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Cost-Benefit Analysis and Technical Efficiency of Crayfishermen in the Lower Cross River Basin, Nigeria.

Effiong, Mfonobong Okokon[1]; Akwo, Theresa Cyril [2] and Samuel, Jimmy Preye[3]
[1,2]Department of Agricultural Economics,University of Calabar, Calabar
[3]Department of Agricultural Economics, Extension and Rural Development,Niger Delta University, Bayelsa State, Nigeria
Correspondence: theresacakwo@gmail.com

Abstract

The study analyzed the cost -benefit and technical efficiency of Crayfishermen in the area. Specifically, it determined the factors affecting crayfish catch generally and in the two seasons of the year, estimated the technical efficiency of the fishermen as well as identified the determinants of the technical efficiency generally and in both seasons. Also, cost benefit of Crayfishermen in the area was determined. Data were analyzed using stochastic frontier and budgeting technique. Accessible fishing villages were purposively sampled with data collected through the use of questionnaire. The wet weight of crayfish caught by the fishermen was obtained by measurement. Results showed that labor, credit, mesh size and motorization were all significant variables at 5% level for aggregate data. However, credit was not significant in the dry season while mesh size was not significant in the wet season. The signs of the coefficients of credit and motorization were not in conformity with a priori expectation. Result of technical efficiency shows that crayfish producers were technically inefficient. The mean technical efficiency was 79% for aggregate data but 49.7% and 62.8% for dry and rainy seasons respectively. The determinants of technical efficiency were age, fishing experience and educational levels. Finally, the results of the budgetary analysis show that the total cost (TC) of ₦3,716,000 was incurred and total revenue (TR) of ₦5,750,000 was realized in Cross River while in Akpa Yafe, the total cost (TC) of ₦3,690,000 with a total revenue (TR) of ₦5,450,000. Recommendations were made on special credit arrangement for respondents especially in the rainy season. Mesh size should be monitored and enforced especially in the dry season.

Keywords: Cost-benefit, Crayfishermen, Maximum likelihood estimates, Technical efficiency

Introduction

Aquaculture has been described as the fastest growing animal food-producing sector and to outpace population growth in the world. Nigeria's fisheries sub sector contributes about 3–4% to the country's annual gross domestic product and generates employment and income for a significant number of artisanal fishermen and small traders. (Food and Agricultural Organization,(FAO, 2012; FAO 2018). Crayfish is the highest contributor to aquaculture production among the crustacean species and this is particularly significant at a time when Nigeria's fish production is only 0.78 million metric tons, compensated by the importation of 750,000 MT of fish worth USD 600 billion all tailored towards meeting the projected demand of at least 2.66 million MT per annum in an attempt to maintain a per capita consumption level of at least 13.9 kg (Belton & Thilsted, 2014; Weya *et al.,* 2017; Tall, 2020; Gicheha *et al.*, 2024).

In Cross River Basin, it is the second largest in the marine/ estuarine fisheries with an estimated catch composition of 17.5%, with others in the order of Bonga (22.3%), catfish (8.7%), croakers (8.5%), threadfins (7.0%), etc. About 40% of the inhabitants of the Cross River estuaries are involved in fishing (Crayfish, Bonga etc.). Crayfish/fish are important in human food, livestock feed, income generation, foreign exchange generation and health and has provided business and economic activities for the fishermen, crayfish dealers as well as consumers of crayfish (Enang, 2014). Worse still, animal protein sources such as beef, chicken, snails and mutton are presently beyond the reach of the average Nigerian household, with increasing population and dwindling incomes suggestive of the fact that things may not get better any soon, many people now settle for seafood products like crayfish as cheap source of animal protein (Esheya, 2021). Crayfish production is mostly wild caught and not farmed in Africa, Crayfish are usually caught in baited wire mesh between March and October when they are at peak quality. Yields of crayfish from fishing (wild caught) can vary depending on the species, season, processing technique, and other factors (Ahamefule *et al.*, 2021; FAO 2018). The Cross River Basin is a highly productive basin. At the lower/southern end of the basin is the Atlantic Ocean which is a source of pelagic, bathypelagic and demersal species of fishes.

