend represents the long-term price evolution, and reflects the general aspect of series. The cycle, a smooth and quasi-periodic movement around the trend, reveals a succession of growth and recession phases. The seasonal component is repeated at equal time intervals with a slightly constant form. It can result from seasonal rhythm or from human factors. In the case of this study, its period is equal to 12 because it is the monthly series. The residual component includes everything that has not been taken into account by trend, cycle and seasonality. It is the result of irregular and unpredictable fluctuations due to non-permanent disruptive factors. These fluctuations suggest low amplitude and zero mean on a small number of consecutive observations. Exceptional climatic factors are also included.

For the multiplicative decomposition method, the observed price data were first smoothed by a 12 order centered moving average (MM_{12}). This moving average contains only the trend and the cycle. By dividing the gross series by the moving average, the result obtained contains only the seasonal component and the random component.

$$\frac{P_t}{MM_{12}} = \frac{T_t C_t S_t E_t}{T_t C_t} = S_t E_t \quad (3)$$

The seasonal coefficient was then calculated as the average median of 9 ratios obtained by dividing the raw data by the moving averages on every month of the period. The average median of a group of values is the average after the smallest and largest values have been excluded. The values obtained were standardised in order to balance the seasonal differences within each observed year. The standardisation was to adjust every monthly component so that the sum of all the components divided by 12 will be one.

The original series divided by the seasonal component gives an adjusted series of seasonal variations or non-seasonal series (CVS) that is equivalent to the product of the trend, the cyclical component and the random component.

The cyclical component is different from the seasonal component in that the cycle often exceeds the seasonal periodicity, and the different cycles may have distinct lengths. The combined trend-cycle components were estimated by applying to the *CVS* series, a moving average weighted and centered on length 5, with weights 1, 2, 3, 2, 1. From every smoothed *CVS* series, the cycle was estimated by dividing the trend-cycle component (smoothed *CVS* series) by the trend.

Finally, the irregular component (residuals) was isolated by dividing the *CVS* series by the trend-cycle component.

As for the additive decomposition method, it makes it possible to isolate the different components using simple subtraction. Thus, subtracting the moving average from the gross series, we obtain the seasonal component and the random component.

$$P_t - MM_{12} = S_t + E_t \quad (4)$$

The seasonal coefficient was calculated as the average of the 9 differences obtained between the raw data and the moving averages for every month of the period. The values obtained were then standardised by adjusting every monthly component so that the average of all components becomes zero.

The original series minus the seasonal component gives a non-seasonal series (*CVS*) which is equivalent to the sum of the trend, the cyclical component and the random component.

$$CVS_t = P_t - S_t = T_t + C_t + E_t \quad (5)$$

The combined trend-cycle components were estimated by applying to the *CVS* series, a weighted and centered moving average of length 5, with weights 1, 2, 3, 2, 1. From each smoothed *CVS* series, the cycle was estimated by subtracting the trend from the trend-cycle component (smoothed *CVS* series).

Finally, the irregular component (error) was isolated by subtracting the trend-cycle component from the *CVS* series.

In order to evaluate the influence of rainfall conditions on the price for every market, the stepwise regression was used, for every market. The annual average price is the variable to be explained and the monthly rains of each year represent the explanatory variables. Thus, for the prices of each district, we have 12 explanatory variables.

2.3 Criteria for Evaluating Models

For every market, the best model that fits the overall trend is the one with the lowest mean square (MSD) value defined as follows:

$$MSD = \frac{1}{n}\sum_{1}^{n}\left(P_t - \hat{P}_t\right)^2. \quad (6)$$

The price variation percentage explained by the model was calculated by the following formula:

$$\%Model = 100 \times \frac{(Total\ variance - MSD)}{Total\ variance} = 100 \times \frac{\left(\frac{1}{n}\sum_{1}^{n}\left(P_t - \overline{P}\right)^2 - \frac{1}{n}\sum_{1}^{n}\left(P_t - \hat{P}_t\right)^2\right)}{\frac{1}{n}\sum_{1}^{n}\left(P_t - \overline{P}\right)^2}. \quad (10)$$

3. RESULTS

3.1 Descriptive Characteristics of Prices

The description of the data shows, in a comprehensive manner, a price increase from one year to another and sometimes starting from simple to double in most of the markets during the period considered (Table 1). However, the upward trend occurs differently in the 11 markets. It mostly occurs in the following markets: Azovè, Comè, Dantokpa, Natitingou, Parakou, Pobè and Tanguiéta. It is moderate in Djougou and Malanville markets and practically absent in Bohicon and Glazoué markets. The lowest values of the price (per kg) were observed in Azovè, Comè, Dantokpa, Natitingou, Parakou, Pobè and Tanguiéta markets in 2008, 2008, 2009, 2006, 2007, 2007 and 2006 respectively; and the highest prices in the same markets were observed in 2014, 2015, 2015, 2012, 2010, 2015 and 2010 respectively. This shows that the lowest prices were noted at the beginning of the study period considered and the highest prices towards the end of the period considered. For the 11 markets considered, the lowest average price was noted in Azové market (182 XOF / kg in 2006), while the Dantokpa market has the highest average price (654 XOF / kg) in 2015. The price increase over the period is also not linear. The price variability within a year as measured by the coefficient of variation is relatively high in most markets, except in Natitingou market. The highest coefficient values of variation were observed in Azové and Dantokpa markets. For the same market, the coefficient of variation varies from one year to another. This shows the price instability between the different months of the same year and between years. From these results on the coefficient of variation, it is clear that the importance of seasonality will depend on the level of the series and the use of the multiplicative model is more appropriate for the series studied. Indeed, if the seasonality was additive, the variations will be constant in the series, regardless of the overall level of the series. On the other hand, if seasonality is multiplicative, then the fluctuations are greater when the level of the series is higher. Therefore, in the following, the results will be the object of the multiplicative models only, although the additive models were also studied.

