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SPATIAL EQUILIBRIUM PRICES IN THE INTERNATIONAL BEEF MARKET

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ABSTRACT

The research empirically tests for spatial equilibrium of beef prices among the major exporting countries in the world using yearly time series data sourced from FAO database. The data spanning from 1991 to 2016 covered producer prices from the four major exporting countries *viz.* USA, Brazil, China and India and the collected data were analysed using descriptive and inferential statistics. Evidence showed that the major exporting countries comply with the World Trade Organization (WTO) terms on agricultural commodity as the law of one price (LOP) existed between these markets in the international beef market. Furthermore, only Indian beef market (IM) had the tendency of establishing spatial equilibrium regardless of any innovation in the prices of beef that may emanate from any of the short-run equilibrium. Therefore, to strengthen the linkages and interconnectedness among the markets for faster transmission of price and management of beef commodity from surplus to deficit regions, the study recommended the need to enhance the development of market infrastructure especially the Brazil beef market (BM), use of ICT in the transaction of the product, processing, transportation and other backward-end supply chain of bovine products as this would definitely helped in the development of single integrated international economic market for beef in the world

Keywords: Spatial equilibrium; Prices; Cattle beef; International market

INTRODUCTION

No one can ignore the importance of balanced diet for good health and productive capabilities of the people. One of the important ingredients of a balanced diet is a protein which is mainly extracted from animals and plants sources. The population of the world is surging at a rapid pace, thus the gap between production and requirement for the protein of animal origin is widening with the passage of time. In this situation, bovine product seems to have enough potential to bridge this gap both in terms of quality and quantity compared to the other sources of animal protein available in the world.

Agricultural and food trade policy reform, especially, is a priority issue in the WTO negotiations, as trade liberalization is viewed as encouraging allocative efficiency and long-run growth. The absence of market integration or of complete pass-through of price changes from one market to another has important implications for economic welfare (Barrett, 2001; and Barrett and Li, 2002). Tradability and nonzero trade flows are sufficient conditions that establishes market integration, whilst efficiency is established when prices in two different markets differ by transfer costs. Incomplete price transmission arising either due to trade and other policies or due to transaction costs such as poor transport and communication infrastructure, results in a reduction in the price information available to economic agents and consequently may lead to decisions that contribute to inefficient outcomes.

The large body of research on market integration and price transmission, both spatially

and vertically, has highlighted several factors that impede the pass-through of price signals. Distortions introduced by governments in the form of policies either at the border or as price support mechanisms weaken the link between the international and domestic markets. Agricultural policy instruments such as import tariffs, tariff rate quotas, export subsidies or taxes, intervention mechanisms, as well as exchange rate policies insulate the domestic markets and hinder the full transmission of international price signals by affecting the excess demand or supply schedules of domestic commodity markets (Abdulai, 2000; Baffes and Ajwad, 2001; Sharma, 2002).

In addition to the body of research, price transmission mechanisms featured prominently in all global agricultural partial equilibrium models, such as the World Food Model of the UN, Food and Agriculture Organization (FAO) and other models such as the one developed by Tyers and Anderson (1992). Sharma (2002) reported that the outcomes of these models showed that price transmission plays an important role in determining the direction, magnitude and distribution of welfare effects of trade policy scenarios.

Given the increasing use of these models to address sensitive policy issues, such as trade liberalization and the distribution of benefits and costs across countries and population groups, there is urgent need to have a review of the current scenario of livestock product (cattle beef) given that it has enough potential to bridge the supply and demand gap of animal protein both in terms of quality and quantity compared to the other sources of animal protein available in the world. The specific objectives were to determine the extent and degree of market integration; to determine the effect of innovation on the current and future prices of beef in each of the selected markets; to determine trade usefulness of beef commodity in the selected markets; and, to forecast ten years ahead of beef prices in each of the selected markets.

RESEARCH METHODOLOGY

The present research made use of yearly time series data spanning from 1991-2016 sourced from the database of FAO. The data covered producer prices of cattle beef for the major beef exporting countries viz. USA, Brazil, China and India as shown by FAO statistics. The collected data were analysed using descriptive and inferential statistics. Objectives I, II and IV were achieved using the Johansen co-integration test and restricted vector autoregressive model; and, objective III was achieved using generalized autoregressive conditional heteroscedasticity(GARCH) model. The cattle beef markets in USA, Brazil, China and India were denoted as UM, BM, CM and IM respectively.

Empirical model

Augmented Dickey Fuller test

Following Sadiq *et al.* (2017) the autoregressive formulation of the ADF test with a trend term is given below:

$$\Delta P_t = \alpha + P_{t-1} + \sum_{j=2}^{it} \beta_i \Delta P_{it-j+t} + \varepsilon \quad \ldots (3)$$

Where, $P_{it}$is the price in market *i* at the time *t*, $\alpha$and$\Delta P_{it}(P_{it} - P_{t-1})$ is the intercept or trend term.

Johansen's co-integration test

Following Johansen (1988) the multivariate formulation is specified below:

$$P_t = A_1 P_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

So that

$$\Delta P_t = A_1 P_{t-1} - P_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$P_t = (A_1 - 1)P_{t-1} + \varepsilon_t$$

$$\Delta P_t = \prod P_{t-1} + \varepsilon_t$$

Where, $P_t$and $\varepsilon_t$are $(n \times 1)$vectors; A_t is an$(n \times n)$matrix of parameters; I is an $(n \times n)$ identity matrix, and $\prod$ is the $(A_1 - 1)$ matrix.

Using the estimates of the characteristic roots, the tests for the number of characteristic roots that are insignificantly different from unity were conducted using the following statistics:

$\lambda_{trace} = -T \sum_{i=r+1}^{n} ln\,(1 - \lambda_i)$ ..... (6)

$\lambda_{max} = -T\ ln(1 - \lambda_i + 1)$ ..... (7)

Where, λ_i denotes the estimated values of the characteristic roots (Eigen-values) obtained from the estimated $\prod$ matrix, and *T* is the number of usable observations.

Granger causality test

Following Granger (1969) the model used to check whether market P_1 Granger causes market P_2or vice-versa is given below:

$P_t = \alpha + \sum_{i=1}^{n}(\emptyset P_{1t-i} + \delta_i P_{2t-i}) + \varepsilon_i$..... (8)

A simple test of the joint significance of $\delta_i$was used to check the Granger causality i.e.

