How Climate Factors Influenced the Spatial Allocation of and Returns to Texas Cattle Breeds[1]

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Abstract

A multivariate binary choice model is used to examine the climate effects on cattle breed selection across Texas counties. Angus, Brangus, and Brahman are considered in the model. Results suggest that it is more efficient to estimate the binary choice equations jointly than separately. Counties having higher summer temperatures are more likely to choose Brahman and warmer winters increase the likelihood of adopting Brangus and Brahman. Angus price imposes positive effects on both Angus and Brangus. In general, the marginal probability of selecting Angus is much higher than that of Brangus or Brahman.

Key Words: multivariate probit model, binary choice, Angus, Brangus, Brahman

Introduction

Genetic traits in beef cattle are of great importance for the US beef production sector because they biologically determine the carcass quality and the range of mature weight of beef cattle – factors that are primarily judged and valued in market and thus critically shape the profitability potential for individuals and corporations in the beef cattle industry.

While essentially determined by genetic traits, the physical performance of beef cattle would be influenced by environmental factors like climate and forage conditions also. Constraints as such are quite apparent in the southwestern part of the US where the semiarid rangelands can hardly accommodate market-desired Europe-originated *Bos taurus* breeds economically. In fact, beef cattle producers always have to select an optimal combination of, if not a trade-off between, market-desired and feedlot-desired traits (Hawkes, et al., 2008). For example, the use of *Bos indicus* and crossbreed cattle for beef production has not been uncommon in the Southwest.

Comparing to *Bos taurus* breeds, *Bos indicus* and crossbreeds generally yield less favorable beef and they show greater adaptability in the Southwest environment. In an economic sense, *Bos indicus* and crossbreeds may not receive market premiums for preferred beef quality but their survival traits that enhance their output productivity in semi-arid and hot-climate environment compensate (Hawkes, et al., 2008). As pointed out in (Winder, et al., 1992), producers have to figure out whether "the increase in animal productivity stemming from the use of *Bos indicus* breeds outweigh the discounts seen from the resulting calves Southwest cow-calf producers sell".

Unlike hogs and poultry that get raised in confined facilities, calves and feeder cattle grow up in open space, which indicates direct exposure to changes in climatic situation. Animal science suggests that hotter weather creates difficulties for cows to calve and decreases feed intake desire in cattle. In addition, hotter weather and insufficient precipitation negatively influence forage conditions as well, making it more challenging for cattle to survive.

(IPCC, 2007) projects that climate change is inevitable in the coming decades — based on that a positive link between global climate change and increased GHG concentrations is suggested by cumulative evidence, and that the atmospheric GHG concentrations will likely continue to rise due to the inertia in the high-carbon style society (Rose and McCarl, 2008). Given above, beef cattle producers will have to make ongoing adjustments in breed selection so that cattle can get more adapted to increases in temperature and uneven changes in precipitation. Tougher choices may have to be made to seek a balance between market-desired *Bos taurus* breeds and survival oriented breeds such as Brangus – a typical crossbreed of Angus (*Bos taurus*) and Brahman (*Bos indicus*).

An understanding of how climate factors have played in livestock breeds selection will help beef cattle producers make better informed decisions for the future. This paper will examine breeders' responses to investigate the climate effects on cattle breed adoption. Texas is chosen for this study, given that its climatic and ecological conditions are quite diverse across the territory. More importantly, Texas serves as the primary center for the US beef cattle industry.

The rest of the paper is organized as follows. Climate change studies that focus on the livestock sector would be briefly visited. Then in the model development section, multivariate probit model is introduced and the relevant variables to be included will be discussed. Summary statistics of data will be given and estimation results will be presented and discussed. In the final part, this paper concludes and discusses about the future research.

Literature Review

Cross-sectional analysis has been widely carried out in climate change studies for the agricultural sector (Schimmelpfennig, et al., 1996). The underlying anticipation behind such spatial analogue method is that colder areas will follow and adopt practices in warmer areas when global warming happens. Cross-section data could be viewed as results of natural experiments and differences in observed diversity can serve as the source of identification for effects of interested factors.

(Seo, et al., 2009) did a cross-section study of climate sensitivity of livestock management in Africa. Based on the derived climate sensitivities stemming from a large-scale survey data and the imposed climate change scenarios, they find that small farms would turn to raising livestock from planting crops and switch from temperate animal species to heat-tolerant species.