The water surface of the Cross River which is the main river in the Cross River basin is 3,900,000 hectares. The Atlantic Ocean, the rivers and streams in the area have abundant potentials for fish production in Cross River and Akwa Ibom States. The crayfish fishery is worth more than ₦1 billion annually to the Cross River State Government and people with markets in the beaches in Calabar, Ikang, etc. This crustacean can be sourced in abundance from Akwa Ibom and Cross River States, respectively, and enjoys wide patronage locally from operators of restaurants, bukateria, and hotel. Crayfish is exported to other states of the federation – North, East and Western States and used as seasoning in most food prepared in Nigeria. The fresh crayfish is used for preparing stews and soups. Some food companies also use crayfish in noodles and pastas as flavors. In the lower Cross River basin, crayfish are neglected compared to other aquatic animals because it is believed to yield low profit in terms of sales and it is usually called a poor man's business (Flake, 2007).

There is the general problem of demand-supply gap, high prices of fish products, high import bills and dearth of production data for fish and its production. The study therefore sets out to: analyze the factors affecting crayfish production in the study area. analyze the determinants of technical efficiency of the Crayfishermen; analyze the estimates of technical efficiency of the Crayfishermen on seasonal basis; and determine the benefit-cost ratio of Crayfishermen in the area.

Theoritical Issues: The issues relevant to this study are those of technical efficiency and production function. Technical efficiency is one component of economic efficiency. Farell's Contribution led to a well-developed methodological and empirical literature on the measurement of efficiency. For the estimation techniques, information is derived from extreme observations from the body of the data to determine the best practice production frontier. Stochastic estimation involves estimation of a stochastic production frontier where the inputs of the firm (the crayfishermen) is a function of a set of inputs, inefficiency and random error (Aigner and Chu,1968; Aigner, Lovell and Schmidt1977;Meeusen and Van,1977;Pift and Lee,1981;Battese and Coelli,1988; Lewin and Lovell ,1990; Greene,1993)

Profit maximization requires a firm to produce the maximum output given the level of input employed (that is, to be technically efficient), use the right mix of inputs in the light of the relative price of each input (allocative efficiency) and produce the right mix of output The production function is the technical relationship between input and outputs. The function is assumed to be continuous and differentiable. Production function is one of the approaches to the study of production theory. The other is the isoquant-isocost approach (Kumbhakar and Lovell,2000;Olayide and Heady,1982;Bishop and Toussaint,1985;Upton, 1996;Penson, Capps and Rosson,1996).

Methodology: Study Area

The study area is the lower Cross River Basin. The whole Cross River Basin is divided into three segments for fishery studies. The lower segment is from the Itu-Calabar Bridge Head to the Atlantic Ocean and it is the marine/estuarine section. The Cross River and the Akpa Yafe River along Ikang Bakassi axis fall into the lower Cross River Basin. The area is in two states, Cross River and Akwa Ibom states. The Cross River Basin has two distinct seasons, the rainy and dry seasons, which comes up April to September and October to March respectively. The lower Cross River Basin may have some rainfall during the dry season since it is surrounded by rivers and the Atlantic Ocean. Relative humidity in the area is about 80 to 90% throughout the year. Crayfish are landed in beaches and village settlements scattered in the lower Cross River Basin.