3.2 Trend Study

The results of the adjustments made on different models with the price data (per kg) of tomatoes during the period 2006-2015 in every of the 11 markets studied are presented in Table 2. From this table analysis, it is apparent that the exponential, linear and quadratic models have the highest mean square values. The single and double exponential smoothings give intermediate mean square values. The adjustments that are made by the moving averages give low mean square values. This ensues then that the proportions of the variability of the price data explained by the exponential, linear and quadratic models are the lowest (1.72% in Bohicon market to 22.24% in Natitingou market for linear model, 2.98% in Glazoué market to 42.28% in Natitingou market for quadratic model, and -1.67% in Tanguiéta market to 19.14% in Natitingou market for exponential model). Those relating to the exponential smoothing models are average (7.39% in Malanville market to 59.24% in Natitingou market for simple exponential smoothing and -5.99% in Malanville market to 56.31% in Natitingou market for double exponential smoothing) and those relating to the moving average models are relatively high (15.99% in Azové market to 79.50% in Natitingou market). Among the moving average models tested, the lowest mean square values or the highest percentages of price variation explained by the models were obtained with the 3rd order moving average. The criteria for the choice of the best model were based on the model which minimises the average square; it therefore seems that the 3rd order moving average models are more suitable for trend adjustment. The mean square values obtained for these models however vary strongly from one market to another. They are weaker in Natitingou, Glazoué and Bohicon markets (1234.8, 3271.5 and 5302.6 respectively), while they are high in Parakou, Comè and Azovè markets (24513.5, 22355 and 21479.9 respectively). Thus, the adjustments by the 3rd order moving average model are better in Natitingou, Bohicon Glazoué markets than in Parakou, Comè and Azovè markets.

3.3 Seasonality Study

The multiplicative model makes it possible to decompose and to reconstruct every one of the starting series as mentioned earlier. The seasonal standardised coefficients for the price (per kg) of tomatoes in every market are presented in Table 3. These coefficients correspond to the relative price (per kg) of tomatoes in every month of the year in relation to the annual average price fixed at 100. For

Table 1. Average values, coefficient of variation, minimum and maximum of the price (per kg) of tomatoes in the 11 markets from 2006 to 2015

Markets	Parameters	Years									
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Azovè	Mean	182	190	136	189	278	373	409	445	467	424
	CV	44	71	43	61	70	66	75	92	70	55
	Min	90	50	50	80	110	115	150	130	105	145
	Max	290	495	220	415	710	723	861	1000	1000	1000
Bohicon	Mean	433	330	355	358	361	292	223	317	425	388
	CV	27	30	8	13	26	40	34	26	27	26
	Min	265	155	300	268	185	100	150	150	300	250
	Max	560	468	375	430	485	400	400	400	600	500
Comé	Mean	332	310	284	480	601	394	536	437	521	640
	CV	67	82	23	35	50	41	54	36	43	23
	Min	85	65	185	240	260	160	225	250	190	290
	Max	685	925	375	855	1135	674	1000	760	835	835
Dantokpa	Mean	274	270	313	266	274	411	357	454	363	654
	CV	38	26	31	34	73	44	34	52	45	47
	Min	130	173	236	160	80	210	145	195	175	385
	Max	525	425	545	500	640	705	503	800	700	1285
Djougou	Mean	290	345	284	453	607	395	324	472	463	408
	CV	2	58	24	42	77	42	41	44	29	41
	Min	285	160	188	293	115	185	155	195	295	200
	Max	300	920	395	823	1335	770	660	800	710	700
Glazoué	Mean	309	306	285	394	307	359	289	448	409	292
	CV	64	46	36	17	29	21	19	35	23	13
	Min	115	125	100	305	130	240	230	270	260	250
	Max	705	563	460	525	430	450	400	675	500	350
Malanville	Mean	352	369	343	411	438	520	399	371	365	507
	CV	65	47	44	24	30	39	40	23	21	26
	Min	125	160	160	265	250	300	250	275	250	350
	Max	950	773	595	548	615	950	725	500	525	715
Natitingou	Mean	303	311	351	429	420	439	497	404	392	417
	CV	28	19	10	16	9	6	14	8	11	16
	Min	155	260	290	355	380	405	400	350	300	300
	Max	475	430	395	565	480	490	600	450	450	500
Parakou	Mean	340	205	364	554	577	425	449	496	548	560
	CV	37	26	50	49	56	48	33	41	35	53
	Min	170	120	160	225	245	235	260	250	355	345
	Max	630	335	713	961	1210	865	730	830	1045	1365
Pobè	Mean	325	261	281	323	376	408	378	412	412	498
	CV	39	65	41	37	49	49	53	63	28	21
	Min	150	45	155	205	175	120	155	135	250	225
	Max	565	532	520	585	780	765	730	835	600	600
Tanguiéta	Mean	209	416	502	340	538	475	410	403	435	431
	CV	46	42	54	35	47	33	35	43	50	38
	Min	100	115	123	130	213	230	230	120	275	250
	Max	365	750	1000	505	995	755	745	720	880	800

Note: CV = coefficient of variation, Min = minimum, Max = maximum

Table 2. Adjustment of model parameters to the trend of price series of every of the 11 markets