$H_0 : = \delta_1 = \delta_2 = \ldots\ldots \delta_n = 0.$

Vector error correction model (VECM)

The VECM explains the difference in $y_t$and y_{t-1} (i.e.Δy_t) and it is shown below (Sadiq *et al.*, 2016a; Sadiq*et al.*, 2016b) :

$\Delta\gamma_t = \alpha + \mu(\gamma_{t-1} - \beta_{xt-1}) + \sum_{i=0}^{i=t} \delta_i \Delta x_{t-1} + \sum_{i=1}^{i=t} \gamma_i \Delta\gamma_{t-1}$..... (9)

It includes the lagged differences in both *x* and *y*, which have a more immediate impact on the value of$\Delta\gamma_t$.

Impulse response functions

The generalized impulse response function (GIRF) in the case of an arbitrary current shock (δ) and history (ω_{t-1})is specified below (Rahman and Shahbaz, 2013; Beag and Singla, 2014):

$GIRF_Y(h, \delta, \omega_{t-1}) = E\left[Y_t + h \,|\, \delta, \omega_{t-1}\right] - E\left[Y_{t-1} \,|\, \omega_{t-1}\right]$ ..... (10)

Forecasting accuracy

For measuring the accuracy in fitted time series model, mean absolute prediction error (MAPE), relative mean square prediction error (RMSPE), relative mean absolute prediction error (RMAPE) (Paul, 2014), Theil's U statistic and R^2 were computed using the following formulae:

$MAPE = 1/T \sum_{i=1}^{5}(A_t - F_t)$ ..... (11)

$RMPSE = 1/T \sum_{i=1}^{5} (A_t - F_t)^2 / A_t$ ..... (12)

$RMAPE = 1/T \sum_{i=1}^{5} (A_t - F_t)/A_t \times 100$..... (13)

$U = \sqrt{\frac{\sum_{t=1}^{n-1} \frac{(\hat{Y}_{t+1} - Y_{t+1})^2}{Y_t}}{\sum_{t=1}^{n-1} \frac{(Y_{t+1} - Y_t)^2}{Y_t}}}$ ..... (14)

$R^2 = 1 - \frac{\sum_{i=1}^{n}(A_{ti} - F_{ti})}{\sum_{i=1}^{n}(A_{ti})}$ ..... (15)

Where, R^2= coefficient of multiple determination,A_t = Actual value; F_t = Future value, and T = time period

GARCH model

The representation of the GARCH (*p*, *q*) is given as:

$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \varepsilon_i$(Autoregressive process) ..... (17)

And the variance of random error is:

$\sigma_t^2 = \lambda_0 + \lambda_1 \mu_{t-1}^2 + \lambda_2 \sigma_{t-1}^2$ ..... (18)

$\sigma_t^2 = \omega + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 + \sum_{j=1}^{q} \alpha_i \varepsilon_{t-i}^2$..... (19)

Where $Y_t$is the price in the i^{th}period of the i^{th} market, *p* is the order of the GARCH term and *q* isthe order of the ARCH term. The sum of ARCH and GARCH $(\alpha + \beta)$ gives the degree of persistence of volatility in the series. The closer is the sum to 1; the greater is the tendency ofvolatility to persist for a longer time. If the sum exceeds1, it is indicative of an explosive series with a tendencyto meander away from the mean value.

RESULTS AND DISCUSSION

Summary Statistics of International Beef Prices for the Major Beef Exporting Countries

A perusal of the results showed that the price of beef was lowest in IM which might be due to the surplus of exportable beef product as the majority of Indian populace is vegetarians while highest in UM which may be due to value addition (Table 1). In addition, the price of beef was stable in IM while unstable in the CM and BM as indicated by their respective coefficient of variation (CV). Furthermore, the results showed that the markets UM, BM and CM had inventories of the beef commodity as indicated by their respective prices which were positively skewed while IM didn't have an inventory of the beef commodity as evident by negative skewness of its price. Stigler (2011) reported that floor price tends to introduce positive skewness while ceiling price tends to promote negative skewness. However, despite WTO trade agreement IM prices was negatively skewed as they have surplus exportable commodity because the majority of the Indian populace is vegetarian. From a practical perspective, the presence of positive skewness can help policy design in that positive price asymmetry implies that one can be quite confident in establishing a minimum price level.

Table 1: Summary statistics of beef prices for the selected markets

Markets	Mean	Min	Max	SD	CV	Skewness	Kurtosis
UM	1923.00	1307.00	3351.00	585.51	0.305	1.092	0.191
BM	1328.70	499.80	3686.40	1037.60	0.781	1.166	-0.275
CM	1646.90	609.10	3981.00	1114.70	0.677	0.919	-0.586
IM	246.92	152.30	350.00	62.56	0.253	-0.058	-1.304

Lag Selection Criteria

Because of the sensitivity of time series to lag length, lag selection criteria was performed to ensure that the error term is pure white noise and also make the model parsimoniously interpretable. The length of lag chosen for truncation is four (4) as advised by all the selection criteria *viz.* Akaike information criterion (AIC), Bayesian information criterion (BIC) and Hannan-Quinn criterion (HIC) as indicated by the asterisk against the value of the respective information criterion (Table 2).

Table 2: Lag selection criteria

Lag(s)	AIC	BIC	HQC
1	51.20	52.19	51.44
2	50.70	52.48	51.12
3	49.83	52.41	50.44
4	46.40*	49.77*	47.19*

Source: Computer print-out, 2018

Stationarity Test

The results of the traditional unit root tests *viz.* ADF and KPSS (Kwiatkwoski, Phillips, Schmidt and Shin) applied at level to all the price series showed that none of the variable series in the case of the former while with the exception of India beef price in the latter was stationary as indicated by their respective estimated tau-statistics which were greater than their t-critical values at 5% probability level. However, the reapplication of the unit root test at first difference showed that all the price series were stationary as evidenced by their respective ADF and KPSS tau-statistics which were greater than their t-critical values at 5% probability level. Therefore, for the ADF test, the series are integrated of the same order i.e. order one [I(1)] while for the KPSS test the series are integrated of different order [I(0) and I(1)]. Because of the inherent weakness of the traditional unit root tests the neo-classical unit root test *viz.* ADF-GLS test was applied to verify the robustness and validity of the estimates of the traditional unit root tests. The results of the ADF-GLS at level accepted the null hypothesis of non-stationary for all the price series against the alternative hypothesis and at first difference rejected the null hypothesis in favour of alternative hypothesis of stationary as indicated by their respective estimated tau-statistics which were greater than their t-critical values at 5% probability level (Table 3). Therefore, based on the ADF-GLS test results, the ADF unit root test estimates were robust and valid [I(1)] while that of the KPSS test [I(0) and I(1)] were not robust and valid, an indication that it has lost its power to test for stationary due to long-time length is chosen for the truncation. With the proof of the ADF-GLS test results that the price series were non-stationary and integrated of order one, the horizontal relationship between the prices was estimated using the cointegration test.

