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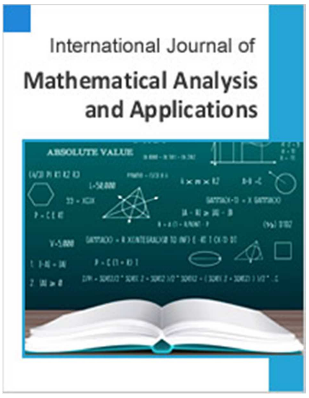

Determination of a Better Mathematical Model for Food Security in Nigeria (A Case Study of Taraba State)

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Abstract
Food is source life to human existence. It is a known fact that no living thing can survive without food. For a country to be said to have food security, the prices of available food commodities must be affordable to everybody in that country and that is determined by the cost of the food commodities. As prices of agricultural commodities keep increasing, the availability of food becomes limited to every home in Nigeria. This is because, not everybody can afford high cost of food. When such happens, there will be food insecurity instead of food security. The aim of this paper is to use Time series equations and Non Linear equations to compare the prices of the selected agricultural commodities. Price is considered because, price plays a major role to food security in any country. Data were collected at monthly basis from the prices of three agricultural commodities for the period of nine years (2008-2016). The commodities include local rice, cassava flour and Red maize. The results from the models formulated from the selected commodities were used to compare the two methods. The results show that nonlinear equation method is better than Least Square method because Non linear equation method has a minimal error compared to the Least Square method.

