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Original

Evaluation of the Impact of Organizational and Structural Changes Implemented in Cuban Agriculture on the Reproductive Efficiency of Cattle Systems Using Artificial Insemination

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ABSTRACT

Background: The economic changes implemented in Cuba during the so called Special Period (1991-2000), led to the adoption of measures intended to mitigate scarcities in livestock raising. **Aim:** To evaluate the impact of different stages of organizational and structural changes in Cuban agriculture in the 1982-2017 period on the reproductive efficiency of cattle systems under artificial insemination. **Materials and Methods:** The annual data regarding birth index (BI) collected between January 1982 and December 2017 from six livestock companies in the province of Camagüey were included. The evaluation of intervention impact was made by regression analysis, using the Newey-West method. **Results:** A decreasing trend of BI was observed throughout the period, with two stages characterized by an interruption in 1994. The following year a non-significant increase was observed, followed by a decreasing trend, with a significant annual decline of 0.51%. A significant growth of the annual BI trend of 0.93% was confirmed, in relation to the pre-intervention trend. **Conclusions:** According to the BI observed, the organizational changes implemented in Cuban agriculture had an impact on reproductive efficiency. The absence of correspondence between the point of intervention of the series to the exact moment of the application of the measures corroborates that the effects observed on reproduction were long-term, due to time delayed inter-variable relations, and because the results expected at certain times are not always observed.

Keywords: interrupted time series analysis, cattle, reproduction (*Source*: *MESH*)

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INTRODUCTION

The economic changes that took place in Cuba during the so called Special Period (1991-2000) led to the adoption of policy measures to mitigate shortages in livestock rearing, one of the most affected sectors. Among the most significant steps were the creation of Basic Units of Cooperated Production (UBPC), the adjustment of the genetic structure of commercial dairy herds, and the reduction in the number of cows under artificial insemination (AI).

Farmers in the Cooperatives of Credits and Services (CCS), with the greatest percent of females perform AI only in 16.5% of cows (MINAG, 2017), which has a direct effect on the low levels of annual growth of milk and beef. To counteract that situation, Guideline No. 06/2017, issued by the Ministry of Agriculture established the Integrated System of Attention to Reproduction, with the purpose of introducing artificial insemination in 52% of all the female population in the country, and achieve 80% natality on average, until December 31st, 2019. Today, only 30% of the female population ready for reproduction is part of AI, and the economic effects due to the low productive efficiency have not been estimated yet.

In Cuba, the evaluation of impacts on livestock raising has been made through state-of-the-art analytical methods (Fernández Ibáñez, Bertot Valdés, and Montes de Oca, 2012; Torres *et al*., 2013; Leal Labrada *et al.,* 2018; Alonso-Vázquez *et al*., 2019), though they cannot be applied in the context of time series.

The methods implemented initially for time series impact analysis were integrated auto-regressive integrated models of moving averages or ARIMA (McDowall *et al*., 1980). Nowadays, regression by ordinary least squares is more commonly used to adjust self-correlation, due to their flexibility, and because they are more applicable in a context of interrupted time series.

In its simplest form, a regression model is used for modeling (linear, logistic or Poisson), which includes only three time-dependent covariables, whose regression coefficients calculate the pre-intercept slope, the change of level at the intervention point, and the change in the slope from pre-intervention to post-intervention (Kontopantelis *et al.,* 2015).

Interrupted time series analysis (ITSA), or intervention analysis, is thought to be the most potent *quasi* experimental design used to fix the effect of intervention when randomization is not feasible (Penfold and Zhang, 2013; Ewusie *et al.,* 2017). This tool allows for evaluation of time series, and it consists, according to López Bernal, Cummins, and Gasparrini (2016), in utilizing time series for establishing an underlying tendency, which is interrupted by intervention in a known moment.

This design has been increasingly applied in the research of several areas, such as clinical and healthcare services, epidemiology (Bhaskaran *et al.,* 2013; Ewusie *et al.,* 2017), education (Jacob *et al.,* 2016), social policies (Linden and Yarnold, 2018), veterinary medicine (Boerlage *et al.,* 2019), and food transmitted diseases (Aik *et al.,* 2020), among others. However, no studies have

dealt with the effects of interventions in animal reproduction, possibly because in the zootechnical sector time series analysis is unusual.

The aim of this paper was to evaluate the impact of changes in the organization and structure in Cuban agriculture, in the 1982-2017period, on the reproductive efficiency of cattle systems under artificial insemination.

MATERIALS AND METHODS

The monthly primary data of reproduction from six livestock raising companies between January 1982 and December 2017 was collected from the official institutional records at the livestock raising department of the Ministry of Agriculture in Camagüey province. The annual data on birth index (BI) were selected to evaluate the impact of organizational and structural changes in reproductive efficiency, in Cuban agriculture. Exploratory time series analyses (sequences, self-correlation, and partial self-correlation) were performed. A point of intervention for AI in 1994, was defined by means of visual inspection.