Type of model	**Model parameters**	**Markets**										
		Azovè	**Bohicon**	**Comé**	**Dantokpa**	**Djougou**	**Glazoué**	**Malanville**	**Natitingou**	**Parakou**	**Pobè**	**Tanguiéta**
Linear	b0	136.0	365.6	311.8	215.2	347.3	318.8	359.5	333.4	314.4	271.2	355.8
	b1	2.86	-0.03	2.34	2.45	0.94	0.43	0.79	1.04	2.27	1.59	0.99
	MSD	56496.4	11221.3	47792.7	33302.7	47646.3	14423.6	23797.1	4684.5	48722.0	27040.2	37477.2
	%Model	15.54	1.72	12.84	18.47	3.0	2.33	3.86	22.24	12.0	10.85	3.88
Quadratic	b0	113.4	439.5	296.2	284.8	262.1	291.5	331.1	253.8	238.6	293.6	277.4
	b1	3.97	-3.92	3.11	-0.097	5.13	1.53	2.19	4.96	6.0	0.49	4.85
	b2	-0.01	0.03	-0.01	0.03	-0.04	-0.01	-0.01	-0.03	-0.03	0.01	-0.03
	MSD	56399.3	10183.1	47746.8	32379.8	46267.0	14328.6	23643.5	3477.1	47627.6	26944.7	36308.7
	%Model	15.69	10.81	12.93	20.73	5.81	2.98	4.48	42.28	13.98	11.16	6.88
Exponential	b0	134.33	352.74	262.62	227.48	308.9	279.17	317.57	324.06	276.84	242.81	296.59
	b1	1.01	0.1	1.01	1.01	1.003	1.002	1.003	1.003	1.01	1.01	1.004
	MSD	62412.2	11554.6	50691.0	34856.5	49538.8	14959.9	24676.5	4871.7	51200.5	28484.4	39640.0
	%Model	6.7	-1.2	7.56	14.67	-0.85	-1.3	0.31	19.14	7.53	6.09	-1.67
Moving average 2	MSD	24386.1	3644.1	25464.0	16485.0	19289.1	5901.4	13400.0	1444.6	27567.2	13460.6	22880.1
	%Model	63.55	68.08	53.56	59.64	60.73	60.04	45.87	76.02	50.21	55.62	41.32
Moving average 3	MSD	21479.9	3271.5	22355.0	14619.7	17218.7	5302.6	11344.5	1234.8	24513.5	11926.6	20331.9
	%Model	**67.89**	**71.35**	**59.23**	**64.21**	**64.95**	**64.09**	**54.17**	**79.5**	**55.73**	**60.68**	**47.85**
Moving average 4	MSD	22476.3	3444.2	22129.2	14708.4	17883.3	5365.4	11925.8	1330.6	24610.5	12202.3	20208.8
	%Model	66.4	69.83	**59.64**	63.99	63.59	63.67	51.82	77.91	55.55	59.77	**48.17**
Moving average 5	MSD	23801.6	3580.7	23724.7	15760.4	19179.2	5767.1	13130.9	1459.4	26449.9	13175.3	21433.4
	%Model	64.42	68.64	56.73	61.42	60.96	60.95	46.95	75.78	52.23	56.56	45.03
Moving average 6	MSD	26902.3	3970.6	26710.1	18605.2	21701.6	6412.4	14407.3	1602.4	30106.4	14797.0	24120.1
	%Model	59.78	65.22	51.29	54.45	55.82	56.58	41.8	73.4	45.63	51.21	38.14
Moving average 12	MSD	56197.3	6944.3	43644.5	29724.4	41238.8	9702.1	17862.7	2423.5	42808.9	25261.1	30768.7
	%Model	15.99	39.18	20.41	27.23	16.05	34.3	27.84	59.77	22.68	16.71	21.08
Simple exponential smoothing	Alpha	0.98	1.17	0.91	0.98	1.03	1.07	0.71	0.83	1.02	0.98	1.01
	MSD	38980.2	5381.8	41567.3	26270.8	29907.9	8954.5	22924.3	2455.9	43239.3	21375.2	35975.5
	%Model	41.73	52.86	24.2	35.69	39.11	39.37	7.39	59.24	21.91	29.53	7.73
Double exponential smoothing	Alpha	1.1808	1.302	1.17	1.249	1.23	1.311	1.066	1.011	1.261	1.184	1.322
	gamma	0.009	0.014	0.01	0.008	0.01	0.01	0.021	0.028	0.00001	0.006	0.014
	MSD	40911.5	5560.3	46466.0	27937.8	31631.3	9582.9	26234.8	2632.2	44929.8	22404.9	37463.5
	%Model	38.84	51.3	15.26	31.61	35.61	35.11	-5.99	56.31	18.85	26.13	3.91

Note: %Model = Percentage of variance explained by the model example, in Azovè market, the price (per kg) of tomatoes in April is equal to 210.6% of the annual average price. During the month of October in the same market, this price is 34.2% of the annual average price. In other words, in Azovè market, the price (per kg) of tomatoes experienced an increment of 210.6% - 100% = 110.6% in April compared to the annual average and a drop of 100% - 34.2% = 65.8% in October compared to the annual average.

From the table analysis, it is evident that in Azovè, Bohicon, Comé, Dantokpa, Glazoué and Pobè markets, the price of tomatoes from January to June exceeds the annual average, while in Djougou, Malanville and Parakou Nattingou markets, an increase is observed from May to July. Tanguiéta market is an exception to the two groups. Indeed, in Tanguiéta market, the increments in the average annual prices are observed in June and July, and later from October to January. The highest price increase (+ 110.6%) was observed in Azovè market. The highest drop (- 65.8%) was also observed in the same market. Furthermore, Azovè, Bohicon, Comé, Dantokpa and Pobè markets, located in southern Benin, substantially have the same periods of increase and decrease in the price of tomatoes. Similarly, Djougou, Malanville, Nattingou and Parakou markets, located in the north, show the same trends in terms of the fluctuation period. Therefore, geographical zones influence fluctuation periods.

3.4 Seasonal Adjustment of Series and Determination of the Combined Trend-cycle Components

As mentioned earlier in the methodology, the original series were adjusted by dividing every one of them by the corresponding seasonal component. The series thus obtained are adjusted series of seasonal variations (CVS). The combined trend-cycle components were then estimated by applying a moving average weighted and centered on length 5 to the CVS series. Fig. 1 presents the original series, the seasonally adjusted series and the trend-cycle of the markets. The seasonally adjusted series no longer show seasonal fluctuations because they represent only the trend-cycle component. The latter presents an overall trend and cycles that are different from seasonal coefficients because cycles generally stay longer than a simple seasonal period, and intervene at irregular intervals. For comparisons over time, the difference between the seasonally adjusted price estimates for two consecutive months cannot be interpreted as the gross difference between total prices during these months. The gross difference is the difference between the non-seasonally adjusted prices estimates obtained directly from the actual data. The difference between the seasonally adjusted estimates for two consecutive months represents a direct measurement of price change after taking into account the expected changes that are due to the seasonal price change between these two months. The resulting number may be less than or greater than the gross difference, depending on how seasonal factors vary from one month to another. The Fig. 1 analysis shows that in most markets, the pace of seasonally adjusted series (trend-cycle component) is in the form of saw teeth. This means that during the period, prices actually went up and down between months of the year and between years. The overall trend of the trend-cycle series is slightly up in most markets, except for Bohicon, Djougou, Glazoué and Natitingou markets.