1. Introduction

Food security is defined as the ability of people to meet their required level of food consumption at all times. This means that for any country to boast of food security, food must be available at all times, must be accessible, there must be quality nutritious food and stability of food for the entire populations. Food utilization (Food safety, Hygiene and manufacturing practices applied in: primary agricultural production, harvesting and storage; food processing; transportation, retail, households; Diet quality and diversity meeting needs in terms of energy, macro and micro nutrients must be pronounced in such country (world food Summit, 1996) [15]. Food security refers to the ability of the household to secure, either from its own production or through purchases, adequate food for meeting the dietary needs of all members of the household. Food security describes a country's access to food of sufficient quantity and quality at all times either from domestic production or world food markets. Accordingly, a country is considered food secure at the macro level if domestic food production is sufficient to meet the domestic food demand, if the country's external balance and currency reserves allow for importing sufficient food (also in times of global food price spikes), or both (Diaz-Bonilla, Thomas, and Robinson 2002 [3]; Pinstrup-Andersen 2009) [11]. Food has become an instrument of national power and they noted that much still needs to be done if the crisis in the sector will not escalate (Emmanuel O. Ojo and Peter F. Adebayo) [4]. Food security is recognised world-wide as a fundamental dimension of national development, good governance and basic human rights (Phnom Penh, 2008) [10]. Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. (1996 World Food Summit) [14]. Adequate access to food is a universal right (Richard Hodson, 2017) [12]. Massive food import, particularly by developing countries, usually has negative effect on foreign reserves and causes budgetary hemorrhage (Davies, 2009) [2]. The sole objective of food security is to satisfy all the food requirements of the population. For countries to have food security, Farmers worldwide will need to increase crop production, either by increasing the amount of agricultural land to grow crops or by enhancing productivity on existing agricultural lands through fertilizer and irrigation and adopting new methods like precision farming.(Maarten Elferink and Florian Schierhorn, 2016) [8]. Countries that are food-secure do not have this dreadful situation to contend with (Davies, 2009) [2]. In essence, a country should be considered as food-secure when food is not only available in the quantity needed by the population consistent with decent living, but also when the consumption of the food should not pose any health hazard to the citizens (Davies, 2009) [2]. Olivier Ecker and Clemen Breisinger (2012) [9]; In their study, observed that Macro level food security is considered a necessary but not sufficient condition of micro-level food security, whereas an individual's nutritional status is a direct outcome of various micro-level factors and an indirect outcome of a set of macro-level factors. The issue of food security really came to the fore in the 1970s and at the 1974 World Food Conference in Rome the first explicit acknowledgement was made that this issue concerned the whole of mankind: Food security is a difficult concept to measure since it deals in very broad terms with the production, distribution and consumption of food. Food insecurity on the other hand lends itself more readily to measurement and analysis. It should be stressed that food security and famine and hunger are not to be confused: food security refers to the availability of food whereas famine and hunger are the consequence of the non- availability of food, in other words the results of food insecurity. FAO report (2014) [5] emphasised that agriculture is a key to food security in many parts of the world. The report indicates further that agriculture contributes to poverty alleviation by reducing food prices, creating employment, improving farm income and increasing wages. The Food and Agriculture Organization of the United Nations (FAO) [5]. State of Food Insecurity for 2010 assesses that nearly 1 billion people are estimated to be undernourished, representing almost 16 percent of the population of developing countries. Although the strong commitment of international institutions and the efforts conducted to reach the objective to half, within year 2015, the number of people suffering from hunger, food insecurity still represents one of the biggest challenges for a big part of the world population and must be treated with the utmost urgency. It is generally recognized that food security, and therefore food insecurity, is a multi- dimensional phenomenon. Several indices measuring hunger and the progress in achieving hunger eradication helped understanding the issue and monitoring the progress in eliminating hunger as well as providing targets for national and international political action (Clay E., 2002) [1]. However, none of these indexes reach to capture all aspects of food insecurity, as stated by the Scientific Symposium on Measurement and Assessment of Food Deprivation and Under nutrition in 2002. The lack of a commonly accepted, comprehensive measure for food security on an international scale has been identified as one of the roadblocks on the way to the eradication of hunger and malnutrition (Heidhues and von Braun 2004) [7]. A suite of indicators is therefore needed to cover the different dimensions of food security: availability, access, utilization and stability. Emmanuel O Ojo and Adebayo P. F (2012) [4], stated that Nigeria needs to come up with food policy which is lacking in order to alleviate crisis is food security. A world where all enjoy freedom from want, and progressively realize their right to adequate food and nutrition can only be realized through far reaching transformations, supported by policies and programmes promoting sustainable development in all its three dimensions (Stocktaking, 2015) [13]. One of the motivations for this study is from the USAID (2016) projection and declaration of food security for now and the next 2030, The declaration shows that, the U.S. Government's global hunger and food security initiative, Feed the Future, has been working with its partners around the world to help countries overcome agriculture and nutrition challenges with entrepreneurship, partnership and innovation [14].

2. Methodology

In this research, our main objective was to find a model that will be suitable for determining food security in Taraba State.

2.1. Estimating Trends by Regrssions

In this paper, the standard method for determining a linear trend is the method of least square that was used for linear regreesion is used to model the selected agricultural commodities. This is accomplished by replacing the variable x by the variable t in

$$Y = \alpha + \beta x \quad to \quad Y_t = \alpha + \beta t$$

Which is $\overline{Y}t = \alpha + \beta t$

The estimates for α *and* β *i. e a and b* are then

$$b = \sum \frac{t_i y_i - n\overline{t}\overline{y}}{\sum t_i^2 - n\overline{t}^2}$$

u here $\overline{t} = \frac{\sum t}{n}$ and $a = \overline{y} - b\overline{t}$

In this work, we assign the values of x to the years so that $\sum x = 0$. The equation of the least square is written as

$$Y = \overline{Y} + \left(\frac{\sum xy}{\sum x^2}\right) x = \overline{Y} + bt$$

With the equations above, we obtain the following models for the five common food commodities in Taraba State;

