TIME SERIES ANALYSIS AND FRACTAL CONFIGURATION OF GLOBAL MEAT PRODUCTION OF PORK, POULTRY AND BEEF

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ABSTRACT

This paper aims to examine the meat production figures as individual time series, and intra-correlated time series. Both traditional autocorrelation technique and fractal methods were utilized to highlight the unique dynamics of global meat production. The study is anchored on the premise that the dynamics of the meat production data provides deep insights into the geopolitical-economic context in the global setting Production data for chicken, beef, and pork was obtained from United Nation-Food and Agricultural Organization from 1965 to 2015. The result shows that the increase in any of the meat production values would imply a corresponding increase in the other meat products. Apparently, the meat production values obtained over the years are really functions of the population growths experienced by all countries worldwide. The pork and poultry are considered staple meats in most parts of the world. Among the meat products, poultry meat production is the most erratic followed by beef production with pork registering the least erratic movement in the global market. Poultry meat production appears to be the most unpredictable compared to other meat product. The study concludes that poultry meat has the highest demand in the market than other meat products. The continual increases in demand of these meat products are due to inexpensive prices which make it more available to a lower class family. Development of poultry meat production is necessary to supply the demand for meat worldwide because it characterized with a short production period than other meat products. In contrast, pork and beef are more expensive which make it unavailable to a lower class family and has a long production period.

Keywords: time series analysis, fractal configuration, global meat production

Introduction

Global production of three (3) types of meat: chicken, beef, and pork, have a long term record (1965-2015) which can be used for a deeper understanding of the dynamics of these production quantities. The dynamics of these production quantities, in turn, yield insights into the global events that tend to influence the fluctuations in the recorded production values. This paper aims to examine the meat production figures as (a) individual time series, and (b) intra-correlated time series. Both traditional autocorrelation technique and fractal methods were utilized to highlight the unique dynamics of global meat production.

Analysis of the individual time series data normally provides information on trends, seasonality and cycles (when the data are long enough) (Box, Jenkins and Reinsel, 1994). These traditional time series techniques when coupled with methodologies 124 fractal statistical analysis (Padua, 2013) yield reasonable insights into the geopolitical-economic context in the global meat industry (Brown, 2012). For instance, the epidemic of foot and mouth disease had dramatically affected beef production in some years within the series and so did the spread of bird flu in other years, affecting the production of chicken (UN-FAO, 2012). Fractal analysis is a useful tool for uncovering such condition in the time series information.

It is well-known that time series data that display heteroscedasticity are far more difficult to forecast than homoscedastic ones (Box et. al., 1994). A more sensitive index of heteroscedasticity is the series fractal dimension (Padua, 2013). The higher the fractal dimension, the smaller fluctuations than larger fluctuation there will be. It is the ability of fractal analysis to detect small deviation that makes it a useful tool for variability analysis.

Conceptual Framework

The study is anchored on the premise that the dynamics of the meat production data provides deep insights into the geopolitical-economic context in the global setting (Brown, 2012). The fluctuation and long-term behavior of the production indicate the political and economic forces that shape the global meat market. These forces tend to dictate the upward and downward movement of meat production in tandem with other such fortuitous episode of epidemics in the animal industry. The conceptual framework of this study is schematically shown below:

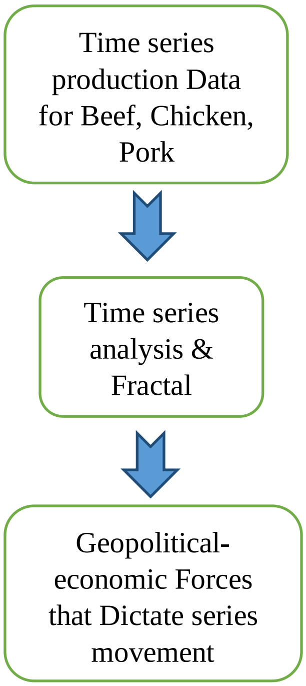


Figure 1: Schematic Diagram of the Conceptual Framework

Methods and Design

Production data for three types of meat: chicken, beef, and pork were obtained from the database of the United Nation-Food and Agricultural Organization (Faostat.Org. 2012). The data consisted of the production data from 1965 to 2015.