3.5 Determination of Cyclic and Irregular Components

The knowledge of the combined trend-cycle components makes it possible to estimate the cyclical component by dividing the trend-cycle component by the previously determined trend. Fig. 2 presents the evolution of the observed prices, trend, cycle and irregular component in every market. The figure analysis shows that the trend correctly fits the price data in most of the markets. The peaks observed on the cyclical component curves of most markets correspond to the lowest points of the observed price curve. In other words, the cycles correspond to the months when prices have declined. The cyclical component mostly occurs in Azovè and Pobè markets and almost zero in Natitingou market.

The irregular component represents price changes that are not explained by long-term trends, the seasonal component, or the cyclical component. It corresponds to the price deviation that could be expected by considering the long-term price trend and the standard cyclical and seasonal fluctuations. The Fig. 2 analysis shows that this component is relatively weak and does not present exceptional events in all the markets.

Table 3. Seasonal coefficients of the price of tomatoes (per kg) of the 11 markets

Months	Azovè	Bohicon	Comé	Dantokpa	Djougou	Glazoué	Malanville	Natitingou	Parakou	Pobè	Tanguiéta
Jan	97.0	107.2	112.6	110.0	81.7	99.4	75.6	93.2	88.5	86.6	108.9
Feb	129.3	106.0	109.5	101.5	90.9	105.1	72.3	92.5	70.1	109.8	84.9
Mar	158.8	115.2	108.3	100.0	115.6	118.2	99.6	98.8	66.0	122.5	88.1
Ap	210.6	122.3	124.1	136.7	165.1	122.5	105.0	97.1	97.2	135.1	86.6
May	184.2	122.7	146.3	171.3	153.0	131.7	141.1	108.7	170.1	170.0	95.4
June	143.9	115.1	124.0	122.0	130.0	128.3	132.6	113.5	159.6	161.0	130.7
Jul.	57.5	99.8	89.6	91.3	85.8	101.4	128.9	115.4	118.6	98.9	130.9
August	53.0	79.2	83.5	63.8	81.1	78.4	121.7	99.1	88.8	58.0	74.8
Sept.	46.3	71.0	74.3	67.4	70.2	75.5	72.0	96.6	77.3	48.4	51.8
Oct.	34.2	77.5	74.8	69.7	58.5	73.3	69.5	96.8	70.3	56.0	104.5
Nov.	38.6	91.1	78.0	80.5	73.9	74.8	86.3	96.8	98.6	75.6	128.1
Dec.	46.6	93.0	74.9	85.8	94.2	91.3	95.5	91.6	94.8	78.2	115.1
Average	100	100	100	100	100	100	100	100	100	100	100

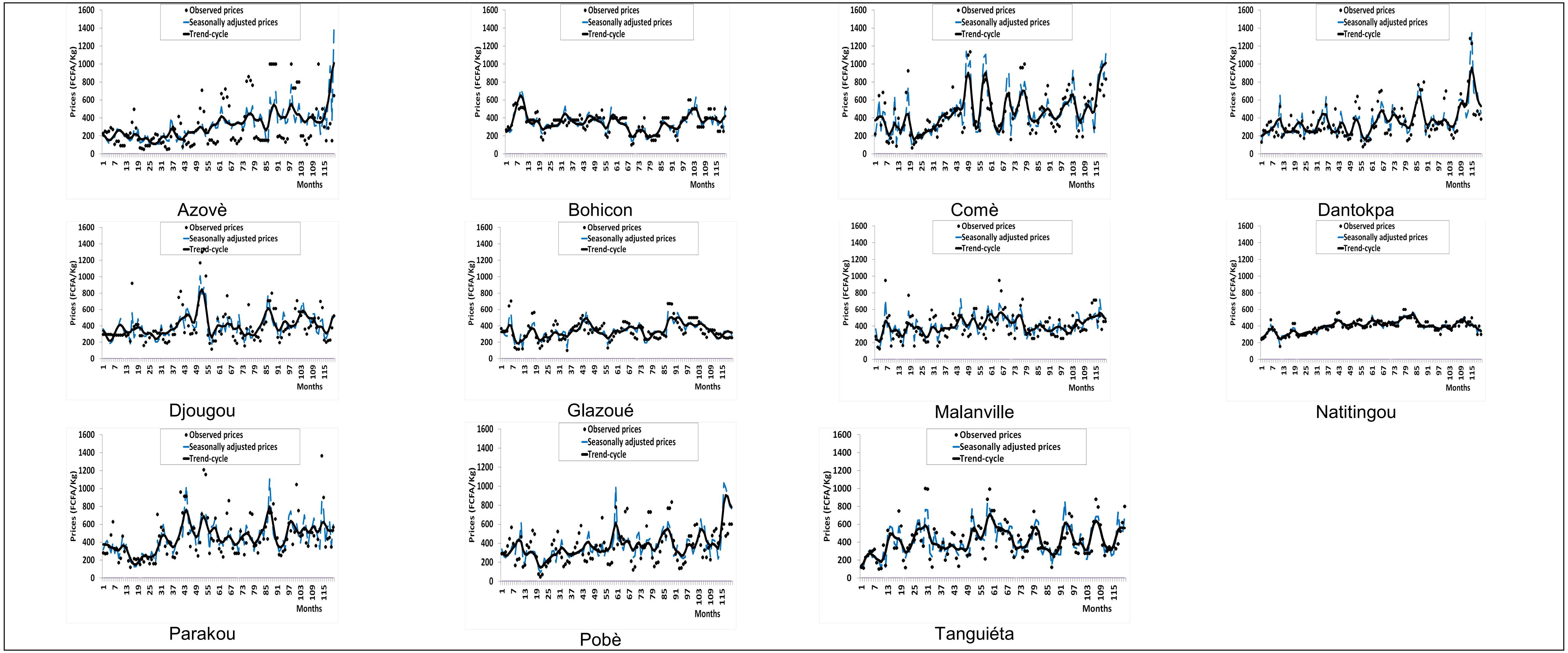

Fig. 1. Evolution of observed prices, seasonally adjusted prices and trend-cycle components in the 11 markets over the period 2006-2015