The evaluation of intervention impacts was done by regression analysis using the Newey-West method, which estimates the coefficients by ordinary least squares (OLS), though it produced standard errors of Newey-West by self-correlation of the possible heterocedasticity between independent variables in the model. The model specified was the following:

$$\mathbf{Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 X_t T_t + \in_t}$$

Where:

Y_t is the BI at annual time intervals (t).

T_t is time since the beginning of the study.

X_t is a dual variable (indicator) that represents intervention in 1994 (periods of pre-intervention = 0, intervention = 1).

$X_t T_t$ is a term of interaction.

β_0 is the intercept or initial level of the response variable (BI).

β_1 is the BI tendency until the introduction of intervention.

β_2 represents the change in the BI level during the period, immediately after intervention.

β_3 represents the differences between the pre and post intervention curves.

$_t$ random error term that follows a first order auto-regressive process (AR1):

where, $_t = \rho \in_{t-1} + u_t$

and the self-correlation parameter p is the correlation coefficient between adjacent error terms, so $|\rho| < 1$, and u_t disturbances are independent, and $\sim N(0, \sigma_{Ut}^2)$

The post-estimation slope was calculated, according to $\beta_1 + \beta_3$

Every analysis was based on the *itsa* module (Linden, 2015), implemented in Stata 15.1 (StataCorp, College Station, Texas, USA).

RESULTS AND DISCUSSION

Exploratory analysis of BI series

An increasing tendency was observed throughout the 1982-2017 period after visual inspection of BI series. Two stages were defined due to an interruption in 1994; the next year the values of the variable rose, to later keep a decreasing tendency (Figure 1). The fact that he values from the last years were comparable to the values recorded in the 1990-1993 period was outstanding.

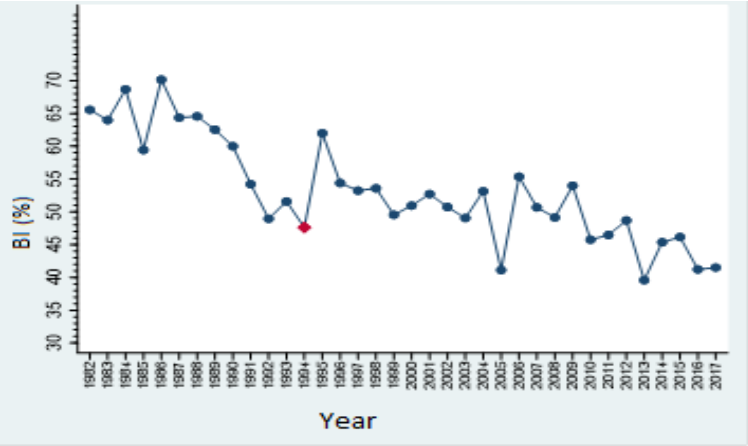

Figure 1. Annual values of birth index (BI) in the 1982-2017 period. The red dot represents the intervention in 1994.

Although the intervention point in the series does not correspond exactly to the implementation of measures, it is important to consider that the effects on reproduction take place in the long run, since there are interrelations between variables, which occurred with some time delays, thus the expected results are not always observed (Bertot Valdés *et al.*, 2009; Figueroa, Bertot, and Vázquez, 2010). Besides, though the actions that cause changes are both taken internationally and domestically, they are customized, depending on the territorial application.

The situation described is related to the long-term effect of damage originated in the Special Period, and as a result of organizational, structural, and economic policy measures adopted to tackle the negative interactive, overlapping, and accumulative effects. The underlying cause of these actions is the tightening of blockade actions by the USA during the period evaluated.

The above-mentioned problem, which is often presented in time series analysis, has been studied by López Bernal, Cummins, and Gasparrini (2016), who noted that in some evaluations, it is difficult to determine when the intervention begins, and to distinguish the effects of different components, but it is necessary to establish a clear differentiation between pre-intervention and post-intervention periods.

Significant self-correlations were observed in the first two delays (Figure 2), which suggests the need of conducting regression analysis that include self-correlation error correction. Consequently, the utilization of the first delay for regression analysis using OLS (ordinary least squares) with self-correlation error correction, according to Newey-West, is justifiable.