1.1 Production data of meats (Faostat.Org. 2012)

Year	Beef	Pork	Broilers
1965	74.7	51.5	NA
1966	78.1	50.3	32.1
1967	79.8	55	32.6
1968	82	56.2	32.9
1969	82.5	54.3	34.9
1970	84.4	55. 4	36.5
1971	83.9	60.6	36.3

Table 1 continuation…

1972	85.3	54.7	37.9
1973	80.5	48.7	36.6
1974	85.6	52.7	36.5
1975	88.2	42.9	36
1976	94.1	45.1	39.4
1977	91.5	46.7	40.1
1978	87.1	46.5	42.5
1979	77.9	53.2	45.4
1980	76.4	56.8	45.2
1981	77.2	54.2	46.2
1982	76.9	48.6	46.5
1983	78.5	51.3	46.8
1984	78.3	51	48.8
1985	79	51.5	50.5
1986	78.7	48.6	51.1
1987	73.7	48.8	54.5
1988	72.5	52.1	54.8
1989	68.9	51.5	56.1
1990	67.5	49.4	59
1991	66.4	49.8	61.4
1992	65.9	52.3	64.9
1993	64.4	51.6	67.4
1994	66.1	52.1	68.4
1995	66.4	51.5	67.6
1996	67	48.1	69
1997	65.5	47.6	71.1
1998	66.5	51.3	71.7
1999	67.3	52.5	76
2000	67.5	50.8	76.6
2001	66	50	76.3
2002	67.5	51.3	80.1
2003	64.8	51.6	81.1
2004	65.9	51	83.9
2005	65.4	49.6	85.4
2006	65.7	49	86
2007	65	50.3	84.7
2008	62.1	48.9	82.9
2009	60.8	49.6	79.2
2010	59.4	47.2	81.8

Table 1 continuation…

2011	57	45.1	82.3
2012	57.1	45.3	79.8
2013	56.3	46.8	81.9
2014 est.	54.2	46.4	83.4
2015 proj.	54.1	50	88.3

1.2 Univariate Times Series Analysis

The Box-Jenkins methodology was followed in the analysis of the individual time series (Box, Jenkins, and Reinsel, 1994). The autocorrelation function (ACF) was first computed in order to determine the appropriate time series model for each series. Trends, seasonalities, and cycles were determined through smoothing techniques.

1.3 Fractal statistical Analysis

Each series was then subjected to a fractal statistical analysis. The purpose of the fractal analysis is to determine the “Outliers” (in years) which cause a departure from smoothness in the data trends. Once the year is discovered, the geopolitical and economic reasons are then deduced from global events that happened in those years.

1.4 Bivariate Time Series Analysis

The time-serial correlation between meat pairs (beef, chicken), (beef, pork) and (pork, chicken) was calculated to determine which meat production pairs are most similar in terms of their dynamical behavior.

Results and Discussions

Poultry

Figure 2 shows the time series plot of the poultry production data:

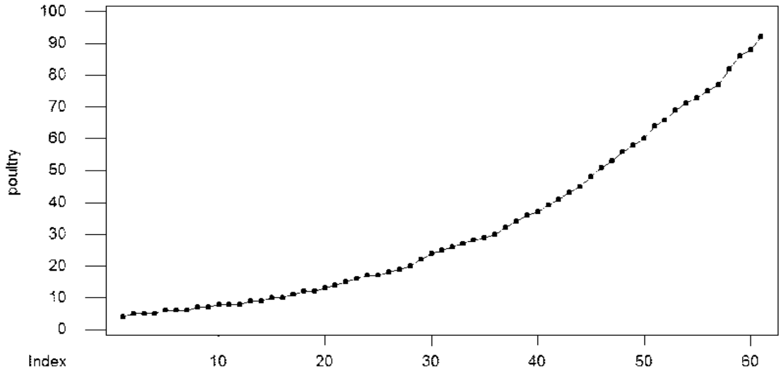


Figure 2: Time Series Plot of the Poultry Production Data

The time series plot of the poultry production data shows a definite upward trend. Trend analysis revealed an exponential trend as shown in Fig. 3:

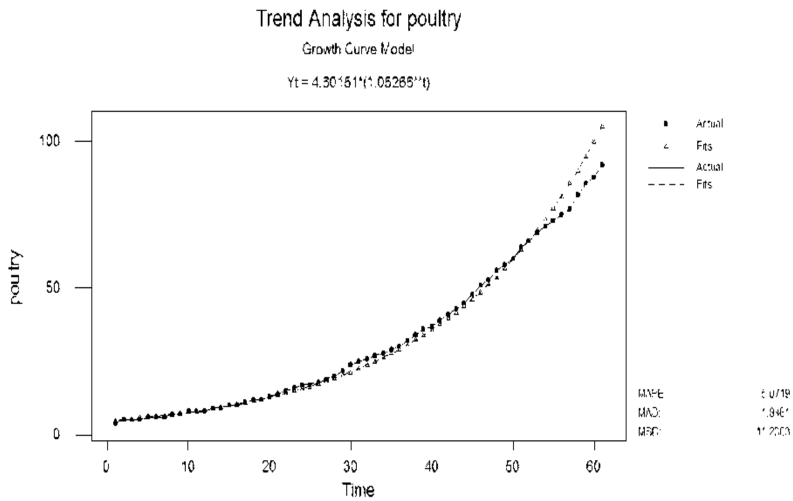
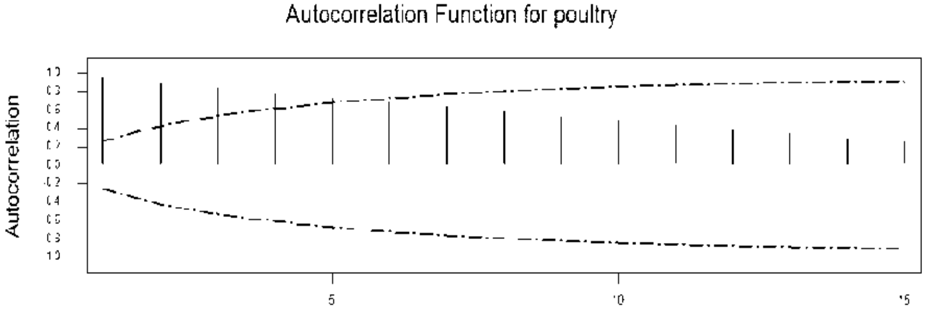


Figure 3: Trend Analysis revealed an exponential trend

The trend is provided by the equation:

$Y(t) = 4.6015*(1.05266)^t$

Moreover, the autocorrelation function revealed an autoregressive model of order 5: AR (5).



Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ
1	0.94	7.37	56.07	8	0.58	1.45	316.64	15	0.24	0.54	[illegible]
2	0.89	4.18	108.42	9	0.53	1.28	337.16				
3	0.83	3.17	[illegible]	10	0.48	1.13	[illegible]				
4	0.78	2.51	195.34	11	0.43	0.99	368.45				
5	0.73	2.18	[illegible]	12	0.38	0.87	379.84				
6	0.68	1.87	264.20	13	0.33	0.75	[illegible]				
7	[illegible]	[illegible]	[illegible]	14	0.29	0.74	[illegible]				

Figure 4: Autocorrelation Function of the Poultry Production Data

The analysis above reveals that the poultry production increases exponentially with time and there is a five-year memory lag in the data. That is, the present production level of the poultry is the weighted average of the last five years in production.