$LocalRice;\ Y = 317 + 14.2t$

$Cassavaflour;\ Y = 122 + 3.7t$

$RedMaize;\ Y = 177 + 16.5t$

2.2. Non Linear Models

We suppose that the nonlinear price of the Local Rice $P_L(t)$, certify the equation below;

$$P_L(t) = at^2 + bt + c;$$

Thus, minimizing the cumbersome data for $P_L(t)$ using Least Squares method, we have that,

$$Z_{\min} = \min \sum_{i=1}^{9} \left(P_{Li}(t) - at_i^2 - bt_i - c\right)^2$$

$$\frac{\partial Z}{\partial a} = -2\sum_{i=1}^{9} \left(P_{Li}(t) - at_i^2 - bt_i - c\right) * t_i^2 = 0 \quad (at\ turning\ po\text{int})$$

$$\Rightarrow \sum_{i=1}^{9} P_{Li}(t)t_i^2 = a\sum_{i=1}^{9} t_i^4 + b\sum_{i=1}^{9} t_i^3 + c\sum_{i=1}^{9} t_i^2$$

$$\frac{\partial Z}{\partial b} = -2\sum_{i=1}^{9} \left(P_{Li}(t) - at_i^2 - bt_i - c\right) * t_i = 0 \quad (at\ turning\ po\text{int})$$

$$\Rightarrow \sum_{i=1}^{9} P_{Li}(t)t_i = a\sum_{i=1}^{9} t_i^3 + b\sum_{i=1}^{9} t_i^2 + c\sum_{i=1}^{9} t_i$$

similarly;

$$\frac{\partial Z}{\partial c} = -2\sum_{i=1}^{9} \left(P_{Li}(t) - at_i^2 - bt_i - c\right) * 1 = 0 \quad (at\ turning\ po\text{int})$$

$$\Rightarrow \sum_{i=1}^{9} P_{Li}(t) = a\sum_{i=1}^{9} t_i^2 + b\sum_{i=1}^{9} t_i + c\sum_{i=1}^{9} 1$$

2.3. Model for Cassava Flour

We suppose that the nonlinear price of the Cassava Flour $P_C(t)$, certify the equation below;

$$P_C(t) = At^2 + Bt + C;$$

Thus minimizing the cumbersome data for $P_C(t)$ using Least Squares method, we have,

$$Z_{\min} = \min \sum_{i=1}^{9} \left(P_{Ci}(t) - At_i^2 - Bt_i - C\right)^2$$

$$\frac{\partial Z}{\partial A} = -2\sum_{i=1}^{9} \left(P_{Ci}(t) - At_i^2 - Bt_i - C\right) * t_i^2 = 0 \quad (at\ turning\ po\text{int})$$

$$\Rightarrow \sum_{i=1}^{9} P_{Ci}(t)t_i^2 = A\sum_{i=1}^{9} t_i^4 + B\sum_{i=1}^{9} t_i^3 + C\sum_{i=1}^{9} t_i^2$$

$$\frac{\partial Z}{\partial B} = -2\sum_{i=1}^{9} \left(P_{Ci}(t) - At_i^2 - Bt_i - C\right) * t_i = 0 \quad (at\ turning\ po\text{int})$$

$$\Rightarrow \sum_{i=1}^{9} P_{Ci}(t)t_i = A\sum_{i=1}^{9} t_i^3 + B\sum_{i=1}^{9} t_i^2 + C\sum_{i=1}^{9} t_i$$

similarly;

$$\frac{\partial Z}{\partial C} = -2\sum_{i=1}^{9} \left(P_{Ci}(t) - At_i^2 - Bt_i - C\right) * 1 = 0 \quad (at\ turning\ po\text{int})$$

$$\Rightarrow \sum_{i=1}^{9} P_{Ci}(t) = a\sum_{i=1}^{9} t_i^2 + b\sum_{i=1}^{9} t_i + c\sum_{i=1}^{9} 1$$