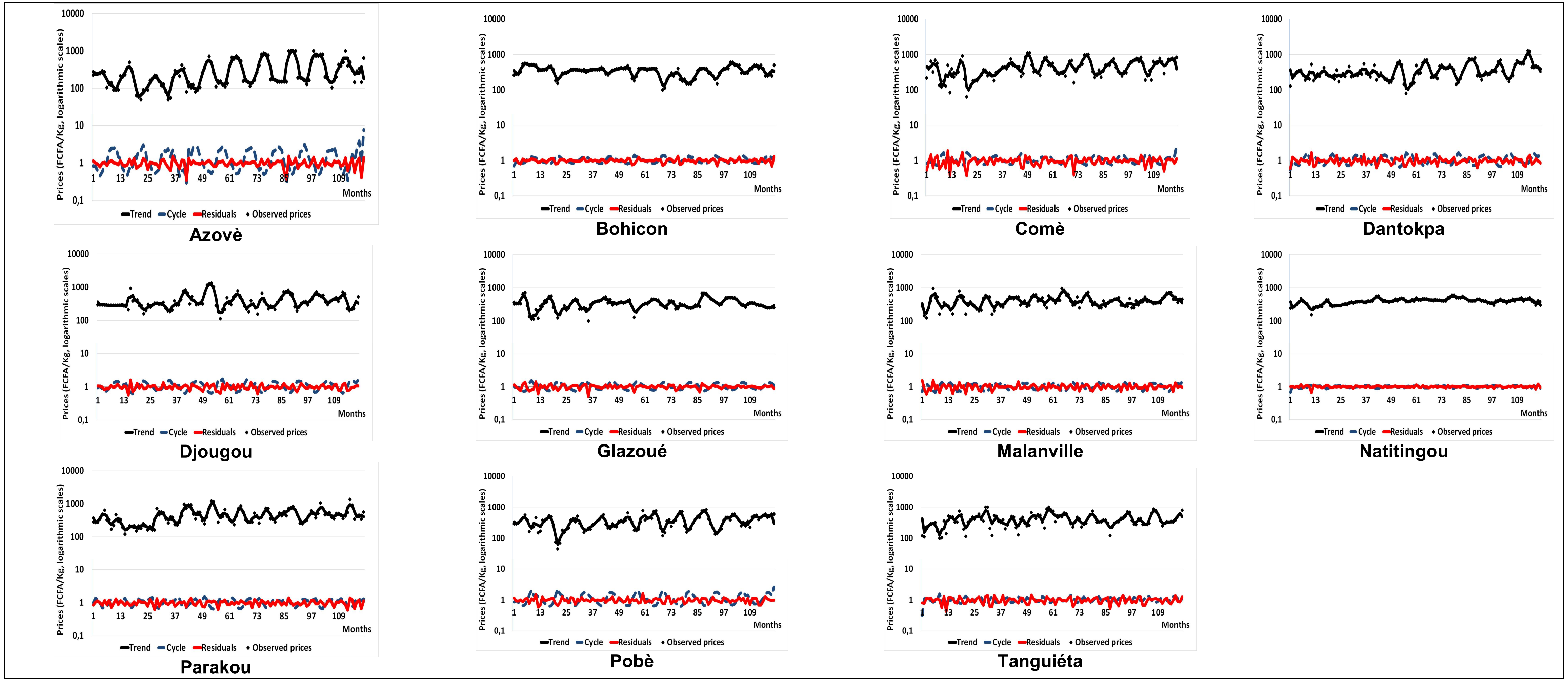

Fig. 2. Evolution of observed prices, seasonally adjusted prices, the trend component, the cyclical component and the irregular component in the 11 markets over the period 2006-2015

3.6 Cyclic Variation and Rainfall

Seasonal adjustment makes it possible to eliminate the average or expected effect of seasonal effects from the data. The seasonal effects are related to all seasonal aspects (weather and climate or others) that are likely to be influenced by trend analysis or cyclical effects in the data. Most of these effects are related to weather or climatic changes, if in all, weather or climate conditions reflect historical trends. However, unusual weather conditions for the season do not reflect the average profile and will affect seasonally adjusted estimates.

Table 4. Effect of rain on price: Results of stepwise regression

Districts	Rainy month	Coefficients	t of Student	p-value	adjusted R²
Azové	Constant	412.20	3.57	0.00	33.27
	April	1.28	1.74	0.12	
	June	-1.52	-2.87	0.01	
Bohicon	Constant	349.10			98.61
	January	2.91	10.47	0.00	
	March	0.38	5.54	0.00	
	April	-0.63	-9.95	0.00	
Comé	Constant	578.20	-4.15	0.00	99.84
	January	0.43	6.66		
	March	2.21	42.92	0.00	
	May	-1.40	-26.21	0.01	
	October	0.45	16.72	0.00	
	November	-0.74	-13.01	0.01	
Dantokpa	Constant	254.00			99.02
	February	0.94	24.37	0.00	
	September	0.13	3.85	0.02	
Djougou	Constant	248.70			90.74
	February	-1.27	-3.67	0.02	
	September	1.04	4.86	0.01	
	December	-57.00	-5.64	0.01	
Glazoué	Constant	332.10			98.61
	May	-0.49	-11.49	0.00	
	April	0.93	15.23	0.00	
	September	-0.16	-3.89	0.01	
	December	3.74	13.09	0.00	
Malanville	Constant	335.30			31.83
	May	0.90	2.18	0.06	
Natitingou	Constant	240.50			76.83
	February	2.86	3.71	0.01	
	June	0.70	3.50	0.01	
Parakou	Constant	200.20			62.37
	May	1.84	3.99	0.00	
Pobè	Constant	-174.60			95.79
	February	1.42	3.80	0.02	
	March	2.27	10.30	0.00	
	April	2.37	7.17	0.00	
Tanguiéta	Constant	332.20			97.54
	February	-17.20	-11.18	0.01	
	September	0.40	4.56	0.04	
	October	0.87	7.64	0.02	

Table 5. Standard deviation of the different components for every market

Market	Observed prices	Seasonality	Trend	Cycle	Irregular
Azovè	258.64	0.63	222.29	0.99	0.21
Bohicon	106.85	0.18	93.61	0.17	0.11
Comé	234.17	0.24	188.58	0.27	0.24
Dantokpa	202.11	0.32	169.83	0.28	0.19
Djougou	221.63	0.34	188.32	0.29	0.17
Glazoué	121.52	0.22	102.90	0.21	0.13
Malanville	157.33	0.26	121.72	0.20	0.18
Natitingou	77.62	0.8	68.98	0.07	0.06
Parakou	235.30	0.34	188.99	0.23	0.17
Pobè	174.16	0.41	142.68	0.42	0.17
Tanguiéta	197.46	0.24	145.84	0.18	0.21

Thus, in order to better understand the trend and cycles observed, in Fig. 3, the rainfall data were linked to the observed prices and to the cyclical component. From the analysis of this figure, it is shown in a comprehensive way that the period when the rain is abundant coincides with the highest points of the observed price curve and with the lowest points of the cycles curve. On the other hand, the results of the stepwise regression (Table 5) indicated that in the markets in the south, it is the first rainfalls (February to April and those of September) of the rainy season that have an effect on the price. While in the markets located in the north of the country, it is the rainfalls of off-season (September to April) that have an influence on the price. Overall, the models adjust correctly to the data (adjusted R^2 ranging from 31.83% to 99.84%), except those relating to the Azové (adjusted R^2 = 33.27%) and Malanville (adjusted R^2 = 31.83%) Districts.