Fractal Analysis

The histogram of the poultry production data over the period is shown below:

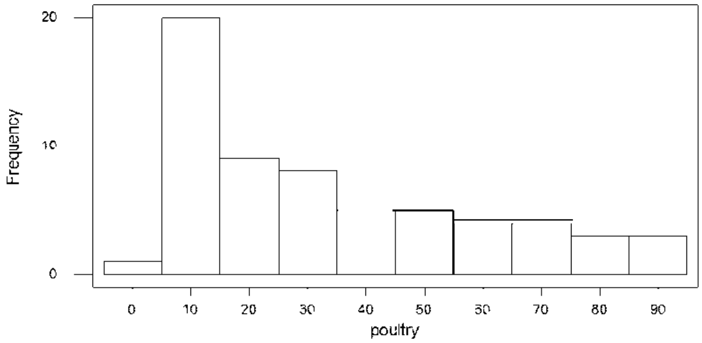


Figure 5: Histogram of the Poultry Production Data

The probability distribution of the poultry production data appears to behave like an exponential distribution with mean 35.52 million tons. The probability distribution of the corresponding fractal random variable Y = exp (poultry) is shown in Fig. 6:

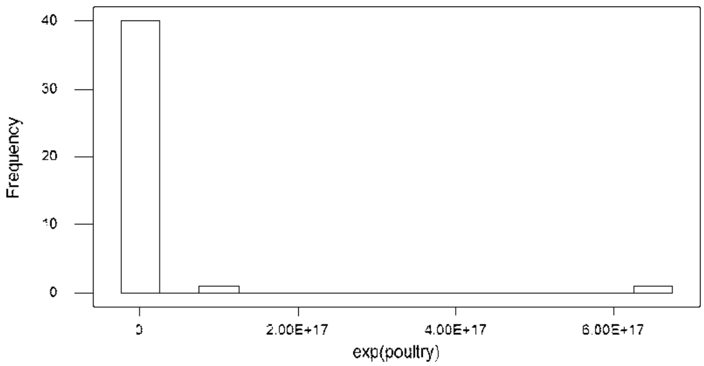


Figure 6: Fractal Random Variable for the Poultry Production Data

The calculated fractal dimension is 1.037503 which shows relatively low fluctuations in the values of the production observations of this meat type. Two (2) years namely, 1973-1974 and 1991-1992 emerged as outliers are detected (larger than usual poultry production values). There is a huge price increase in these years because of the law H.R. 17262 – Emergency Dairy, Livestock, and Poultry Act of 1973-1974 (United States of America) that promotes food price changes to increase the price of agricultural commodity and preserve and protect the essential source of food supply in the interest of various countries. Prices of poultry and poultry products essentially spiked over these years. The first spike in the years 1973 and 1974 can be attributed to the quick market reaction to the law. The international market, however, subsequently settled in its natural state until about 18 years later when the agreement was revived through multilateral agreements among the affected poultry and poultry product producers globally.

Beef

Figure 7 shows the time series plot for the beef production over the same period.

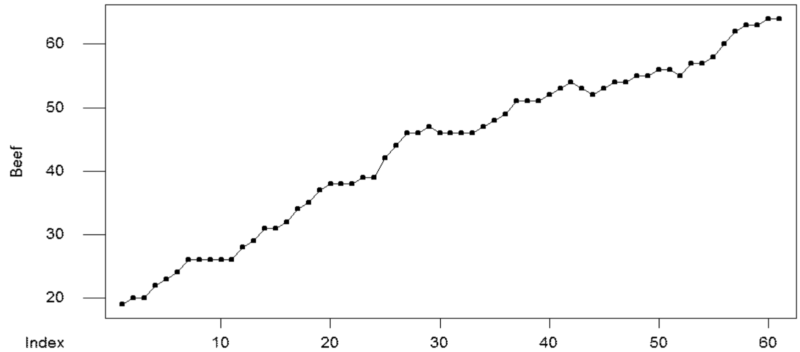
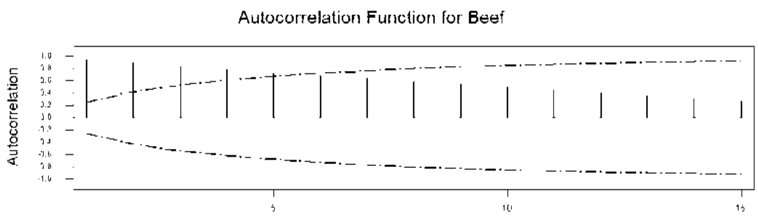