Table 3: Stationarity test

Markets	Stage	ADF	KPSS	ADF-GLS
UM	**Level**	-0.995(0.757)^{NS}	0.525^{NS}	-2.134^{NS}
	$1^{st}\Delta$	-4.394(0.0003)^{S}	0.133^{S}	-2.938(0.003)^{S}
BM	**Level**	-0.803(0.801)^{NS}	0.468^{NS}	-2.042^{NS}
	$1^{st}\Delta$	-5.605(0.0001)^{S}	0.152^{S}	-5.803^{S}
CM	**Level**	0.669(0.974)^{NS}	0.567^{NS}	-0.918^{NS}
	$1^{st}\Delta$	-5.80(3.5E-06)^{S}	0.437^{S}	-7.807^{S}
IM	**Level**	-0.701(0.829)^{NS}	0.277^{S}	-1.531^{NS}
	$1^{st}\Delta$	-4.91(0.003)^{S}	-	-1.841(0.063)^{S}

Note: Δ, NS and S indicates first difference, non-stationary and stationary at the level or at first difference at 5 percent significance`

The critical values for the KPSS and ADF-GLS test at 5% probability are 0.462 and 3.19 respectively.

Law of One Price (LOP)

The results of the multivariate horizontal extent of integration among the markets showed that the prices of the beef in all the selected four markets shared the same stochastic trend i.e. has one stochastic trend as indicated by both the trace and max tests which co-integrate at rank three for the four selected markets (Table 4). The presence of one stochastic trend for all the markets means that the beef prices of the selected markets move together in the long-run or have a long-run association as all the markets are dependent on each other in terms of price transmission. Therefore, it can be inferred that the extent of integration of international market price of beef is very efficient: the international beef cattle markets are strongly integrated as the law of one price (LOP) was found to hold across

these markets i.e. the price differential across the markets operating on the same market level is equal to the cost of transfer despite that these markets are geographically far apart. Furthermore, this result is a clear testimony that the major exporter of cattle beef comply with the WTO agreement on agriculture i.e. they trade according to the present rules and commitments on agriculture which is called the "Uruguay round reform programme". The rules include the reduction in subsidies, protection as well as other disciplines on the trade. In another word, these agreements on agriculture rules relate to the areas of improving market access, domestic support and export competition-reduction in trade-distorting subsidies. The presence of one stochastic trend implies the presence of pair-wise cointegration of prices between the selected markets.

Table 4: Multivariate horizontal-wise co-integration result

H_0	H_1	Eigen value	Trace test	P-value	Lmax test	P-value
r = 0	r ≥1	0.972	153.71**	0.0000	78.51**	0.0000
r ≤ 1	r ≥2	0.877	75.20**	0.0000	46.09**	0.0000
r ≤ 2	r ≥3	0.622	29.12**	0.0017	21.39**	0.0047
r ≤ 3	r =4	0.296	7.72	0.0947	7.72	0.0946

Note: **denotes rejection of the null hypothesis at 5 percent level of significance

The pair-wise cointegration results showed the presence of LOP between the market pairs: UM-CM, UM-IM and CM-IM; while the LOP was absent in the market pairs: UM-BM, BM-CM and BM-IM (Table 5). This implies that the former three market pairs shared one stochastic trend each, suggesting long-run association in the cattle beef prices between these markets, while in the later three market pairs each market pair had two stochastic trends, suggesting no long-run association between these markets in a pair. Therefore, it can be inferred the former three market pairs of beef were efficiently and strongly integrated while the latter three market pairs were poorly integrated. The non-integration of the latter three market pairs which has BM in each pair showed inefficiency of the BM in the international beef market which may owe to poor or inadequate marketing infrastructure and not output quantity (Brazil is the second largest producer of cattle beef) since all the selected markets trade according to the rules and commitments of WTO "Agriculture Agreement". In addition, technological advancement made these markets (UM, CM and IM) in pair with each other to be efficiently integrated.

Therefore, based on these findings the following inferences were made: from the multivariate dimension the influence of price transmission of UM, CM and IM phase-out the weakness in the price transmission of the BM against the pair-wise integration results which evidently showed the extent of integration of BM in pair with each of the selected market to be poor.

Degree of Market Integration

The results of the degree of market integration showed that only India market (IM) was the most efficient in the international beef market as it established long-run equilibrium across the three lag error period as indicated by its attractor coefficients which were negatively signed and significant at less than 10% probability level ($p<0.10$) (Table 6). The implication is that this market absolves any price shocks that emanate from any of the short-run parameters by correcting its disequilibria from the equilibrium at the speed of 20.5%, 13.1% and 9.9% per annum at lag 1, lag 2 and lag 3 ECTs respectively. In addition, the approximate time

period to be taken per annum for the beef price of India to converge back to their respective equilibriums from their respective disequilibrium's for lagged 1 and 3 ECTs; and, the time taken at lag 2 ECT to converge towards the equilibrium would all be less than a month. The adjustment rates were very fast at each attractor lag period. The fact that most Indians are vegetarian creates a far bigger exportable surplus which makes the market very efficient as it reacts to price news immediately in order to maximize its comparative advantage in the international cattle beef market. However, the UM and BM were found to established equilibrium at lag 2 and 3 attractor coefficients as such weakly efficient. The CM did not react to news on price changes from any of the price shocks that emanate from any of the short-run coefficients an indication poor degree of integration due to non-establishment of spatial equilibrium.

In the short-run, IM adjusted by 22.4%, 19.2% and 12.2%; 12.6%, 14.0% and 6.5%; and, 15.5%, 8.1% and 5.2%; with respect to price at lag 1 to 3 for UM, BM and CM respectively; if there arises an external shocks that affects the short-run equilibrium. In addition, for IM at lag 2, it will adjust by 66.1% if an external shock arises that affects the short-run equilibrium. Therefore, it can be inferred that a clear multidirectional lead-lag relationship can be established that flow across all the selected markets to India cattle beef market (IM).