(Seo, et al., 2010) applied similar spatial analogue method to the livestock adaptation study in South America. They depend on climatic variation as a source of identification and the data covers 1300 livestock farms in seven countries. Their results suggest that climate is a significant determinant in primary species adoption when farms share common backgrounds in soil, geography, household characteristics and when country fixed effects are controlled. Further, they point out that the climate impact varies among species – the probability of adopting beef and dairy cattle decreases while that of sheep increases.

For the US livestock sector, (Adams, et al., 1999a) employed a computable general equilibrium (CGE) approach to forecast the climate change impacts on the US crop and livestock sectors. They estimated that climate impacts on livestock could be mild – (Seo, et al., 2009) pointed out that this is probably because the initial average climate values in the US are lower than those in Africa, thus it could take long before the US reaches threshold temperature and the consequent effects follow.

The literatures above in general agree that climate factors exercise significant influence over the spatial pattern of African livestock sector. Some of them used multinomial choice models under the cross-section framework to forecast the likely adjustments in livestock species adoption.

In the US, the basket of adaptation options may not include changing livestock species, should the climate effects be mild. However, farmers may turn to breeds that are more heat-tolerant for “within species” adaptation. So far, few literatures have examined this issue quantitatively. This paper will explore how spatially differentiated climate differences have been reflected in cattle breed selection by analyzing the cross-section binary choices of Angus, Brangus, and Brahman.

Model Development

Multivariate Binary Choice Model

Following (Greene, 2008), we have a 3-equation multivariate probit model:

$$y_{i,j}^{*} = X_{i,j}'\beta_j + \varepsilon_{i,j}$$

$$y_{i,j} = \begin{cases} 1, & if\ y_{i,j}^{*} > 0 \\ 0, & otherwise \end{cases}$$

where i denotes the observation unit – county, and $j = 1, 2, 3$, indicating Angus, Brangus, and Brahman respectively. For error terms, they follow

$$\begin{pmatrix} \varepsilon_{i,1} \\ \varepsilon_{i,2} \\ \varepsilon_{i,3} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{21} & 1 & \rho_{23} \\ \rho_{31} & \rho_{32} & 1 \end{pmatrix}\right] = N[0, R]$$

where $\rho_{jk} = \rho_{kj}$.

We adopt the method in (Cappellari and Jenkins, 2003) to estimate the model. As stated in (Cappellari and Jenkins, 2003), the application of the GHK simulation method for maximum likelihood estimation of the multivariate probit regression is used. Following the mathematical derivations in (Cappellari and Jenkins, 2003) and (Greene, 2008), we let

$$Q_i = \begin{bmatrix} 2y_{i,1} - 1 & & \\ & 2y_{i,2} - 1 & \\ & & 2y_{i,3} - 1 \end{bmatrix}$$

$$b_i = (X'_{i,1}\beta_1,\ X'_{i,2}\beta_2,\ X'_{i,3}\beta_3)'$$

$$\mu_i = Q_i b_i$$

$$\textstyle\sum_i = Q_i R Q_i$$

The log likelihood would then be given by:

$$L = \sum_{i=1}^{n} ln\Phi_j(\mu_i; \textstyle\sum_i)$$

Econometric Specification

Following (Hammack, 2010), the decision of breed selection is based on production and market conditions. Production conditions include two major groups of factors: climate and forage. Market conditions refer to the economic returns and costs.

(Meyer, 2010) discussed how market rewards high quality beef and discounts less-preferred beef. In general, European breeds produce more beef graded Prime than breeds with exotic influence (*Bos indicus*). To overcome the revenue gap caused by price differentials, beef producers who raise *Bos indicus* and/or crossbreeds need to have gain in output productivity outperforming that revenue gap. In fact, cattle breeds with exotic influence, in particular the pure ones, do receive bidding discounts when traded in market (Hawkes, et al., 2008).

For cattle breeders, the demand for cattle breeds come primarily from cow-calf operators, who identify an optimal combination of market-desired and production-suitable traits for their breeding systems. This implies that for the Southwest region with hot and dry climates, a trade-off between European breeds and *Bos indicus* influenced breeds may occur.