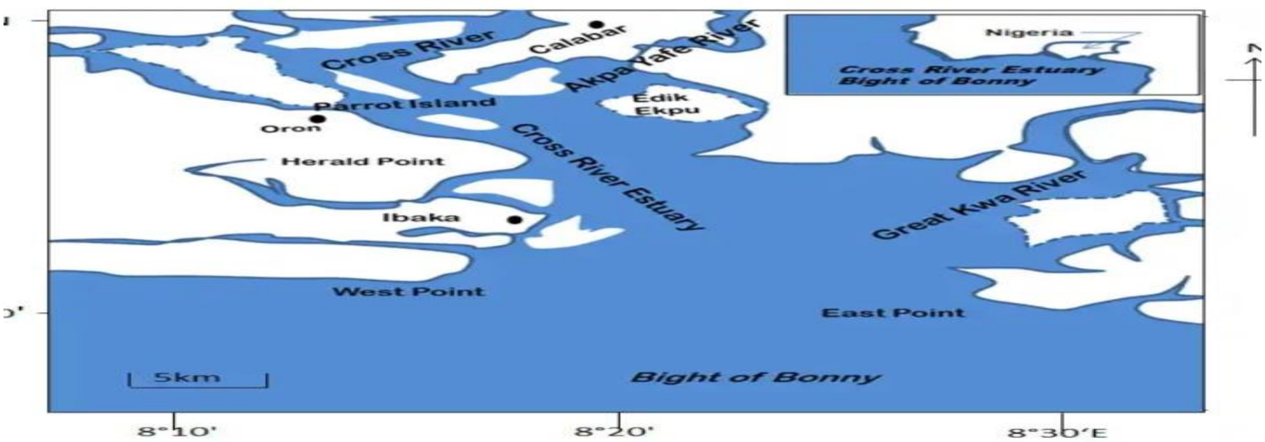

Figure 1: Map of Cross River showing lower Cross River Basin.: **Source:** Udoh *et al.,* 2017

Sampling Procedure: The study was carried out in the lower Cross River Basin in the marine/estuarine section. Purposive sampling was used to select two (2) Local Government Areas of Oron and Mbo in Akwa Ibom states where commercial fishing of crayfish is done. Purposive sampling was also adopted to sample six (6) fishing settlements/villages that were used for the study. These are Ibaka, Esukenwang, Utaniyata, illue, lneokong and Parrot Island. Random sampling was finally used to select crayfish fishermen/women from a sampling frame provided by community leaders. Twelve (12) crayfishermen were selected from the six (6) villages/settlements giving a total of seventy-two (72) respondents. However, only sixty-four (64) respondents had complete information and were used for final analysis.

Model Specification

A double log (Cobb Douglas) specification was adopted for N firms

$LnY_i = \beta_0 + \Sigma\ \beta LnX_{ki} + V_i - U_i$ … (1)

Where,

Y_i = Crayfish output of the i^{th} firm

X_{ki}= Imports or factors determining the production frontier (labor, credit use, rental price, mash size, motorization).

V_i = Random variable reflecting noise and other stochastic shocks.

U_i = Non-negative random variable which measures technical inefficiency.

The random variable $V_i$is specified as independent normally distributed with zero mean, constant variance σ^2_y and independent of the X_{ki}

$V_i \approx$iid N (O, σ^2_v) i= 1,…, N

The non-negative random variable $U_i$is assumed to be distributed independently of V_i and X_{ki}..The model can be estimated by maximum likelihood once the density function for U_i is specified. The log likelihood function is

$$Ln\ Y\ = \frac{N}{2} Ln\ \frac{2}{\pi} - NLn\sigma - \sum_{t=1}^{N} Ln\ 1\ - \frac{F}{\sigma}\left[\left(-\frac{\varepsilon_{i\infty}}{2}\right)\right] - \sum_{i=1}^{N} -1\ \sigma^2\ ^{\Sigma \varepsilon_i^2} \quad (2)$$

Estimation of the U_i provides a measure of the technical efficiency of the firms in the sample.

$$\mathbf{U_{it} = iid\ N\ (U_{it}, \sigma^2_u)}$$

The cost-benefit analysis was determined using simple budgetary techniques such as benefit-cost ratio.

BCR = TR/TC (3)

Where, BCR = Benefit Cost Ratio

TR = Total Revenue

TC = Total Cost

Total Cost (TC) = total fixed cost (TFC) + total variable cost (TVC)

Total variable cost (TVC) consists of all the operating cost incurred by the farmer throughout the period of farming from stocking to harvest.

Total Fixed Cost (TFC) considered was the cost of maintaining the rivers during the period.

Total revenue (TR) consists of receipts from total sales. It is equal to quantity of fish (Kg) X price. simply the quantity harvested multiplied by the price of fish per kg.

Data Collection: Wet weight of crayfish harvested were weighed from seventy-two (72) fishermen and women on each fishing trip for a period of one year. A structured questionnaire was also used to collect production data from the respondents.

Data Analyses: Regression analysis and budgetary technigue were used to achieve the objectives of the study. Maximum likelihood production and inefficiency frontier function were estimated using the stochastic frontier production package by Coelli,(1995) while budgetary analysis was used to determine the cost-benefit of Crayfishermen in the area.