2.4. Model for Red Maize

We suppose that the nonlinear price of the Cassava Flour $P_M(t)$, certify the equation below;

$$P_M(t) = et^2 + ft + g;$$

Thus minimizing the cumbersome data for $P_M(t)$ using Least Squares method, we have,

$$Z_{\min} = \min \sum_{i=1}^{9} \left(P_{Mi}(t) - At_i^2 - Bt_i - C\right)^2$$

$$\frac{\partial Z}{\partial e} = -2\sum_{i=1}^{9}\left(P_{Mi}(t) - et_i^2 - ft_i - g\right)*t_i^2 = 0 \ \ (at\ turning\ point)$$

$$\Rightarrow \sum_{i=1}^{9} P_{Mi}(t)t_i^2 = e\sum_{i=1}^{9} t_i^4 + f\sum_{i=1}^{9} t_i^3 + g\sum_{i=1}^{9} t_i^2$$

$$\frac{\partial Z}{\partial f} = -2\sum_{i=1}^{9}\left(P_{Mi}(t) - et_i^2 - ft_i - g\right)*t_i = 0 \ \ (at\ turning\ point)$$

$$\Rightarrow \sum_{i=1}^{9} P_{Mi}(t)t_i = e\sum_{i=1}^{9} t_i^3 + f\sum_{i=1}^{9} t_i^2 + g\sum_{i=1}^{9} t_i$$

similarly;

$$\frac{\partial Z}{\partial g} = -2\sum_{i=1}^{9}\left(P_{Mi}(t) - et_i^2 - ft_i - g\right)*1 = 0 \ \ (at\ turning\ point)$$

$$\Rightarrow \sum_{i=1}^{9} P_{Mi}(t) = e\sum_{i=1}^{9} t_i^2 + f\sum_{i=1}^{9} t_i + g\sum_{i=1}^{9} 1$$

Table 1. *Data on averaged prices of three selected common food commodities per mudu (i. e bowl used in measurement) in Taraba State.*

ITEMS	YEARS								
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
LOCAL RICE	278	278	278	300	300	320	345	350	400
CASSAVA FLOUR	112	112	112	120	120	120	120	130	150
RED MAIZE	142	142	142	150	150	150	150	250	300

SOURCE: TARABA STATE STATISTICAL YEAR BOOK

3. Results

Tabular presentation of the results of the commodities

Table 2. *Computational details for Local Rice using Least Square method.*

Year	Y	t	$\bar{Y}$	e	Absolute error
2008	278	-4	260.2	17.8	17.8
2009	278	-3	274.4	3.6	3.6
2010	278	-2	288.6	-10.6	10.6
2011	300	-1	302.8	-2.8	2.8
2012	300	0	317	-17	17
2013	320	1	331.2	-11.2	11.2
2014	345	2	345.4	-0.4	0.4
2015	350	3	359.6	-9.6	9.6
2016	400	4	373.8	26.2	26.2
Total					99.2

Table 3. *Computational details for Local Rice using Non linear equation method.*

T	$P_L(t)$	t^2	t^3	t^4	$t^2P_L(t)$	$tP_L(t)$
0	278	0	0	0	0	0
1	278	1	1	1	278	278
2	278	4	8	16	1112	556
3	300	9	27	81	2700	900
4	300	16	64	256	4800	1200
5	320	25	125	625	8000	1600
6	345	36	216	1296	12420	2070
7	350	49	343	2401	17150	2450
8	400	64	512	4096	25600	3200
$\sum_{i=1}^{9} t_i = 36$	$\sum_{i=1}^{9} P_i(t) = 2849$	$\sum_{i=1}^{9} t_i^2 = 204$	$\sum_{i=1}^{9} t_i^3 = 1296$	$\sum_{i=1}^{9} t_i^4 = 8772$	$\sum_{i=1}^{9} P_i(t)t_i^2 = 72060$	$\sum_{i=1}^{9} P_i(t)t_i = 12254$

Substituting the collected data into equations above give rise to the following equation below;

$$72060 = 8772a + 1296b + 204c$$
$$12254 = 1296a + 204b + 36c$$
$$72060 = 204a + 36b + 9c$$