Explanatory variables in this study thus include extreme temperature variables that impose critical climate effects, precipitation and grazing capacity and type that influence forage conditions, market prices for different breeds, and county characteristics such as cattle inventory and income level. Note that for breeders, the market prices of breeds indicate returns and climate and forage conditions constitute implicit costs.

Table 1 provides a summary of *ad hoc* variables that are to be used in model specification. Broadly speaking, we expect that higher temperature in summer suppresses the likelihood of raising Angus but increases the probability of adopting Brangus and Brahman. The interaction effects of summer temperature and precipitation are expected to be negative for Angus but positive for Brangus and Brahman. Warmer winter may encourage the adoption of Brangus and Brahman. Also, for forage conditions, greater amount of non-native pastureland may imply a greater presence of Angus because Angus requires higher quality forage conditions.

Data

Table 2 displays the numbers of counties for each kind of breed selection combination. The membership data of Texas Angus Association[4], Texas Brangus Breeders Association[5], and Texas

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[4] See http://texasangus.com/

[5] See http://www.txbrangus.org/

Brahman Association[6] are used to generate the binary choice data for each county. We define that a county adopts a particular breed if there is at least one breeder of that particular breed locating in that county. 1 indicates adoption while 0 indicates otherwise.

Table 3 provides summary statistics for variables to be included in model specification. The climate data are obtained by processing data provided by the PRISM Climate Group, Oregon State University[7]. The ArcGIS data files that contain information of monthly averages of maximum temperature, minimum temperature and precipitation over the period of 1980-2009 for the entire contiguous US are used. Following the logic in (Mendelsohn, et al., 1994) and (Schlenker, et al., 2006), the long-term climate data – instead of the short-term weather data featured by intense variation – are employed for this study, since our interests lie in understanding how breeders have incorporated the lasting climate effects into their decision making. Also, the longitude and latitude data for Texas counties are obtained from the TravelMath.com[8], which returns the point information for each county query. These geo-data are then used for making queries in the ArcGIS database mentioned above to generate the point climate data for Texas counties. They are used for calculating the Euclidean distances between counties as well. The distance information is utilized to help generate the market prices of breeds for each county, as will be introduced below.

Data of forage conditions – to be exact, non-native pastureland and native rangeland – are collected by accessing the Trend Visualizer provided by the Texas A&M Institute of Renewable Natural Resources (IRNR)[9]. The most recent 2007 data are used for this study.

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[6] See http://www.texasbrahmans.com/

[7] See http://www.prism.oregonstate.edu/index.phtml for more information. Accessed 10 November, 2010.

[8] See http://www.travelmath.com/ for more information.

[9] See http://www.texaslandtrends.org/ to obtain more information.

The cattle inventory data come from the USDA National Agricultural Statistics Service (NASS). And the county-level median household income data are taken from the database of Small Area Income and Poverty Estimates[10] from the US Census Bureau.

The price data are difficult to obtain. Sale reports from the American Angus Association[11], the Brangus Journal published by the International Brangus Breeders Association[12], and the Brahman Journal[13] are used. To obtain consistent and comparable market prices for breeds, the April – May prices for female are selected to exclude seasonal variation effects and the price differences between bulls and cows. The April-May period is selected for use also because the Brangus data for Texas in 2010 are only available for May. To take into account the regional variation, we assume that each county responds to the price in its nearest market where a livestock sale occurs. The Brangus and Brahman data are sparse lacking variation. They are thus included in constants for regression. Angus prices vary by five levels across Texas counties.

A review of Tables 2 and 3 suggests that Texas is featured by great diversity – annual precipitation could be as low as 240mm in a dry county and as high as 1530mm in a wet county. The pasture and rangeland acres and cattle inventory also vary intensely across the counties. Overall speaking, the significant variation in the data is expected to provide a good source for effects identification.

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[10] See http://www.census.gov/did/www/saipe/data/statecounty/data/index.html for more information.
[11] See http://www.angus.org/
[12] See http://gobrangus.com/bpi/bpi-current-issues.php
[13] See http://brahmanjournal.com/brahman/

Results

Table 4 provides the detailed estimation results. As expected, higher maximum temperature in summer (*tmaxsum*) increases the likelihood of adopting Brahman. The coefficients of *tmaxsum* for Angus and Brangus are not significant, yet their negative signs indicate the stress high summer temperature places on Angus and Brangus. The interaction term of *tmaxsum* and *prepsum* reduces the possibility of raising Angus and Brangus significantly. The magnitude of *tmaxprepsum* is smaller in Brangus equation than in Angus equation, consistent with the expectation that Brangus is more heat tolerant. The coefficient of *tmaxprepsum* is not significant in Brahman equation, but it positive sign may reflect the advantage of tropically-adapted Brahman under hot and humid environments.