Results and Discussions: Seasonal Production: Crayfish catch is affected by seasons because when the volume of water increases, the salinity of the water changes, and there is migration of species especially marine species. Therefore, the need to investigate resource use in the seasonal catch of crayfish. The two seasons in the Cross River Basin are Rainy (April to September) and dry seasons (October to March). Stochastic production frontier models were estimated from data collected in the two seasons. Aggregate data collected were separated into seasons and the models estimated.

The maximum likelihood estimates of the parameters of the Cobb Douglas stochastic frontier model for the effect of season on crayfish is shown in table 1. All the variables except credit were significant in the dry season. A similar result was obtained for the rainy season except that it was the mesh size that was not significant. In the dry season rental price, mesh size and motorization were significant at 1% while labor was significant at 5%. In the rainy season rental price was significant at 1%, labor at 5% and credit and motorization were significant at 10%. Credit had a negative sign in both seasons which shows either misuse of credit or late arrival of credit (Upton, 1996). Crayfish fishermen needed a lot of capital to purchase outboard engine and employ labor for efficient fishing. An outboard engine of 75 horsepower cost about ₦500,000. Mesh size was negative in both seasons this implies reducing mesh size to increase crayfish catch. Labor had a negative sign in the rainy season showing the need to reduce labor during this season and probably use outboard engines for increased production. The motorization variable also showed a negative sign in both seasons implying the need to reduce capacity of outboard engines presently used for fishing. Gamma is significant at the 1% level. Gamma was 0.99 and 18.74 in the dry and rainy seasons respectively. This implies that 99% and 18.7% of the variation in crayfish catch is caused by technical inefficiency in the dry and rainy seasons respectively. The LR test statistic of 11.48 and 11.08 are significant and show that models fit the data.

Table 1 Maximum Likelihood Estimates of Stochastic production Frontier Function for Crayfish Production in the Dry and Rainy Seasons

VARIABLE	DRY SEASON			RAINY SEASON		
	Coefficient	SE	t	Coefficient	SE	t
Intercept	10.3607	1.2613	8.2144***	11.5094	2.3752	4.8437***
Labor(X1)	0.1565	0.0757	2.0650***	-0.1579	0.0602	2.6248***
Rental Price (X2)	0.7898	0.0569	13.879***	0.1289	0.0318	4.0513***
Credit (X3)	-0.0043	0.0049	0.8727	-0.0050	0.0030	1.6824*
Mesh (X5)	-0.2910	0.1637	1.7781***	-0.1026	0.1046	0.9817
Motorization (X6)	-0.0513	0.0041	12.673***	-0.0336	0.0196	1.7142*
Diagnostic Statistics						
Sigma-squared	0.0423	0.0073	5.8270**	0.0156	0.0027	5.7059***
Gamma	0.9999	0.3228	3.0944**	18.7499	2.3411	8.0063***
Log likelihood Function	10.37			42.4013		
LR Test	11.48			11.0846		

KEY: (1) ***Significant at 1%, ***Significant at 5%, *Significant at 10% (2) Diagnostic Statistics are the same as those in table 2

Source: Computed from the Field Survey Data, 2024.

Table 2 shows the maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic frontier for crayfish production in the lower Cross River Basin for aggregate data. The variables labor, rental prices, credit, mesh size and motorization were all significant at 1% level. Labor, mesh size and motorization had negative signs. The outboard engine horsepower which is taken as the motorization variable is very crucial in crayfish production in the study area. The negative sign indicates that there must be a reduction in the horse power currently in use. The negative sign of the mesh size of nets is an expected result. It implies that as you reduce the mesh size, more crayfish including juveniles will be caught. Labor though significant had a negative sign showing that labor is probably over used in crayfish production. Credit had the expected sign indicating that an increase in credit would increase crayfish catch. Gamma is 0.13 and is significant at 1%. The gamma indicates that 13% of the variations in crayfish catch are explained by technical inefficiency. The Likelihood ratio test was 11.31 and it indicates that the model fits the data the critical value of

11.07 is lower than the estimated 11.31 and the hypothesis of no inefficiency is rejected.