The results of the VECM for pair-wise markets which had long-run association showed that only unidirectional equilibrium was established between market pairs *viz.* UM-CM, IM-UM and CM-IM with no existence of bidirectional equilibrium or non-equilibrium between the market pair (Table 7). This implies that only the former in each pair corrects their disequilibrium due to shocks of news about the price of beef. Therefore, it can be inferred that all the selected international markets indirectly react to price news as indicated by UM; IM and CM which adjustment towards the equilibrium in the case of any price shock from the latter markets in pair viz. CM; UM and IM respectively.

Table 5: Pair-wise horizontal co-integration

Markets	H_0	H_1	Trace test	P-value	Lmax test	P-value	CE
UM-BM	r = 0	r ≥1	17.37	0.120	13.93	0.099	None
	r ≤ 1	r ≥2	3.44	0.514	3.43	0.513	
UM-CM	r = 0	r ≥1	22.91**	0.019	20.03**	0.009	1CE
	r ≤ 1	r ≥2	2.88	0.611	2.88	0.610	
UM-IM	r = 0	r ≥1	27.84**	0.003	25.84**	0.001	1CE
	r ≤ 1	r ≥2	1.999	0.774	1.999	0.773	
BM-CM	r = 0	r ≥1	16.54**	0.009	10.93	0.055	None
	r ≤ 1	r ≥2	5.61**	0.0198	5.61	0.021	
BM-IM	r = 0	r ≥1	20.39**	0.046	13.99	0.098	None
	r ≤ 1	r ≥2	6.397	0.168	6.397	0.167	
CM-IM	r = 0	r ≥1	13.54**	0.030	11.58**	0.042	1CE
	r ≤ 1	r ≥2	1.953	0.190	1.953	0.191	

Note: **denotes rejection of the null hypothesis at 5 percent level of significance
CE- Cointegration equation

Table 6: Multivariate horizontal-wise VECM

Variable	ΔUM	ΔBM	ΔCM	ΔIM	Influencing
ΔUM_{t-1}	-0.218(0.605)[0.36]^{NS}	1.507(0.990)[1.52]^{NS}	-1.202(1.123)[1.07]^{NS}	-0.224(0.062)[3.62]**	**1**
ΔUM_{t-2}	-0.554(0.713)[0.78]^{NS}	1.094(1.168)[0.94]^{NS}	-0.817(1.325)[0.62]^{NS}	-0.192(0.073)[2.63]**	**1**
ΔUM_{t-3}	0.042(0.610)[0.07]^{NS}	1.074(0.998)[1.08]^{NS}	0.064(1.132)[0.06]^{NS}	-0.125(0.062)[1.99]*	**1**
ΔBM_{t-1}	0.795(0.305)[2.61]**	1.240(0.499)[2.48]**	1.018(0.566)[1.80]^{NS}	0.126(0.031)[4.03]***	**3**
ΔBM_{t-2}	0.863(0.346)[2.49]**	1.144(0.567)[2.02]*	0.734(0.643)[1.14]^{NS}	0.140(0.035)[3.94]***	**3**
ΔBM_{t-3}	0.560(0.228)[2.46]**	0.548(0.373)[1.47]^{NS}	-0.032(0.423)[0.08]^{NS}	0.065(0.023)[2.78]**	**2**
ΔCM_{t-1}	-1.129(0.377)[2.99]**	-2.178(0.617)[3.53]**	-0.651(0.699)[0.93]^{NS}	-0.155(0.039)[4.01]***	**3**
ΔCM_{t-2}	-0.467(0.301)[1.55]^{NS}	-1.427(0.494)[2.89]**	-0.212(0.560)[0.38]^{NS}	-0.081(0.031)[2.62]**	**2**
ΔCM_{t-3}	-0.343(0.220)[1.56]^{NS}	-1.012(0.360)[2.81]**	0.165(0.409)[0.41]^{NS}	-0.052(0.023)[2.29]*	**2**
ΔIM_{t-1}	3.115(3.554)[0.88]^{NS}	-2.664(5.819)[0.45]^{NS}	-0.276(6.598)[0.04]^{NS}	0.004(0.364)[0.01]^{NS}	**0**
ΔIM_{t-2}	-4.458(2.749)[1.62]^{NS}	-8.864(4.501)[1.97]*	-4.842(5.103)[0.95]^{NS}	-0.661(0.281)[2.35]*	**2**
ΔIM_{t-3}	-3.898(2.669)[1.46]^{NS}	-10.02(4.370)[2.29]*	-2.976(4.955)[0.60]^{NS}	-0.304(0.273)[1.11]^{NS}	**1**
ECT_{t-1}	**0.011(0.524)[0.02]^{NS}**	**-0.831(0.859)[0.97]^{NS}**	**1.093(0.973)[1.12]^{NS}**	**0.205(0.054)[3.82]*** **	**3**
ECT_{t-2}	**-0.578(0.292)[1.98]***	**-2.443(0.478)[5.12]*** **	**-0.488(0.541)[0.90]^{NS}**	**-0.131(0.029)[4.39]*** **	**3**
ECT_{t-3}	**0.804(0.285)[2.82]** **	**2.313(0.466)[4.96]*** **	**0.198(0.529)[0.38]^{NS}**	**0.099(0.029)[3.40]** **	**3**
Influenced	**6**	**9**	**0**	**13**	
R^2	**90.1**	**94.1**	**82.3**	**92.9**	
D-W stat	**2.49**	**2.28**	**1.82**	**1.47**	
Autocor	**2.403{0.121}^{NS}**	**0.762{0.383}^{NS}**	**0.041{0.839}^{NS}**	**1.283{0.257}^{NS}**	
Arch effect	**0.004{0.950}^{NS}**	**0.673{0.412}^{NS}**	**0.125{0.724}^{NS}**	**0.058{0.810}^{NS}**	
Normality	**13.58{0.09}***				

Note: *** ** * means significant at 1%, 5% and 10% respectively
Values in ( ); [ ] and { } are standard error, t-statistic and probability value