Figure 7: Time Series Plot of the Beef Data: 1950-2010

The time series reveals the same upward trend in the production values although the upward movement is characterized by episodes of erratic behavior. The time series movement of the poultry production was smoother than the movements obtained from the beef production data. Fig. 8 shows the autocorrelation function of the beef production data.



Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ
1	0.95	7.39	57.24	8	0.59	1.49	319.20	15	0.27	0.59	414.14
2	0.89	4.17	109.05	9	0.55	1.32	341.47				
3	0.83	3.11	155.16	10	0.50	1.16	360.62				
4	0.78	2.53	196.13	11	0.45	1.04	376.50				
5	0.73	2.15	232.43	12	0.41	0.92	389.46				
6	0.68	1.87	[illegible]	13	0.36	0.80	399.84				
7	0.64	1.66	292.55	14	0.32	0.69	407.99				

Figure 8: Autocorrelation Function of the Beef Production Data

Significant autocorrelation values were noted up to lag 5 or five years, which means that the present production values are likewise the weighted average of the past five years production values. Fig. 9 shows the histogram of the beef production data.

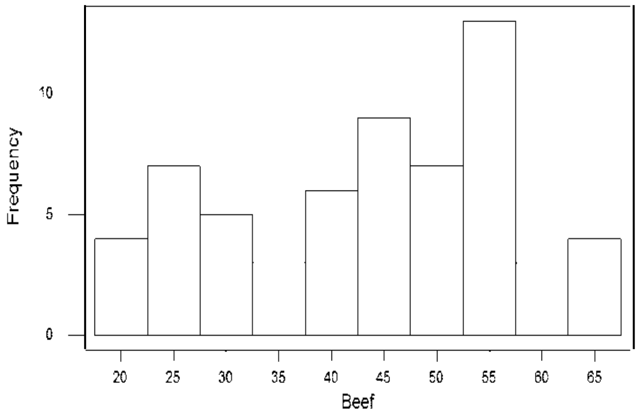


Figure 9: Histogram of the Beef Production Data

The probability distribution of the beef production data appears to be a mixture of three normal distributions: one centered at 26 million tons, the other is at 46 million tons and the remaining one at 55 million tons. These constituted three modal production levels for beef over the period. Fig. 10 shows the histogram of the transformed variable Y= exp(beef):

Fractal Analysis

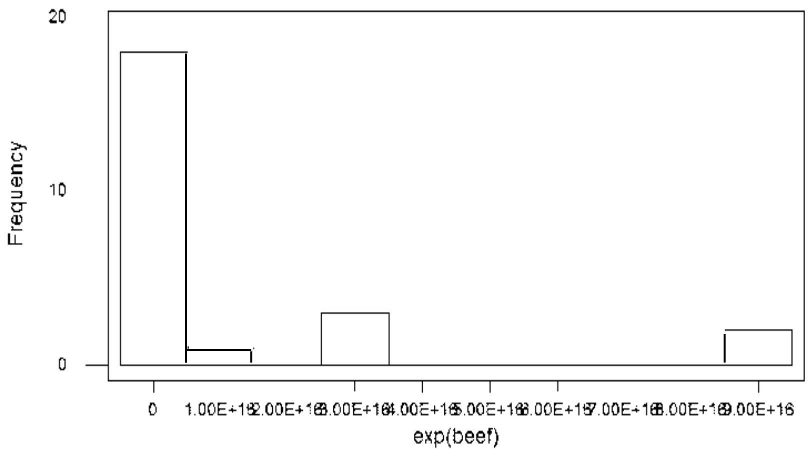


Figure 10: Histogram of the Transformed Variable Y = exp(beef)