Table 2 Crayfish Maximum Likelihood Estimates of Stochastic Production Function for Aggregate Data

VARIABLE	AGGREGATE DATA		
	t	Coefficient	SE
Intercept	11.2495	0.6909	16.282***
Labor (X_1)	-0.4399	0.0954	4.6094***
Rental Price(X_2)	0.1182	0.0371	3.1872***
Credit (X_3)	0.0573	0.0038	15.109***
Mesh (X_5)	-0.1550	0.0141	11.012***
Motorization (X_6)	0.0449	0.0222	2.0216***
Diagnostic Statistics			
Sigma-squared	0.2393	0.0426	5.5330***
Gamma	0.1305	0.0117	11.134***
Log likelihood Function		29.2213	
LR Test	11.3314		

KEY*: (1) ***Significant at 1%, ***Significant at 5%, *Significant at 10%   (2) Diagnostic Statistics are the same as those in table 2*

Source: Computed from the Field Survey Data, 2024.

Technical Efficiency Analysis: Technical Efficiency Analysis Due to Seasons: The estimated measures of technical efficiency of crayfish fishermen are presented below. Deviations from the stochastic production frontier line of the production process indicate technical inefficiency. The technical efficiencies of the firms are presented for the two seasons in table 3.

Table 3 Frequency Distribution of Technical Efficiency Among Crayfishermen in the Marine/Estuary of the Cross River Basin Nigeria.

RANGE OF TECHNICAL EFFICIENCY	DRY SEASON		RAINY SEASON	
	No of fishermen	%	No of fishermen	%
< 0.40	16	25	0	0
0.41-0.50	24	37.5	0	0
0.51-0.60	12	18.8	20	31.3
0.61-0.70	7	10.9	40	62.5
0.71-0.80	3	4.6	4	6.2
0.81-0.90	2	3.2	0	0
0.91-1.00	0	0	0	0
TOTAL	64	100	64	100
Mean	0.4974		0.6277	
Std Deviation	0.1201		0.0477	
Minimum	0.3169		0.5423	
Maximum	0.8623		0.7637	

KEY: Diagnostic Statistics are the same as those in table 2 :**Source: Computed from the Field Survey Data, 2024.**

Table 3 shows that technical efficiency is higher in the rainy season than in the dry season. Mean technical efficiency is 62.8% and 49.7% respectively for the rainy and dry seasons. The pattern of efficiency also differs. No firm had technical efficiency of above 80% in the rainy season but 3.29% (2 firms) had in the dry season. All 100% firms in the rainy season had technical efficiency of between 50-80% while only 34% (22 firms) had this in the dry season. The firms could be encouraged more in the dry season (especially with extension services and credit).

Analysis of Overall Technical Efficiency: This is presented in table 4. Mean technical efficiency is 79%. Only 19 (29.7%) of firms had above mean technical efficiency. The other 45 (70.3%) were below mean technical efficiency. The least technical efficient firms had 0.41-0.50 range of efficiency indicator. These firms need about 50% improvement in the use of current technology. Technical efficiency ranges from 44% to 92%. [17] Measured the average technical efficiency of a Malaysian trawl fishery at 49% which is considered very low.

Table 4: Frequency Distribution of Overall Technical Efficiency of Crayfishermen in the Lower Cross River Basin

RANGE OF TECHNICAL EFFICIENCY	AGGREGATE	
	No of fishermen	%
< 0.40	0	0
0.41-0.50	5	7.8
0.51-0.60	8	12.5
0.61-0.70	9	14.1
0.71-0.80	23	35.9
0.81-0.90	18	28.1
0.91-1.00	1	1.6
TOTAL	64	100
Mean		0.7939
Std Deviation		0.1289
Minimum		0.4438
Maximum		0.9170

KEY: Diagnostic Statistics are the same as those in table 2 ; Source: Computed from the Field Survey Data, 2024.

Determinants of Technical Efficiency: Determinants of Technical Efficiency in Crayfish Production Due To Seasons in the Lower Cross River Basin. The Maximum Likelihood Estimates of the parameter of the determinants of technical efficiency for crayfish production in the two sessions are presented in Table 5. Contact with extension and fishing experience were the only determinants that were consistently significant in both seasons and they had the apriori expected. Age and canoe length were significant only in the rainy season while educational level was significant only in the dry season. Fishing experience was significant at 1% n the dry season but 10% in the rainy season. Contact with extension was significant at 1% in both seasons. Increase in extension services in two seasons would increase technical efficiency and crayfish catch.