Meanwhile, solving the three equations above gives;

$$a = \frac{464}{231},\ b = \frac{-4087}{2310},\ c = \frac{45887}{165}$$

And therefore our model for the price of Local Rice given as:

$$P_L(t) = \frac{464}{231}t^2 - \frac{4087}{2310}t + \frac{45887}{165}$$

The table below gives comparisons between our model results and the gathered data using t=t-2008:

Table 4. *Validation of the model for Local Rice.*

Years	t	P(t) Questionnaire Data	p(t) for model Data	Absolute Error
2008	0	278	278.103	0.10303
2009	1	278	278.3424	0.342424
2010	2	278	282.5991	4.599134
2011	3	300	290.8732	9.12684
2012	4	300	303.1645	3.164502
2013	5	320	319.4732	0.52684
2014	6	345	339.7991	5.20087
2015	7	350	364.1424	14.14242
2016	8	400	392.503	7.49697
Total				≅35.6

Remarks: The minimal absolute error makes the nonlinear model to be preferable over the linear one formulated above.

Table 5. *Computational details for Cassava Flour using Least Square method.*

Year	Y	t	$\overline{Y}$= data from the model	$e$rror	Absolute error
2008	112	-4	107.2	4.8	4.8
2009	112	-3	110.9	1.1	1.1
2010	112	-2	114.6	-2.6	2.6
2011	120	-1	118.3	1.7	1.7
2012	120	0	122	-2	2
2013	120	1	125.7	-5.7	5.7
2014	120	2	129.4	-9.4	9.4
2015	130	3	133.1	-3.1	3.1
2016	150	4	136.8	13.2	13.2
Total					43.6

Table 6. *Computational details for cassava model.*

T	$P_C(t)$	t^2	t^3	t^4	$t^2P_C(t)$	$tP_C(t)$
0	112	0	0	0	0	0
1	112	1	1	1	112	112
2	112	4	8	16	448	224
3	120	9	27	81	1080	360
4	120	16	64	256	1920	480
5	120	25	125	625	3000	600
6	120	36	216	1296	4320	720
7	130	49	343	2401	6370	910
8	150	64	512	4096	9600	1200
$\sum_{i=1}^{9} t_i = 36$	$\sum_{i=1}^{9} P_{Ci}(t) = 1096$	$\sum_{i=1}^{9} t_i^2 = 204$	$\sum_{i=1}^{9} t_i^3 = 1296$	$\sum_{i=1}^{9} t_i^4 = 8772$	$\sum_{i=1}^{9} P_{Ci}(t) t_i^2 = 26850$	$\sum_{i=1}^{9} P_{Ci}(t) t_i = 4606$

Substituting the collected data into equations give rise to the following equations below

$$26850 = 8772A + 1296B + 204C$$
$$4606 = 1296A + 204B + 36C$$
$$1096 = 204A + 36B + 9C$$

Meanwhile, solving the equations gives;

$$A = \frac{347}{462},\ B = \frac{-5333}{2310},\ C = \frac{18808}{165}$$

And therefore our model for the price of Cassava flour is given as: $P_C(t) = \frac{347}{462}t^2 - \frac{5333}{2310}t + \frac{18808}{165}$

The table below gives comparisons between our model results and the gathered data using t=t-2008:

Table 7. *Validation of the model for Cassava Flour.*

Years	t	P(t) Questionnaire Data	p(t) for model Data	Absolute Error
2008	0	112	113.9879	1.987879
2009	1	112	112.4303	0.430303
2010	2	112	112.3749	0.374892
2011	3	120	113.8216	6.17835
2012	4	120	116.7706	3.22944
2013	5	120	121.2216	1.221645
2014	6	120	127.1749	7.174892
2015	7	130	134.6303	4.630303
2016	8	150	143.5879	6.41212
Total				24.9

Remarks: The minimal absolute error makes the nonlinear model to be preferable over the linear one formulated above.