The variability of the irregular component is smaller than the other components in most of the markets (Table 5). It varies from 6% to 24%. The lowest value was obtained in Tanguiété market and the highest value in Comè market.

4. DISCUSSION

The variability analysis of every series has shown that it increases over time. Decomposition using the multiplicative model made it possible to better understand every one of the components. The results of this chronological analysis of the price (per kg) of tomato fruit in the eleven (11) main markets revealed the importance of every component.

The trend of the prices of each market was adjusted by a 3rd order moving average model. This model suggests that the price at time *t* depends, among others, on the price of the two previous months. It seems then that price formulation is based on adaptive expectations [5]. Both local bearish trends (observed price is below moving average) and the local upward trends (observed price is above moving average) are noticed. However, the local upward trend prevails. This is confirmed by the shape of the annual average observed prices curve of the period (Fig. 4). This therefore occurs after a tendency to increase the price (per kg) of tomatoes in most markets during the considered period. Generalising this observation shows a sign of successful integration of these markets in terms of price formation. The successful integration of these markets can be explained, among others, by the improvement of the production system. According to Igué and Aboudou [18], tomato production systems in Benin can be grouped by geographical area. Indeed, in the Northern region, tomatoes are produced using a mechanical irrigation system in off-season cultivation from October to April. In contrast, in the southern region which is better watered, two to three campaigns are conducted annually. It is an essentially rain-fed production. However, in peri-urban areas, there are practices with manual irrigation practices. The integration can be also explained, by the development of road network between the different regions of the country. Indeed, a considerable effort was made on the development of the road network which increased from 9 000 km in 2006 to 15,700 km in 2014, of which slightly more than 6000 km of tarred roads between the interstate and national roads [19]. Despite this integration, there exists, however, for the same period, a variability of prices of tomatoes between different markets. In addition, a correlation matrix between prices in different markets, of which the results are not included in the text for the sake of brevity, revealed a relatively weak relationship between the price series. The strongest relationship was obtained between the prices of Azovè market and those of Pobè ($r = 0.65$). These weak relationships reflect the asymmetry in prices between the markets, particularly among consumer markets such as Dantokpa, Bohicon and Parakou, and producer pooling markets such as Azovè, Comé, Natitingou and Malanville. This asymmetry in price transmission also occurs mostly in food assembly markets because of high transaction costs. A study on regional competitiveness of tomatoes and potatoes in Benin by Bard et al. [20] showed that at equal distances, marketing costs are higher (39 XOF / kg) on the Lalo-Cotonou axis than the Lomé-Cotonou axis (21 XOF / kg). Faivre-Dupaigre et al. [21] also reported that the cost of transportation of agricultural products in West Africa, especially perishable goods, are very high; mainly because many illegal payments are made on the road. According to Ruijs et al. [22], transfer costs are an important part of price differences between markets. Combes et al. [23] reported that the transfer costs between two regions are based on the distance, road conditions and the language of communication between the players. In this context, a study on the determinants of food exchange between rural markets and the Cotonou consumer market (Dantokpa) by Fiahomé [24] has shown that distance, road conditions and sharing at least one vernacular affect the trade of tomatoes in the markets. The transport conditions are often limiting the Benin rural markets and the consumer markets in downtown areas because of the distance and bad roads. Thus, transportation costs vary depending on the state of the road followed. When the road is in poor condition, the transport duration becomes longer. The prolonged duration of the transport has an impact on the cost of transport and therefore on the price of the product. However, Lutz [25] explains that trade unions improve trade efficiency by serving as a middleman in order to reduce the transaction costs. These unions help place bulk orders for goods and collectively charter buses in order to minimise transportation and transaction costs. Concerning assembly market, Tassou [26] mentions that the information concerning the beginning of a transaction and buying and selling price are given by the leaders of each union. The unions are responsible for collectively fixing the prices in advance according to the local measurement units for the collection and sale of products on the various assembly markets they control. Lutz et al. [27] showed that, depending on market days, traders collude to fix prices. This behavior may cause the market price to be coordinated by the trade unions and prices in the consumer market not to be connected linearly. Under these conditions, it is possible that the price adjustments between market pairs are transmitted asymmetrically. This confirms the low correlations noted between the prices of the different markets studied. For Kuiper et al. [28], in the big cities of Benin, it is retailers that play a greater role in the price formation process contrary to what is generally accepted in the literature on development economics. On the contrary, in large rural centers, the wholesalers involved in the arbitration between the urban markets influence the price formation. Further studies can better explain the reasons for this asymmetry in the price transmission of fresh tomatoes. In addition to transportation costs, Faivre-Dupaigre et al. [21] cited production hazards as a factor leading to considerable variations in the prices of agricultural products in developing countries. The rapid population growth estimated at about 3% in Benin and the increment of the standard of living especially that of civil servants who received a raise in their salaries during the study period are also factors that could cause this increase. This situation of unstable price increase would have been more critical with the rapid increase in the urban population if there were no imports from neighbouring countries. This could also partly justify the upward trend contrast noted in the production statistics during the same period (Fig. 4). According to economic theory, the increase in the production (supply) of goods whose price formulation is market-driven, causes a decrease in the price of the goods. Other clues like subsistence farming and the role of agriculture in the GDP can also explain this upward trend.