Table 7: Pair-wise horizontal VECM

Variable	**ΔUM**	**ΔCM**	**Variable**	**ΔUM**	**ΔIM**
ΔUM_{t-1}	0.853(0.273)[3.13]***	0.021(0.445)[0.05]^{NS}	ΔUM_{t-1}	0.816(0.355)[2.30]**	-0.123(0.033)[3.75]***
ΔUM_{t-2}	0.124(0.284)[0.44]^{NS}	-0.026(0.463)[0.06]^{NS}	ΔUM_{t-2}	0.303(0.561)[0.54]^{NS}	-0.114(0.052)[2.20]**
ΔUM_{t-3}	0.901(0.301)[2.99]***	-0.737(0.490)[1.50]^{NS}	ΔUM_{t-3}	0.897(0.578)[1.55]^{NS}	-0.069(0.053)[1.30]^{NS}
ΔCM_{t-1}	-0.350(0.177)[1.99]*	0.131(0.287)[0.46]^{NS}	ΔIM_{t-1}	0.547(2.010)[0.27]^{NS}	0.101(0.185)[0.54]^{NS}
ΔCM_{t-2}	0.048(0.160)[0.30]^{NS}	0.237(0.260)[0.91]^{NS}	ΔIM_{t-2}	-1.890(2.221)[0.85]^{NS}	0.031(0.205)[0.15]^{NS}
ΔCM_{t-3}	-0.157(0.154)[1.02]^{NS}	0.606(0.252)[2.41]**	ΔIM_{t-3}	0.271(2.402)[0.11]^{NS}	0.526(0.222)[2.37]**
ECT_{t-1}	**-0.970(0.279)[3.5]*** **	**0.711(0.454)[1.57]^{NS}**	**ECT_{t-1}**	**-0.487(0.294)[1.66]^{NS}**	**0.096(0.027)[3.53]*** **
R^2	**67.7**	**55.6**	**R^2**	**43.95**	**67.44**
D-W stat	**2.27**	**1.84**	**D-W stat**	**2.39**	**2.42**
Autocor.	**0.870{0.351}^{NS}**	**0.005{0.943}^{NS}**	**Autocorrelation**	**2.517{0.133}^{NS}**	**1.808{0.179}^{NS}**
Arch effect	**1.110{0.295]^{NS}**	**1.088{0.297}^{NS}**	**Arch effect**	**2.496{0.114}^{NS}**	**0.291{0.590}^{NS}**
Normality	**4.015{0.404}^{NS}**		**Normality**	**5.992{0.200}^{NS}**	
	ΔCM	**ΔIM**			
ΔCM_{t-1}	-0.831(0.279)[2.98]***	-0.027(0.039)[0.70]^{NS}			
ΔCM_{t-2}	-0.603(0.253)[2.39]**	-0.029(0.035)[0.81]^{NS}			
ΔCM_{t-3}	0.039(0.288)[0.14]^{NS}	-0.013(0.040)[0.33]^{NS}			
ΔIM_{t-1}	0.575(1.753)[0.33]^{NS}	0.067(0.243)[0.27]^{NS}			
ΔIM_{t-2}	5.281(1.686)[3.13]***	-0.068(0.234)[0.29]^{NS}			
ΔIM_{t-3}	2.896(2.257)[1.28]^{NS}	0.561(0.313)[1.79]*			
ECT_{t-1}	**0.110(0.036)[3.10]*** **	**0.0046(0.0049)[0.92]^{NS}**			
R^2	**71.0**	**26.1**			
D-W stat	**1.83**	**2.12**			
Autocor.	**0.024{0.877}^{NS}**	**0.311{0.587}^{NS}**			
Arch effect	**4.977{0.173}^{NS}**	**2.574{0.462}^{NS}**			
Normality	**4.597{0.331}^{NS}**				

Note: *** ** * means significant at 1%, 5% and 10% respectively
Values in ( ); [ ] and { } are standard error, t-statistic and probability value

Causal Relationship

The results of the Granger causality which shows the direction of price formation between two markets and related spatial arbitrage i.e. physical movement of the commodity to adjust the price differences are presented in Table 8. The null hypothesis of no Granger causality was rejected in each case of CM and IM as evident by their respective F-statistics which were different from zero at 10% probability level. Besides, each of the UM and BM had three F-statistics different from zero at 10% probability level in pair with the other markets. The causal results showed bidirectional causality between market pairs *viz.* UM-CM, UM-IM, BM-CM, BM-IM and CM-IM; implying that a change in the price of the former market in each pair would Granger causes the price formation in the latter market which in turn provide the feedback to the former market as well. The non-causal relationship was observed between UM-BM market pair, indicating strong exogeneity i.e. the price formation between the markets is determined by the external forces as each market is independent of each other in the formation of price. However, a case of unidirectional causality between market pairs was not observed. Therefore, since beef prices of CM and IM had two-way synergy with other markets while UM and BM had no synergy between them, it can be inferred that the prices of beef in CM and IM dominate in ruling the price of beef in the beef international market. In addition, the beef prices adjust in the international markets according to demand and supply situation in the world.

Table 8: Horizontal pair-wise Granger causality test results

Null hypothesis	F-stat	P< 0.10	Granger cause	Direction
$UM \leftrightarrow BM$	3.353^{NS}	0.134	No	None
	2.358^{NS}	0.213	No	
$UM \leftrightarrow CM$	9.834**	0.024	Yes	Bidirectional
	14.958**	0.011	Yes	
$UM \leftrightarrow IM$	8.521**	0.031	Yes	Bidirectional
	62.246***	0.001	Yes	
$BM \leftrightarrow CM$	8.257**	0.033	Yes	Bidirectional
	21.596***	0.006	Yes	
$BM \leftrightarrow IM$	9.082**	0.028	Yes	Bidirectional
	33.301***	0.003	Yes	
$CM \leftrightarrow IM$	8.664**	0.029	Yes	Bidirectional
	25.738***	0.004	Yes	
$\boldsymbol{UM \rightarrow ALL}$	**15.593*** **	**0.009**	**Yes**	**Multidirectional**
$\boldsymbol{BM \rightarrow ALL}$	**17.167*** **	**0.007**	**Yes**	**Multidirectional**
$\boldsymbol{CM \rightarrow ALL}$	**29.788*** **	**0.003**	**Yes**	**Multidirectional**
$\boldsymbol{IM \rightarrow ALL}$	**51.206*** **	**0.001**	**Yes**	**Multidirectional**

Note: *** ** * denotes rejection of the H_0at 1%, 5% and 10% level of significance respectively
NS: Non-significant
$\rightarrow \leftarrow$ *means forward and backward directions respectively*