Table 8. *Computational details for Red Maize using Least Square method*

Year	Y	*t*	$\overline{Y}$= data from the model	error	Absolute error
2008	142	-4	111	31	31
2009	142	-3	127.5	14.5	14.5
2010	142	-2	144	-2	2
2011	150	-1	160.5	-10.5	10.5
2012	150	0	177	-27	27
2013	150	1	193.5	-13.5	13.5
2014	150	2	210	-60	60
2015	250	3	226.5	23.5	23.5
2016	300	4	243	-57	57
Total					215.5

Table 9. *Computational Details for Red Maize Model.*

T	$P_M(t)$	t^2	t^3	t^4	$t^2P_M(t)$	$tP_M(t)$
0	148	0	0	0	0	0
1	142	1	1	1	142	142
2	142	4	8	16	568	284
3	150	9	27	81	1350	450
4	150	16	64	256	2400	600
5	150	25	125	625	3750	750
6	150	36	216	1296	5400	900
7	250	49	343	2401	12250	1750
8	300	64	512	4096	19200	2400
$\sum_{i=1}^{9} t_i = 36$	$\sum_{i=1}^{9} P_{Mi}(t) = 1096$	$\sum_{i=1}^{9} t_i^2 = 204$	$\sum_{i=1}^{9} t_i^3 = 1296$	$\sum_{i=1}^{9} t_i^4 = 8772$	$\sum_{i=1}^{9} P_{Mi}(t)t_i^2 = 45060$	$\sum_{i=1}^{9} P_{Mi}(t)t_i = 7276$

Substituting the collected data into equations above give rise to the following
Equations below

$$45060 = 8772e + 1296f + 204g$$
$$7276 = 1296e + 204f + 36g$$
$$1582 = 204e + 36f + 9g$$

Meanwhile, solving the equations gives;

$$e = \frac{1213}{213},\ \ f = \frac{-30271}{1155},\ \ g = \frac{26662}{165}$$

And therefore our mod*el for the price of Cassava flour is given as*:

$$P_M(t) = \frac{1213}{213}t^2 - \frac{30271}{1155}t + \frac{26662}{165}$$

The table below gives comparisons between our model results and the gathered data using t=t-2008:

Table 10. *Validation of the model for Red Maize.*

Years	t	P(t) Questionnaire Data	p(t) for model Data	Absolute Error
2008	0	148	161.5879	13.58788
2009	1	142	141.0741	0.92594
2010	2	142	131.9499	10.0501
2011	3	150	134.2154	15.7846
2012	4	150	147.8706	2.12938
2013	5	150	172.9155	22.91548
2014	6	150	209.35	59.35002
2015	7	250	257.1742	7.174221
2016	8	300	316.3881	16.3881
Total				132.5

Remark: The minimal absolute error makes the nonlinear model to be preferable over the linear one formulated above.

4. Discussion

Looking at the results in table 2 and table 4, the result from the Least square method computation for local rice shows the total absolute error of 99.2 The total absolute error from the Non linear method for local rice is 35.6. Here, the nonlinear method has a minimal error value which makes it better than the least square method. From table 5 and table 7, the total error obtained from least square method for Cassava flour is 43.6, while the total error from the non linear method is 24.9. This also shows that the nonlinear method is better because of the smaller error obtained. The total error from the least square method computation for red maize is 215.5 while the total error from the non linear method is 132.5 for tables 8 and 10 respectively. In this case, the error from the non linear method is higher than the error from the least square method, showing that the least square method is better than the non linear method.

5. Conclusion

A country can be said to have food security when everybody in that country can boast of having three square meal per day. Looking at this definition, one can say that food security is the bedrock of any successful country. This means that adequate attention should be paid to food security in Nigeria so as to avoid hunger and starvation.

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