The winter temperature coefficients are significant in all equations. For Angus, the negative sign implies that Angus can survive in cold winters. For Brangus and Brahman, the positive signs imply that they prefer warm winters, and the effects of minimum winter temperature are more pronounced for Brahman. Recall that tropically-adapted breeds typically do not have fur thick enough to survive extremely cold winter seasons.

Precipitation (*prep*) appears to increase the adoption rates for all breeds, considering that water richness usually improves forage conditions. The smaller magnitudes for Brangus and Brahman may reflect that they are less water-demanding than Angus. Moreover, the greater the area of pasture and rangeland (*totalland*) in one county is, the less likely a Brangus or Brahman breeder shows up, as indicated by the negative signs of *totalland*. The smaller magnitudes of *pasture* for Brangus and Brahman might suggest that comparing to Angus, they do not need much human-management efforts in ensuring forage conditions. However, overall, the effects of forage conditions captured by *pasture* and *totalland* are not as significant as those of climate factors.

The market price for Angus (*angusprice*) is significantly positive in both Angus and Brangus equations, with the effects on Angus being greater. This may suggest that Brangus is valued by market principally because of its Angus traits. The coefficient of *angusprice* is insignificant for Brahman, implying that Angus price is irrelevant for Brahman adoption decision. As we mentioned earlier in the data section, the Brangus and Brahman prices are embedded in constants. It turns out that the constants in Brangus and Brahman equations are negative while the constant in Angus equation is positive. Also, the Brahman constant is significant and greater than the Brangus constant in magnitude, indicating that *Bos indicus* influenced breeds are not the primary choice for market purposes, compared to Angus.

The significantly positive coefficient of cattle inventory (*cattle*) for Angus indicates that counties with larger herds of cattle are more likely to see Angus breeders, while the insignificant *cattle* coefficients for Brangus and Brahman suggest that tropically-adapted breed selection decision is independent of background county livestock size. County-level income (*income*) is significantly positive in all equations, with the magnitude in Angus equation noticeably higher than in Brangus and Brahman equations. This suggests that counties with higher income levels tend to be the ones raising market-desired Angus breeds.

The estimates for ρ turn out to be statistically significant for Brangus-Angus and Brahman-Angus. The rejection of null hypothesis $\rho_{21} = \rho_{31} = \rho_{32}=0$ at 10% level indicates that it is more efficient to estimate the three binary choices jointly than separately.

Figures 1 to 3 present the histograms of marginal success probabilities of selecting Angus, Brangus, and Brahman respectively. Broadly speaking, Angus has a much higher chance to be selected than the other two breeds.

Conclusions & Discussions

While the livestock sector and the academia recognize that climate factors play an important role in forming the current pattern of cattle breeds, few have explored how climate factors entered into breeders' decision making quantitatively. Possible reasons may include that detailed data describing the location and size of cattle herds by breeds are not routinely available, not to mention the rancher background information that are critical for micro-econometrics analysis. In addition to the data problem, the livestock study requires extensive empirical knowledge – one may need to understand the interplay between meat markets, forage markets, land endowments, and environmental factors. This study tried to develop a quantitative understanding of climate effects on breed selection by looking into the adoption of Angus, Brangus, and Brahman breeds by breeders in Texas. The underlying hypothesis is quite intuitive – the current spatial pattern of the breeders raising various breeds is, to certain extent, a product of long-term environmental configurations. As climate changes (IPCC, 2007), the livestock sector may adjust their practices accordingly, which could include the spatial reallocation of cattle breeds. Thus this study may provide some forecasts into how the breeders would behave in a changing climate.

For the empirical part, it is more efficient to estimate the binary choice equations jointly than separately. The virtue of heat-tolerance in *Bos indicus* breeds is demonstrated in counties with higher summer temperatures. The positive sign of the iteration term – maximum summer temperature and precipitation – indicates that Brahman can survive hot and humid environments, though statistically insignificant. The winter climate effects are negative for *Bos indicus* influenced breeds because compared to Angus, they do not wear thick fur.