Effect of Innovation (Bad or Good-news) on Beef Prices

The estimation of impulse response function is inconsistent at the long horizon when estimated from the unrestricted VAR if there is unit root or co-integration. Therefore, the stable impulse response function was derived from the restricted VAR model. The results showed how and to what extent a shock local to one of the international beef markets affects the current as well as the future prices in all the integrated markets over a period of ten years (Figure 1). Only UM and BM markets would yield a positive response (increase) to their own local shock (unexpected). A cursory review of the results showed that UM prices would respond positively (increase) to any local shocks in the prices of beef that originate from BM, CM and IM; implying that the effect of shocks from the three latter market on UM prices will not die-off as their effects are permanent. The response of beef prices in BM due to orthogonalized shocks from other markets would not be prominent as evidenced by the oscillating trend of the price throughout the stipulated period. The price of the beef in CM would respond positively (increase) but very weak to any local shocks that originate from IM and negatively (decrease) to the local shocks that come from UM and BM. This means that the effect of shocks from UM and BM on CM would be transitory as they will die-off after a short time. Furthermore, it was observed that the IM beef prices would respond negatively (decrease) to any innovation be it good-news or bad-news that are local to each of the other selected markets. This implies that the effect of the local shocks from all the other markets on IM would be transitory as they will die-off after some period of time. Therefore, it can be inferred that IM will rule the price of beef in the international beef market as it dominates the price determination while UM and BM will be relatively market followers and will not play a significant role among the selected major beef exporters in the international beef market.

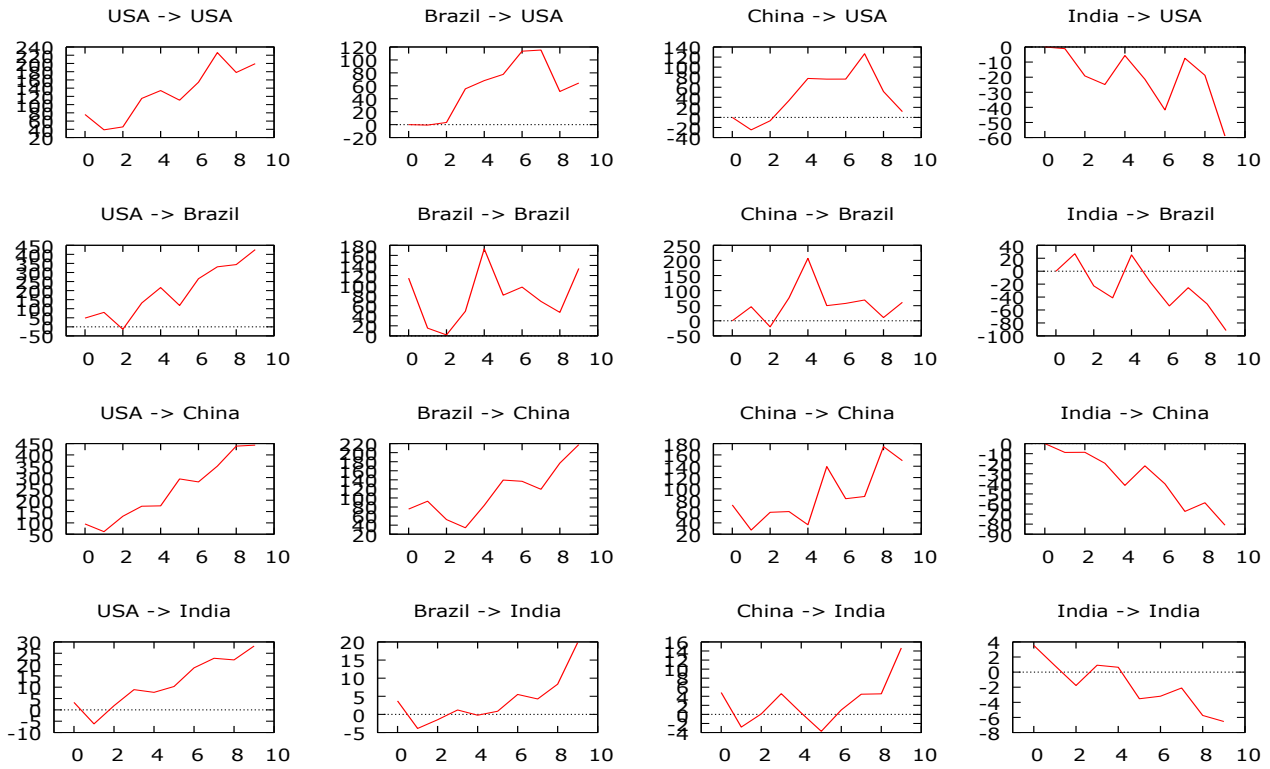


Figure 1: Impulse response of the selected markets to innovation

Price Volatility

All the price series satisfied the pre-condition for volatility test as their respective residuals exhibited cluster volatility and indicate the presence of Arch effects (Table 9). A cursory review of the results showed that all the international beef market exhibited persistence volatility in the beef prices as the estimated sum of the ARCH and GARCH terms were close to "one". This implies that the volatility in the beef prices has the tendency to persist for a while but will not meander away from the mean value. For the entire markets, volatility in their respective current year prices was influenced by the information of the preceding year beef prices volatility as indicated by the significance of their respective ARCH terms. Therefore, it can be inferred that international beef trading is useful as none of the market prices exhibited an explosive volatility pattern. The reason for persistence volatility in the international cattle beef prices could be due to trade rules of "Agriculture Agreement" framed by world trade organization (WTO).The autocorrelation test showed that the residuals of the model were not serial correlated as indicated by their respective Q-stats which were not different from zero at 10% probability level. With the exception of IM, the residuals of all the remaining market prices were found not to be normally distributed as evidenced by their respective Chi^2 values which were different from zero at 10% degree of freedom. However, this is not a problem as Sadiq *et al.* (2017) reported that in most cases data are not normally distributed. Therefore, the GARCH (1,1) model is the best fit for the specified volatility equations.