Another feature of the change in the prices of tomatoes in different markets is the seasonal component. According to the result of Bard et al. [20] for marketing, there are two main periods. The first, which runs from April to October, is devoted to rain-fed tomato transactions, mainly from the southern production areas (Lalo, Azovè), but also from Togo and Ghana. The second, which runs from November / December to March, is intended for the marketing of the off-

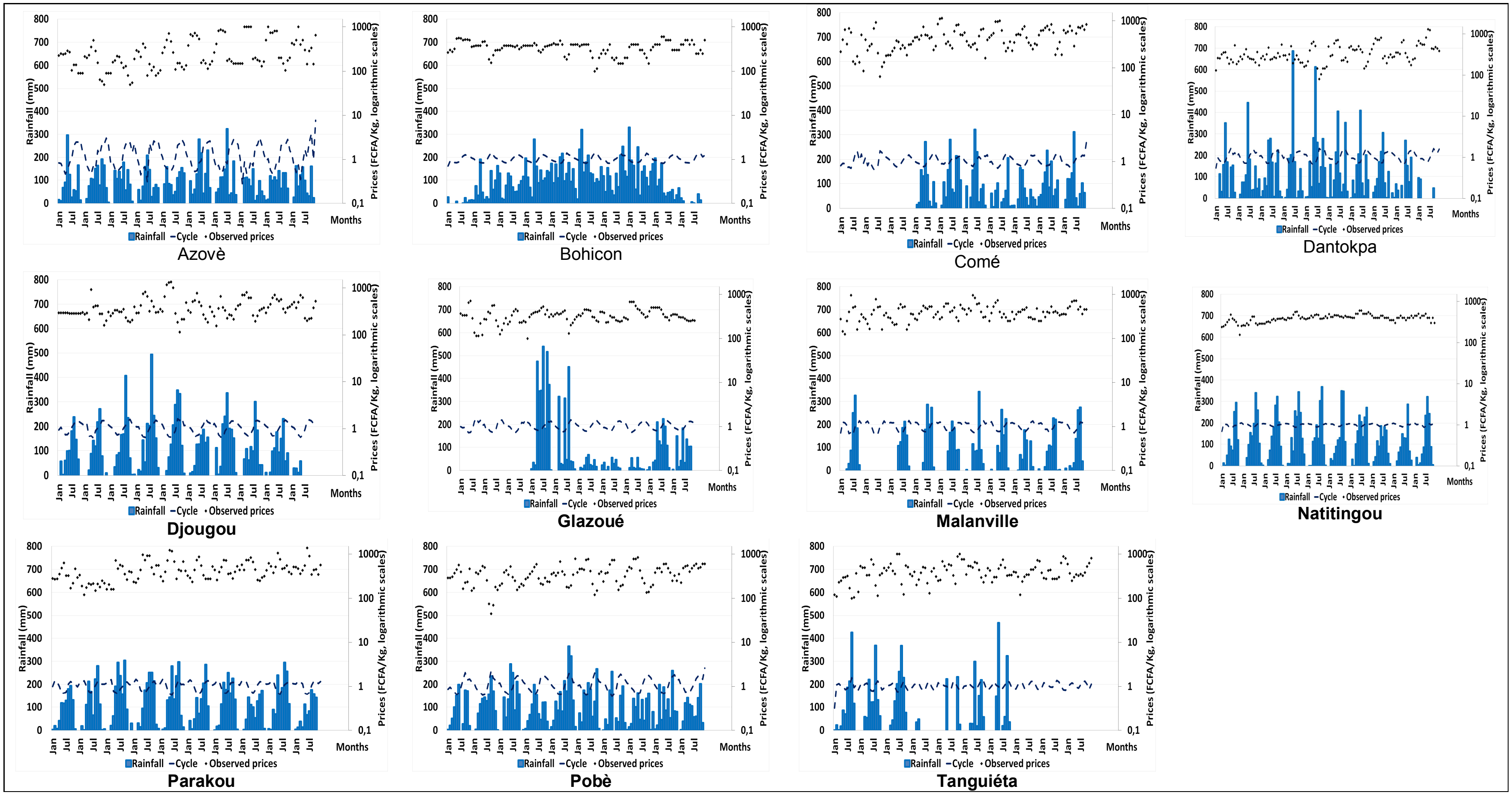

Fig. 3. Evolution of the observed prices and the cyclical component of the 11 markets and the rainfall distribution over the period 2006-2015