While the effects of major climate factors are significant and consistent with expectations, one should exercise caution when using these estimates to forecast the future situation. Recall that the econometric specification in this paper is developed based on certain assumptions – Brangus and Brahman prices are the same for all Texas counties, and forage conditions are represented by pasture and rangeland acres.

Future research that intend to derive long-term predictions may have to consider the possible changes in price differentials and use more accurate measures of climate and forage conditions. Also, effects from other parts of the beef supply chain may need to be reflected in model specification.

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Table 1 Explanatory Variables to Be Selected for Model Specification

		Expected Signs		
Variable	Description	Angus	Brangus	Brahman
Climate Conditions				
tmaxsum	maximum temperature in summer *(Celsius degree)*	-	+	+
prepsum	precipitation in summer *(mm)*	+	-	-
tmaxprepsum	interaction term of tmaxsum and psum *(Celsius degree * mm)*	-	+	+
tminwin	minimum temperature in winter *(Celsius degree)*	-	+	+
prep	annual precipitation *(mm)*	+	-	-
Forage Conditions				
pasture	non-native pastureland *(thousand acres)*	+	-/+	-/+
rangeland	native rangeland *(thousand acres)*	-/+	-/+	-/+
totalland	sum of non-native pastureland and native rangeland *(thousand acres)*	+	-	-
Market Conditions				
angusprice	price of angus *(thousand $ per head)*	+	-/+	-/+
brangusprice	price of brangus *(thousand $ per head)*	-/+	+	-/+
brahmanprice	price of Brahman *(thousand $ per head)*	-/+	-/+	-/+
County Characteristics				
cattle	cattle inventory *(thousand head)*	+	-/+	-
income	median household income *(thousand $)*	+	+	-

Table 2 Breeds Selection Pattern for Texas Counties

Angus	Brangus	Brahman	Count
1	1	1	28
1	1	0	55
1	0	1	13
1	0	0	95
0	1	1	0
0	1	0	9
0	0	1	2
0	0	0	52
			Sum: 254

Table 3 Summary Statistics for Explanatory Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Climate Conditions					
tmaxsum	254	34.52	1.19	27.84	37.41
prepsum	254	61.90	15.04	36.11	127.93
tminwin	254	1.05	3.73	-6.65	10.18
prep	254	806.75	301.79	238.18	1531.48
Forage Conditions					
rangeland	254	364.68	385.46	0.00	2668.46
pasture	254	43.34	57.80	0.00	359.39
totalland	254	408.01	377.40	0.00	2668.46
Market Conditions					
angusprice	254	2.39	0.48	1.84	3.04
brangusprice	254	3.90	0.00	3.90	3.90
brahmanprice	254	1.54	0.06	1.52	1.67
County Characteristics					
cattle	254	52.66	64.30	1.96	550.00
income	254	40.24	9.34	21.35	80.06

Table 4 Estimation Results[a]

	Angus		Brangus		Brahman	
tmaxsum	-0.15185	(0.10967)	-0.01240	(0.13861)	0.39583 *	(0.21682)
tmaxprepsum	-0.00143 ***	(0.00044)	-0.00098 ***	(0.00037)	0.00004	(0.00045)
tminwin	-0.04985	(0.03684)	0.17184 ***	(0.03689)	0.20520 ***	(0.06069)
prep	0.00351 ***	(0.00077)	0.00175 ***	(0.00064)	0.00220 *	(0.00125)
pasture	0.00528	(0.00323)	0.00318 *	(0.00193)	0.00412 *	(0.00218)
totalland	0.00030	(0.00027)	-0.00051	(0.00046)	-0.00067	(0.00073)
angusprice	0.62669 ***	(0.23691)	0.42318 *	(0.22199)	0.19448	(0.35498)
cattle	0.00564 **	(0.00275)	0.00170	(0.00203)	0.00608	(0.00373)
income	0.03964 ***	(0.01422)	0.02448 **	(0.01044)	0.02646 **	(0.01173)
constant	2.82513	(4.30558)	-1.65190	(5.19002)	-19.40916 **	(8.07078)
Log likelihood	-286.1026					
Number of observations	254					
Wald $\chi^2(27)$	147.27					
Probability > χ^2	0.00					
Correlation						
ρ_{21}	0.29033 *	(0.16757)				
ρ_{31}	0.64545 **	(0.28739)				
ρ_{32}	-0.06296	(0.16506)				
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{32}=0$						
$\chi^2(3)$	7.08673					
Probability > $\chi2$	0.0692					

[a] *** indicates significance at 1% level, ** 5% level, and * 10% level.