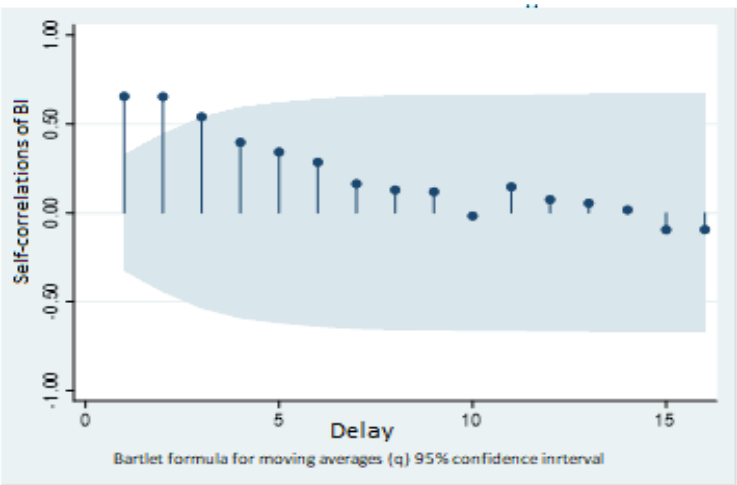

Figure 2.Self-correlations of BI

Births are the purpose of reproduction, and they are expected to be influenced by any type of change. In these companies, the total females showed a growing tendency during the 1982-2005 period (Bertot Valdés *et al.*, 2006), and since they are determinant in the birth totals, BI was used as an expression of the proportion of calves born alive from the total females, expressed in percent. Moreover, one of the strong features of ITSA is that it may be carried out in relation to the population rates (Penfold and Zhang, 2013); hence, the selection of BI to analyze the impacts of organizational and structural changes is justifiable.

In the regression analysis (Table 1), the initial level of BI in the period was 69.05%, with a 1.43% drop annually before 1994 (P =0.000 and CI = -2.15; -0.72). In the first year of intervention, a non-significant increase (3.25%) was observed (P =0.281 and 95% CI = -2.79; 9.29), followed by an annual decline in 0.51% (P= 0.000 and CI 95% = -0.71; -0.31) in BI (Table 2). The significant values observed indicate the timeline of effects on intervention in 1994 (Linden and Adams, 2011; Linden, 2015; Linden, 2017).

Table 1. Changes of level and tendency of BI

BI	Coef.	SE Newey-West	t	P>|t|	95% confidence interval	
					Lower limit	Upper limit
_t ($\beta 1$)	-1.43	0.35	-4.1	0.000	-2.15	-0.72
_x1994 ($\beta 2$)	3.25	2.97	1.1	0.281	-2.79	9.29
_x_t1994 (β_3)	0.93	0.37	2.5	0.018	0.17	1.68
_cons (β_0)	69.05	2.13	32.38	0.000	64.71	73.40
Quantity of observations = 36 F (3.32) = 43.82 Prob > F = 0.0000 Maximum delay: 1 Intervention: 1994						

Table 2. Linear tendency of BI after the intervention in 1994

Linear tendency	Coef.	SE	t	P>|t|	95% confidence interval	
					Lower limit	Upper limit
Intervention: 1994 _b[_t]+_b[_x_t1994]	-0.51	0.10	-5.24	0.000	-0.71	-0.31

An increase of BI annual tendency (0.93%) was confirmed in relation to the pre-intervention tendency (P = 0.018 and 95% CI = 0.17;1.68). The post-intervention period tendency was obtained from the sum of coefficients $\beta_1 + \beta_3$ = -1.43 + 0.93 = -0.51.

The analytical technique provided quite clear and easy-to-read results; the effect of the 1994 intervention on BI was observed without the statistical outcome of the regression models (Figure 1).

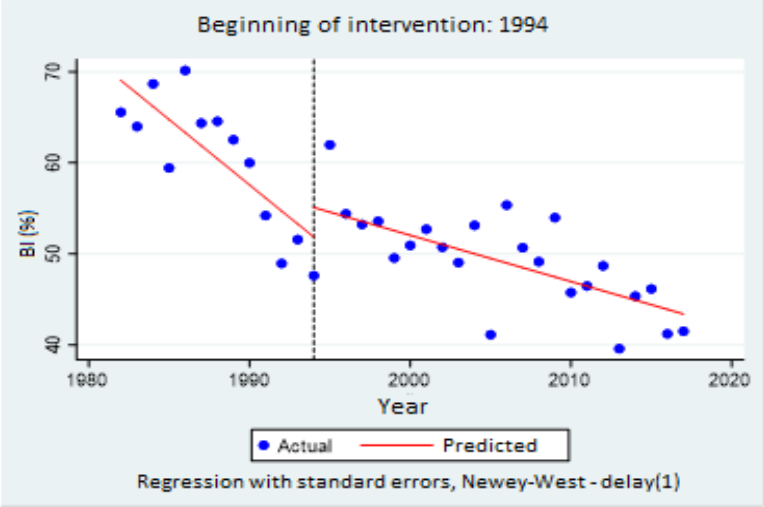

Figure 1. Interrupted time series analysis of BI

CONCLUSIONS

The organizational changes occurred in Cuban agriculture had an impact on the reproductive efficiency, which was expressed in the BI. The absence of correspondence between the series intervention point with the exact moment of the adoption of measures corroborates that the effects on reproduction are observed in the long run, since there are variable interrelations that take place with some time delays, thus the expected results are not always observed in practice at the expected times.

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AUTHOR CONTRIBUTION

Conception and design of research: JABV, MNHJ, RVMO, MGD; analysis and interpretation of data: JABV, MNHJ, RVMO; redaction of the manuscript: JABV, MNHJ, RVMO, MGD.

CONFLICT OF INTERESTS

The authors declare the existence of no conflicts of interests.