Table 9: Price volatility of cattle beef in the international markets

Items	**UM**	**BM**	**CM**	**IM**
		Pre-condition Arch effect test		
Arch effect	12.15{4.9E-04}***	7.96{0.005}***	16.95{3.8E-05}***	7.18{0.007}***
		Price volatility		
Constant	-	-	-	-
Alpha (1)	0.981(0.225)[4.4]***	0.99(0.427)[2.3]**	0.939(0.48)[1.95]*	0.99(0.15)[6.53]***
Beta (1)	5.8E-12(0.34)[0.00]^{NS}	1.01E-12(0.38)[0.00]^{NS}	1.0E-12(0.64)[0.00]*	2.1E-11(0.11)[0.00]***
α + β	**0.98**	**0.99**	**0.94**	**0.99**
GARCH fit		1,1		
Normality test	**11.59{0.003}*** **	**30.5{2.3E-7}*** **	**15.5{0.0004}*** **	**3.22{0.199}^{NS}**
Autocor.	**0.021{0.10}^{NS}**	**0.033{0.10}^{NS}**	**0.09{0.13}^{NS}**	**0.091{0.13}^{NS}**

Note: *** ** * implies significance at 1%, 5% and 10% respectively
NS: Non-significant; and values in ( ); [ ] and {} are standard errors, t-statistics and probability values

International Price Forecast of Beef for the Major World Beef Exporters

Diagnostic checking and validation

The VECM was found to be appropriate in forecasting the price series of the selected markets as indicated by the multivariate horizontal VECM diagnostic test results which exonerated the residuals from the problem of serial correlation and arch effect as shown by the Ljung-Box Q-stats and Langrage multiplier tests respectively which were not different from zero at 10% probability level (Table 6).Therefore, the absence of random error means that the international market prices of beef are predictable, which is good for policy making, consumer decision and consumption pattern.

Validation (ex-post prediction power)

Though price movement predictability is in contrast to the efficient marketing theory as the theory posit that for a market to operate efficiently, prices should be unpredictable in that if they are stationary and predictable they will attract investors and their active participation will ultimately result to the cancellation of the prediction. However, this deductive (theory) idea has little empirical extent as inductive (facts) knowledge showed that prediction of prices is very important in measuring market efficiency except that the prediction should not be too long.

One-step-ahead forecast of the prices along with their corresponding standard errors using naïve approach for the period 2012 to 2016 (total 5 data points) in respect of the VECM fitted model was computed to determine the predictive power of the estimated equation (Table 10a). This was done to examine how closely they could track the path of the actual observation.

Table 10a: One step ahead forecast of prices

Period	UM		BM		CM		IM	
	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast
2012	2668	2699.57	3136.50	3155.90	3275.80	3314.40	287.00	287.40
2013	2756	2732.47	2939.90	2897.30	3464.00	3427.30	296.70	296.10
2014	3351	3355.04	3302.60	3303.60	3081.90	3081.60	303.00	303.90
2015	3241	3172.88	2775.90	2781.90	3961.10	3909.30	299.70	297.50
2016	2624	2698.95	2783.40	2808.20	3981.00	4069.00	350.00	353.50

The price forecasting ability of the producers market prices of beef was measured using the mean absolute prediction error (MAPE), root mean square error (RMSE), Theil's inequality coefficient (U) and the relative mean absolute prediction error (RMAPE) (Table 10b). The results indicated the accuracy of the forecasted price as shown by their respective market RMAPE and U which were less than 10% and less than 1 respectively. Therefore, these relatively low values indicated the consistency of the forecasted prices with the actual prices.

Table 10b: Validation of models

Market	R^2	MAPE	RMSPE	RMAPE (%)	Theil's U
UM	0.99	3.78	0.83	0.24	0.013
BM	0.99	1.72	0.19	0.06	0.006
CM	0.99	7.56	0.69	0.20	0.011
IM	0.99	0.4	0.01	0.10	0.007

Source: Authors computation, 2018

Forecasting

Computed is the one step ahead out of sample forecast of the producer's beef prices (dollars per ton) for the major cattle beef markets from 2017 to 2026. The short span prediction was made in order not to affect market efficiency as long prediction will attract investors which will lead to the breakdown of the forecasted price (Table 10c and Figure 2a-d).

A perusal of the Table showed that the market price of beef in UM will witness an oscillating swing in the earlier years with the price ebb being in the year 2019 after which the price will sharply rise till it reaches the peak in the year 2025 and then declines sharply in the succeeding year. The forecasted prices in BM will exhibit an increasing trend and reaches its peak in the year 2021 and thereafter decline sharply till it reaches ebb in the year 2025 and then a recovery process in the year 2026. For the CM, the predicted prices of cattle beef will be marked by an increasing trend till the expiration of the prediction period. Furthermore, the forecasted beef price of IM will exhibit a complete trade cycle with the ebb point being the year 2023. Therefore, with the exception of CM it can be inferred that all the selected markets will witness boom era which will prompt additional investment in the beef sector by these countries due to high profit and an ebb period (depression) when the beef prices will register an all time-fall which will heavily affect the beef sector. As such, there is the need for a mechanism by WTO to monitor the pricing efficiency of the beef commodity in the international markets in order not to jeopardize food security of animal protein in the world.

CONCLUSION AND RECOMMENDATION

The international beef prices were efficiently integrated as evidenced by the presence of LOP in the international markets which indicate effective compliance of the major exportable beef countries with the agriculture agreement trading rules of the WTO. However, with the exception of IM, the spatial equilibrium (market clearance) in which demand and supply in distinct markets jointly determine prices and trade flows was found weak in all the remaining markets. In order words, almost all the markets were weak in responding to price news as they were unable to incorporate shock or price news available on the market. Furthermore, evidence showed the usefulness of beef tradability at the international market as price volatility will not meander away from the mean but will only persist for a while. Therefore, the study suggested that the network of the international beef market should be well-designed so as to ensure market clearance or spatial equilibrium in the market, thus, enhancing marketing efficiency of beef in the international sphere.

Table 10c: Out of sample forecast of beef prices in selected markets ($ per ton)

Year	UM			BM		
	Forecast	**LCL**	**UCL**	**Forecast**	**LCL**	**UCL**
2017	3206.10	3057.09	3355.11	3459.30	3215.30	3703.30
2018	3271.54	3097.41	3445.67	4223.80	3914.00	4533.60
2019	2898.92	2698.86	3098.99	4968.00	4651.40	5284.70
2020	3620.63	3289.96	3951.31	5679.80	5227.40	6132.20
2021	4242.13	3773.62	4710.65	7112.80	6296.30	7929.30
2022	4417.96	3857.80	4978.12	7038.50	6169.00	7908.00
2023	4506.70	3811.15	5202.25	6328.10	5285.60	7370.50
2024	4666.10	3775.33	5556.88	6328.30	5084.40	7572.30
2025	4726.25	3758.29	5694.21	6428.60	5007.60	7849.60
2026	4307.18	3249.07	5365.29	6846.90	5163.80	8529.90
Year	**CM**			**IM**		
	Forecast	**LCL**	**UCL**	**Forecast**	**LCL**	**UCL**
2017	4635.10	4358.50	4911.80	472.90	457.60	488.1
2018	5209.70	4853.00	5566.50	490.10	468.40	511.80
2019	5025.30	4561.00	5489.50	492.50	470.10	515.00
2020	5992.60	5400.20	6585.00	540.90	510.90	570.90
2021	6216.70	5504.30	6929.20	535.10	501.50	568.80
2022	6339.20	5343.90	7334.60	481.80	441.20	522.40
2023	7068.10	5885.70	8250.60	456.80	400.90	512.70
2024	7013.20	5609.30	8417.00	508.90	436.20	581.60
2025	7617.50	5896.70	9338.20	581.10	493.80	668.50
2026	8272.70	6270.50	10275.00	618.40	503.60	733.20