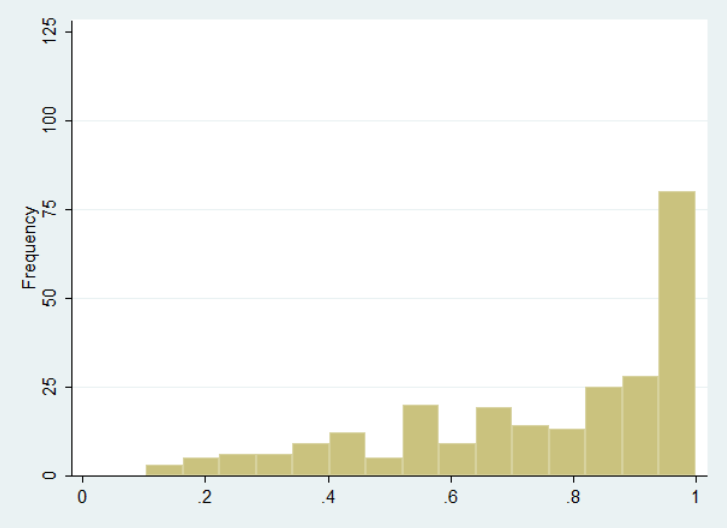

Figure 1 Histogram of Marginal Success Probability of Selecting Angus

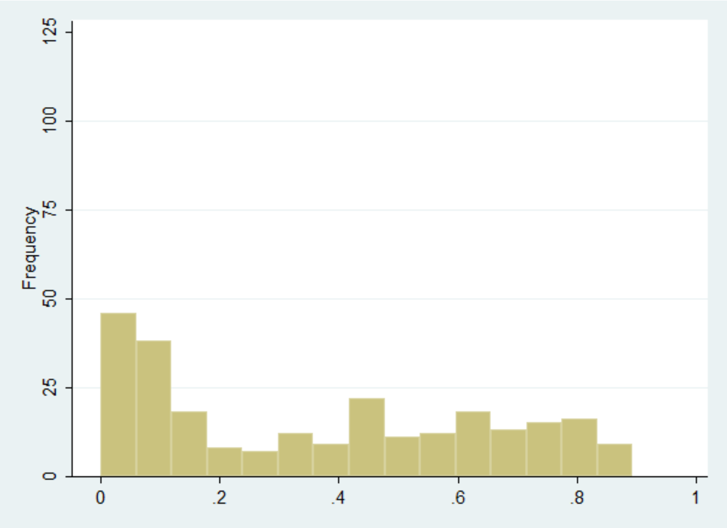

Figure 2 Histogram of Marginal Success Probability of Selecting Brangus

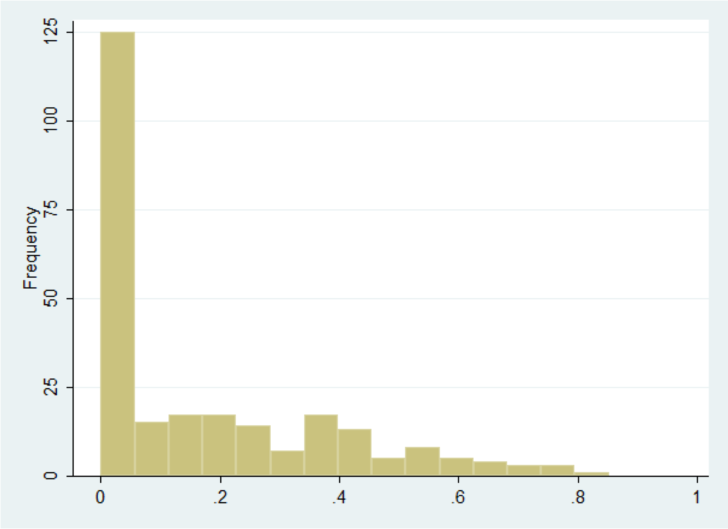

Figure 3 Histogram of Marginal Success Probability of Selecting Brahman