Table 5: Maximum Likelihood Estimates of Determinants of Technical Efficiency Due to Seasons of Crayfishermen in Lower Cross River Basin

VARIABLE	DRY SEASON	RAINY SEASON

	t	Coefficient	SE	t	Coefficient	SE	t
Intercept	0.1347	1.4822	0.0909	-18.4949	0.2386	77.502***	
Age	0.2069	0.2000	1.0346	0.1912	0.0122	15.640***	
Fishing Experience	-0.2010	0.0129	15.58***	-0.1587	0.0799	1.9850*	
Educational	0.1108	0.0493	2.2467**	0.0135	0.0268	0.5052 Level	
Contact with EAS	-0.1590	0.0577	2.7535***	-0.1027	0.0343	2.9911***	
Length of canoe	0.1768	0.2760	0.6408	0.1914	0.0145	13.1509***	

KEY: (1) ***Significant at 1%, **Significant at 5%, *Significant at 10%; (2) Diagnostic Statistics are the same as those in table 2 : Source: Computed from the Field Survey Data, 2024.

Determinants of Aggregate Technical Efficiency among Crayfish Fishermen in the Lower Cross River Basin: The maximum likelihood estimates parameters of the determinants of technical efficiency are presented in Table 6. Educational level was the only variable that was not significant. Age, fishing experience and contact with extension were significant at 1% while canoe length was significant at 10%. As expected, fishing experience and contact with extension had negative signs. The implication is that fishing experience and contact with extension would increase technical efficiency.

Table 6 Maximum Likelihood of Determinants of Technical Efficiency for Aggregate Data of Crayfishermen in Lower Cross River Basin

VARIABLE	AGGREGATE		
	Coefficient	SE	t
Intercept	-0.3111	0.0547	5.686***
Age	0.1191	0.0149	7.9825***
Fishing Experience	-0.1442	0.0096	15.096***
Educational Level	0.0514	0.0354	1.4509
Contact with EAS	-0.1258	0.0441	2.8568***
Canoe of length	0.2129	0.1104	1.9285*

KEY: (1) ***Significant at 1%, ***Significant at 5%, *Significant at 10% (2) Diagnostic Statistics are the same as those in table 2 :Source: Computed from the Field Survey Data, 2024.

Table 7: Cost-benefit of Crayfishermen in the area

Variable Cost	Cross River	Akpa Yafe River
Fishing nets	150,000	175,000
Maintenance cost	256,000	250,000
Labor cost	250,000	245,000
Fishing craft and gear	450,000	455,000
Processing of the catch (Oven, Firewood, Ebanda)	590,000	550,000
Storage and packaging	320,000	300,000
Total Variable Cost	**2,016,000**	**1,975,000**
Fixed cost		
Indirect cost	500,000	520,000
Maintenance cost	450,000	425,000
Sale and distribution cost	750,000	770,000
Total Fixed cost	**1,700,000**	**1,715,000**
Total Cost= TVC+TFC	**3,716,000**	**3,690,000**

Revenue		
Receipt from sales= Quantity of fish harvested × Price per Kg	5,750,000	5,450,000
Total Revenue	**5,750,000**	**5,450,000**
BCR = $^{TR}/_{TC}$	**1.55**	**1.48**

Source: Computed from the Field Survey Data, 2024.

The results as presented in Table in Table 7, shows that Crayfishing in the area were both profitable. While the BCR of from Crayfishermen in Cross River was 1.55 that from Akpa Yafe River was 1.48, with an indication that Crayfishing from Cross River was more profitable.
This is consistent with Adeniyi *et al*. (2015) who obtained similar result in his work Economic Analysis of Costs and Return of Fish Farming in Saki-East Local Government Area of Oyo State, Nigeria, who found that earthen ponds yield higher profit than concrete tank production?

Conclusion: Special credit arrangement should be made for Crayfishermen due to the harsh terrain and accessibility. This is very important especially in the rainy season where credit is significant. Mesh size control should be enforced especially in dry season to avoid overfishing of juveniles.

. Crayfishermen should be educated on the horsepower of the motorized engines to be used for fish catch. The motorization variables had a negative coefficient showing that it needs to be reduced for increased production.
Government and financial institutions should encourage Crayfishermen by making loans readily available to them at zero or reduced interest rates. This policy will encourage them to expand their enterprises and capacity for enhanced productivity of the commodity.

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