The fractal random variable Y has a histogram that clearly highlighted the modal values at 26 million tons, 46 million tons and 55 million tons occurring in the years: 1976-1977 and 1979-1980, 1997-1998 to 2001 respectively. The computed fractal dimension was 1.0229, slightly lower than the fractal dimension of the poultry production data. This could be explained by the fact that in the poultry production data, only one year was found to be an outlier while in the beef production data three such large values were found most frequently.

Pork

Figure 11 shows the time series plot of the pork production data over the same time period.

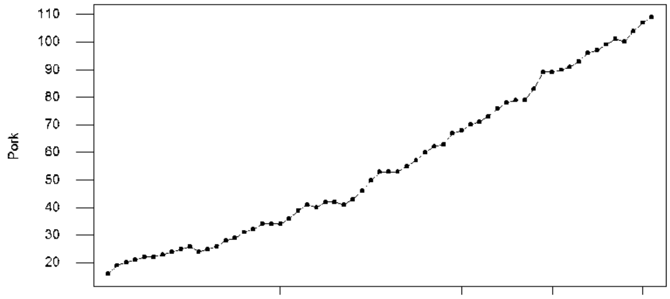
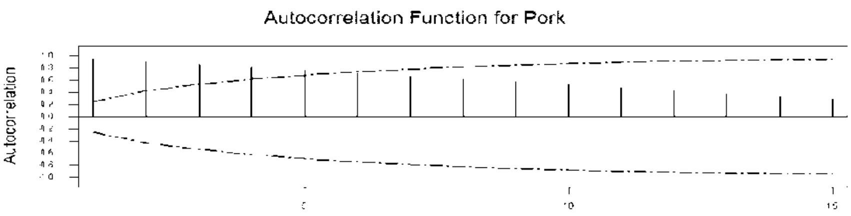


Figure 11: Time Series Plot of the Pork Production Data: 1965-2015

The time series plot of the pork production data shows a linear upward trend. While the beef and pork production data revealed a slightly upward exponential trend, pork production appeared to be linear in character. Fig. 12 shows the autocorrelation function for the pork production data:



Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ
1	0.95	7.42	57.88	8	0.62	1.62	341.65	15	0.29	0.61	448.22
2	0.90	4.21	110.90	9	0.56	1.35	369.40				
3	0.86	3.13	159.63	10	0.52	1.21	387.72				
4	0.81	2.62	204.20	11	0.46	1.07	405.60				
5	0.77	[illegible]	[illegible]	12	0.42	[illegible]	420.37				
6	0.72	1.94	281.00	13	0.38	[illegible]	431.56				
7	0.67	1.71	313.28	14	0.33	[illegible]	441.14				

Figure 12: Autocorrelation Function for the Pork Production Data

The autocorrelation function once again shows that the current observation can be expressed as a weighted average of the previous five years. The computed autocorrelation values were found significant up to and including lag 5. Fig. 13 shows the histogram of the pork production data:

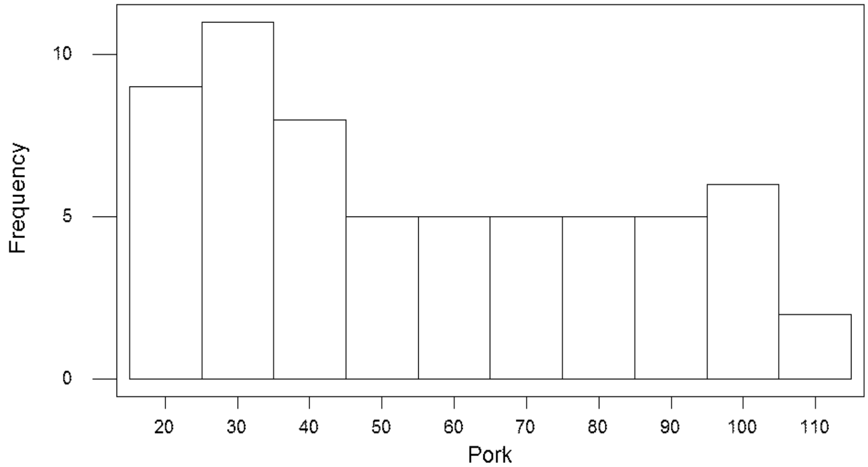


Figure 13: Histogram of the Pork Production Data

The histogram shows a modal production value of 30 million tons of pork. Production between 50 million tons to 90 million tons appears to be uniformly distributed over the years. The histogram of the transformed variable Y = exp (pork) is shown in Fig. 14:

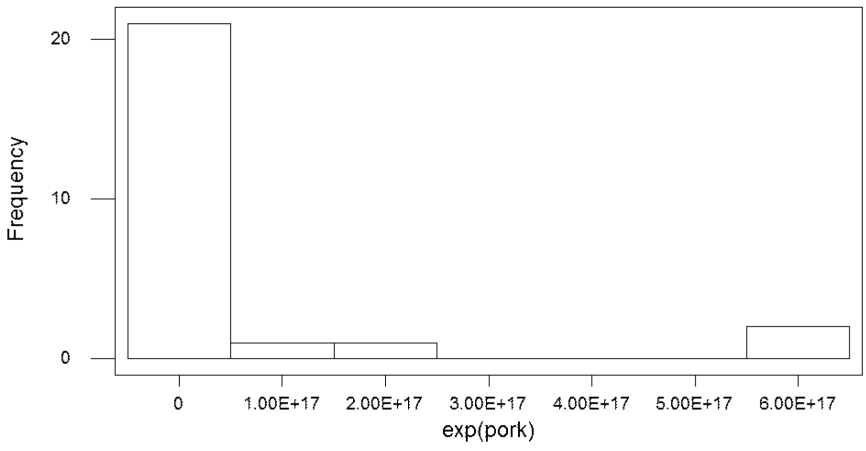


Figure 14: Histogram of the Transformed Data Y = exp(pork)

The fractal random variable Y shows the same pattern as the beef production data with one extreme value at 109 million tons of pork in 2010. The fractal dimension of this data set was found to be 1.01794. The fractal dimension was found to be smaller owing to the linear pattern in the production values.

Correlation Values

Table 2 shows the intercorrelations of the poultry, pork and beef production data:

Table 2: Inter-Correlations of Production Data

Meat Type	Beef	Pork	Poultry
Beef	1.0	0.953	0.904
Pork	.953	1.0	.985
Poultry	.904	.985	1.0

The three meat products are all very highly correlated. This shows the increase in any of the production values of any of the meat products would imply a corresponding increase in the other meat production data. Apparently, the meat production values obtained over the years are really functions of the population growths experienced in all countries all over the world. The high correlation found between pork and poultry can be explained by the relatively easier and faster production rates for these two types of meat as compared to the production of beef. The cows take longer periods of time before they can be slaughtered as compared to pigs and chicken. In other words, pork and poultry are considered staple meats in most parts of the world.

Conclusion

Poultry meat production is the most erratic among the three meat products, followed by beef production with pork meat registering the least erratic movement in the global meat market. This implies more unpredictability in the poultry production data than in the two other meat types. Poultry meat and pork are interchangeable meat products or substitute meat products since these two types of meats registered the highest correlation in terms of their production over the period 1965 to 2015. The study concludes that poultry meat has the highest demand in the market than other meat products. The continual increases in demand of these meat products are due to inexpensive prices which make it more available to a lower class family. Development of poultry meat production is necessary to supply the demand for meat worldwide because it characterized with a short production period than other meat products. In contrast, pork and beef are more expensive which make it unavailable to a lower class family and has a long production period.

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