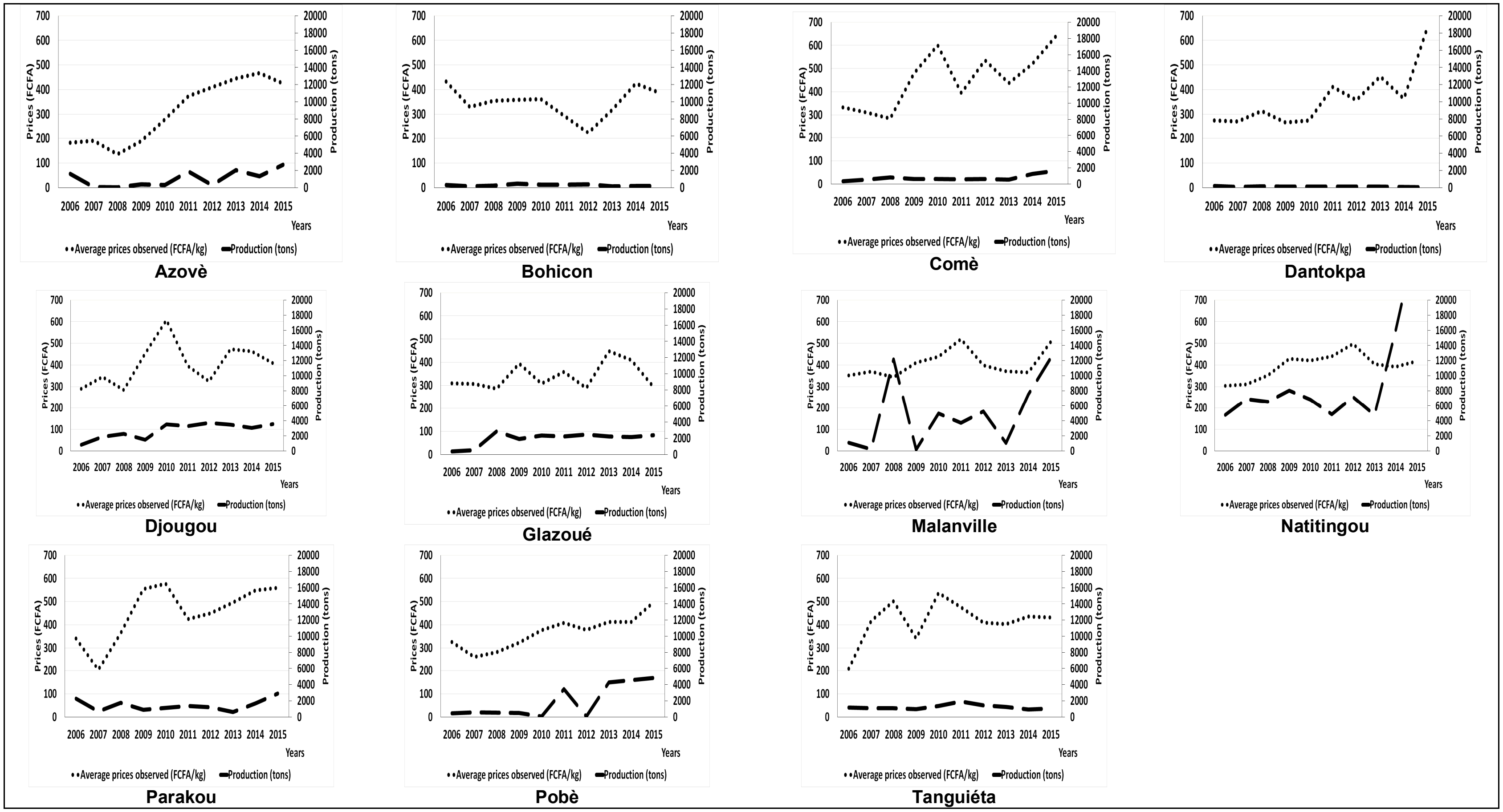

Fig. 4. Evolution of the annual price average of the 11 markets and the production of every municipality that the markets are located during the period 2006-2015

season tomatoes from both north and south. During this last period, production is less abundant, but has a high market value. Tomatoes from Togo, Ghana, Nigeria and Burkina Faso arrive in the markets of southern Benin from December to June. This helps mitigate the scarcity of product from April to June when there are an increase in prices (seasonal coefficients greater than 100). During this period, there are both rain-fed and off-season tomatoes in the Beninese markets. This seasonality has strong implications for the organisation and functioning of the value chain [18]. According to Degand and D'Haese [29], the changes in the seasonal component are essentially related to the combined effect of cropping calendar and climate. Thus, it simply requires the rainy season to come earlier or later for the whole of the seasonal variation to experience a shift. The seasonal component also plays an important role in the producer's marketing strategy. It is indeed a reflection of the cost of storage, post-harvest losses, opportunity cost of capital and financing needs. Tomatoes being a perishable goods and having no technology for its transformation, most producers put their stock in the market to prevent post-harvest losses. The abundant supply creates a general decrease in price. This is particularly observed in southern Benin from July to December and in northern Benin from September to March (seasonal coefficients less than 100). This long period of price decrease is mainly related to the off-season production and the importation of tomatoes from neighbouring countries.

The peaks of the cyclical variations coincide with the periods of abundance of rain and with the period when prices decrease. This component clearly shows around the trend, a succession of price increase and decrease phases. The results indicated that in southern markets, it is the first rains that have an effect on the price. While on the markets located in the north, it is the rains of off-season that have an influence on the price. The cyclical components do not present any particular phenomena except those relating to Azovè and Pobè markets. Both markets represent food assembly markets, one located in an area of low rainfall (Azové) and the other in an area of high rainfall (Pobè). The food crops of the municipalities housing these two markets are therefore very sensitive to particular phenomena, rainfall especially. The curve of the cyclical component relating to every market shows a slight exceptional peak in 2015. This price surge is partly explained by the shortage that was observed in Benin markets in 2015 when these markets did not receive tomato supplies from the neighboring countries.

For farmers, the irregular component is a good risk estimator in food prices because it indicates the unpredictable deviation of prices over the long-term trend, the seasonal component and the cyclical component of the price. Indeed, for tomato producers, there is a large price risk when they decide to start cultivating due to inability to control climatic conditions (especially rainfall) which have a direct impact on output. The decomposition of every series has shown that the variability of this component is relatively low. This is explained by the fact that much of this component is contained in the seasonal and cyclical component. Indeed, seasonal adjustment eliminates the average or expected effect of seasonal effects from the data. These seasonal effects are related to all seasonal aspects (weather and climate or others) that are likely to be influenced by trend analysis or cyclical effects in the data. The knowledge of the various components discussed in this study makes it possible to master the price risk of tomatoes when the variability of the irregular component is low.

5. CONCLUSION

Statistical and mathematical modelling approaches made it possible to break down the price of tomatoes in 11 major markets in Benin during the period 2006-2015. The mathematical models only made it possible to break down the series; they have no statistical significance. On the other hand, the statistical model applied to the trend made it possible to make predictions on price movements. The long-term trend was modelled by a 3rd order moving average. On the whole, there was an increase in the price of tomatoes in the 11 markets. The seasonality of the production which induced very large disparities in the level of supply according to the periods of the year, makes the prices of this product erratic. This fluctuation is so important that sometimes, in the same market and in the same year, the price can be multiplied by six (Azovè market). The main causes of non-supply control are the diversity of cropping systems and the high level of post-harvest losses. The upward trend and price change will increase over time if nothing is done to improve production and marketing. The Benin government and institutions in the agricultural sector should prioritise investments in transport and communication infrastructure. A transformation policy should also be envisaged. Cyclical variations are often the result of random circumstances of political or weather events. According to the Ministry of Economy and Finance of Benin [30], the unfavorable rainfall that has impacted the agricultural sector in general and the decline in the dynamism of foreign trade due to the holding of elections in Nigeria and Benin, depreciation of the naira and lower oil prices would be the main factors behind the slowdown in economic activity in 2015 in Benin. Although there were some exceptional events during the period under review, notably the 2007 crisis and those mentioned previously, these events did not affect the fluctuation of prices in the markets studied. Irregular component variability is relatively low. The price risk of tomato is thus relatively low.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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