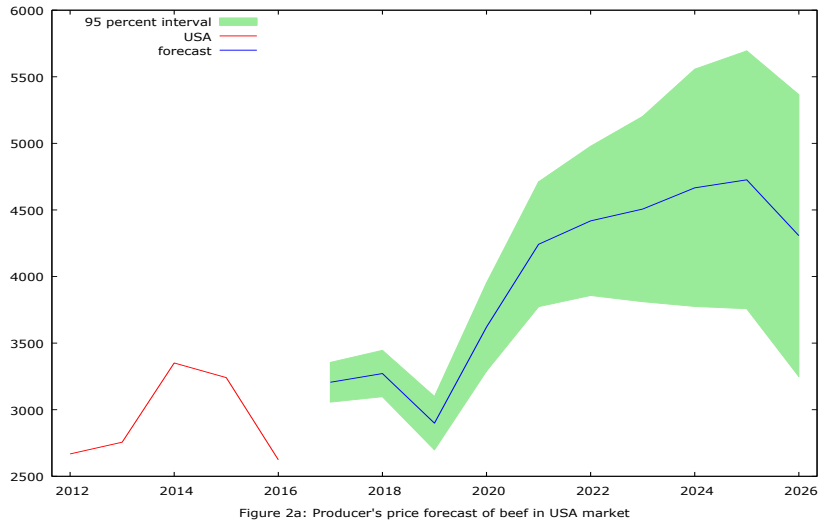


Figure 2a: Price forecast of beef prices in USA market

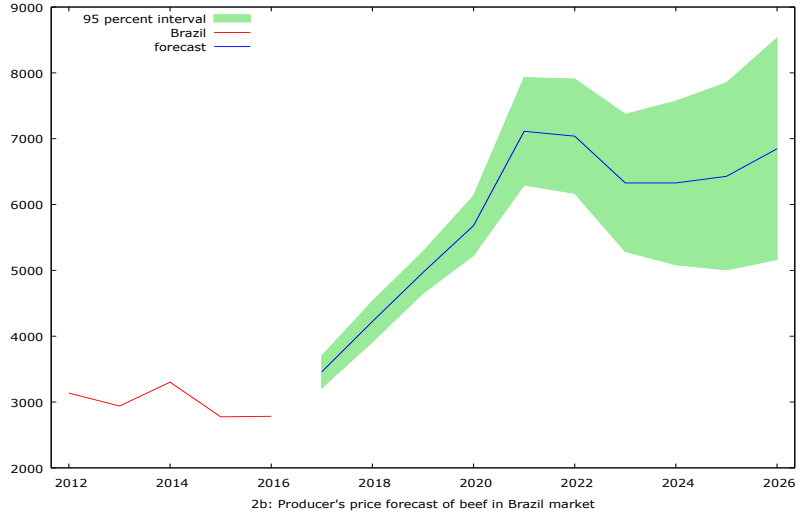


Figure 2b: Price forecast of beef prices in Brazil market

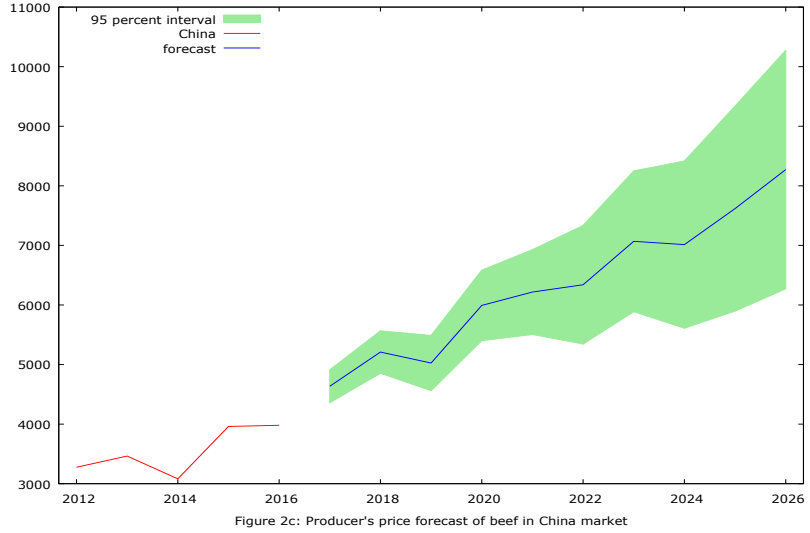


Figure 2a: Price forecast of beef prices in China market

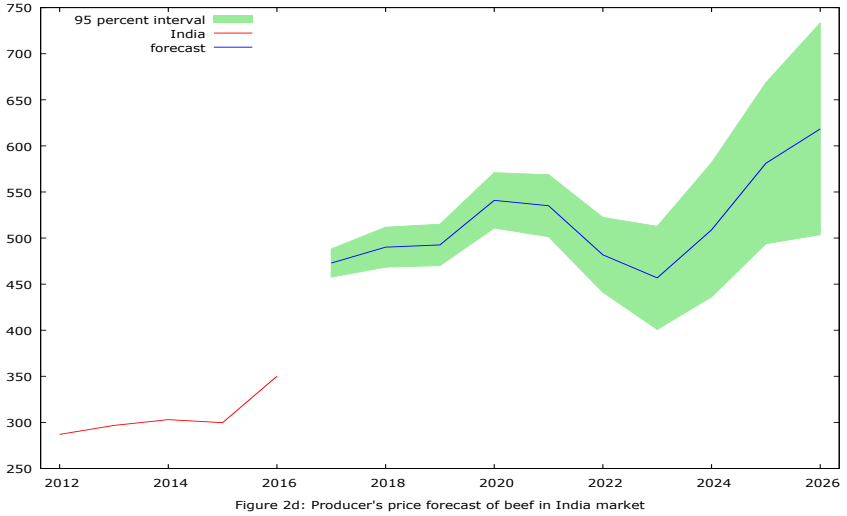


Figure 2b: Price forecast of beef prices in India market

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