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Socioeconomic, Environmental, and Institutional Determinants of Cattle Ranching in the State of Pará, Brazilian Amazon

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Abstract

This study investigates how socioeconomic, environmental, and institutional variables affect the growth of cattle ranching in the state of Pará, Brazilian Amazon. Covering the period from 1995 to 2019, we used an econometric model based on the Ordinary Least Squares method. Resultingly, we found that the price of fat cattle and the supply of rural credit exert a positive effect on herd growth. The deforestation rates are directly associated with herd expansion. More precisely, the variable for the deforestation rate, lagged by two periods, significantly impacts herd increment in the present time. Furthermore, a essential step towards increasing the cattle herd was the creation of the Agricultural Defense Agency of the state of Pará. Overall, this study shows that the expansion of cattle ranching in Pará is a multivariate phenomenon determined by socioeconomic, environmental, and institutional dynamics of the regional and national economies.

Keywords: socio-environmental impact, livestock market, public policy, livestock system

1. Introduction

Pará's cattle raising is a vital component of agribusiness in the Brazilian Amazon. It supplies beef to various national and international markets, playing an essential role in achieving socioeconomic development and food security. In 2020, it represented 7.4% of the total cattle in Brazil, having a herd of 22.3 million heads and slaughtering 2.2 million heads. In the same year, Pará exported 95 thousand tons of beef and 62 thousand tons of live cattle (Ministério do Comércio e Exterior [MDIC], 2020).

Cattle raising in Pará is facilitated by large expanses of land and a favorable climate for pastures, making production more economical and competitive. Lately, it has undergone significant transformations owing to rural credit policies, technological advances, animal health control, and an expanding network of slaughterhouses in the Amazon (Santos, Lourenço-Júnior, et al., 2019). As a result, Pará's cattle products have entered international meat markets (Fundação Amazônia de Amparo a Estudos e Pesquisas do Pará [FAPESPA], 2017). Furthermore, the bovine herd in Pará evolved at the rate of 4.6% every year between 1995 and 2019, faster than the evolution of all bovine herds in Brazil (1.4% annually).

Financial subsidies provided by institutions help rural producers acquire input and capital, fostering the growth of cattle raising (Borges & Parré, 2022). They also facilitate the adoption

of the latest production technologies that boost technical efficiency and productivity. Several studies have highlighted the positive impact of rural credit on agricultural production (Melo et al., 2013; Gasques et al., 2017). The Northern Constitutional Financing Fund (FNO), created in 1988 and regulated in 1989, served as a major institutional advance in financing agriculture activities in the Amazon.

Agriculture protection policies, particularly sanitary controls set forth by regulatory agencies, also contribute to the rise of agricultural activities in Pará. These policies played a vital role in expanding the state's meatpacking agro-industry (Santos et al., 2018) and beef exports. Currently, Pará is also the largest exporter of live cattle in the country, exporting mainly to Middle Eastern countries, such as Turkey, Egypt, Lebanon, Iraq, and Jordan (MDIC, 2020), from the port of Vila do Conde in Barcarena.

This study aimed to determine the effects of endogenous and exogenous factors that impact cattle ranching in Pará. These factors included the quotations on beef arroba, availability of rural livestock credit (Santos, Lourenço-Júnior, et al., 2019; Santos, Santana, et al., 2019; Simsek, 2020), deforestation rate, rural labor supply (De Paula & Rosa, 2019), and animal health policies (Santos, Lourenço-Júnior, et al., 2019).

Therefore, this study intended to analyze how socioeconomic, environmental, and institutional factors contributed to the growth of Pará's bovine herd from 1995 to 2019. We used an econometric model based on the Ordinary Least Squares (OLS) method to obtain useful insights for bolstering cattle ranching in Pará.

2. Method

2.1 Study Area and Data Collection

The researchers focus on Pará, which is located in the Brazilian Amazon and spread across 1.3 million km². In 2020, it had a population of 8.7 million (Instituto Brasileiro de Geografia e Estatística [IBGE], 2020). With 22.3 million heads, the state has the third largest herd in the country, and it has grown annually by 4.6% in the last 24 years (IBGE, 2019a). Furthermore, it is a prominent hub for cattle production, generating livestock products worth R$ 5.1 billion in 2017 (IBGE, 2017).

Focusing on the period from 1995 to 2019, the time-series data were obtained from several official sources. For instance, data on the cattle herd were collected from the Municipal Livestock Survey conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2019a). The price of fat cattle was obtained from the Brazilian Livestock Yearbook (Anuário da Pecuária Brasileira [ANUALPEC], 2020) and the AGROLINK website (AGROLINK, 2020). Furthermore, data on credit obtained for cattle raising was collected from the rural credit applications in the Statistical Yearbook of Rural Credit, which is maintained by the Brazilian central bank (Banco Central do Brasil [BACEN], 2020). The deforestation rates were sourced from the database of the Legal Amazon Deforestation Monitoring System, which is maintained by the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais [INPE], 2020). Data on rural salaries were collected from the Fundação Getúlio Vargas Foundation (FGV) (Fundação Getúlio Vargas [FGV], 2020). Moreover,

monetary variables were deflated using the FGV's General Index of Prices-Internal Availability for December 2019 (IGP-DI) (FGV, 2020).

2.2 Analysis Model

From 1995 to 2019, Pará's bovine herd grew massively, deforestation rates soared, the FNO extended rural credit supply, and the Agricultural Defense Agency of the state of Pará (ADEPARÁ) was created. These environmental, socioeconomic, and institutional factors contributed to the growth of cattle ranching in Pará. This is because they influenced the decision-making of producers and other agents in the production chain.

This study was based on the OLS method, which is widely used in studies analyzing national and international agricultural practices. For instance, Santos et al. (2018) investigated how production factors influenced cattle production in the Brazilian Amazon. Rehman et al. (2017) analyzed the relationship between Pakistan's agricultural GDP and its livestock products. Furthermore, Simsek (2020) identified the determinants of beef production in Turkey.

In this study, the independent variables were expressed in the logarithmic form, excluding the dummy and trend variables. The structural model was developed as follows:

$$ECH_t = \alpha_0 + \alpha_1 PFC_{t-1} + \alpha_2 RC_t + \alpha_3 DRM_{t-2} + \alpha_4 RS_{t-1} + \alpha_5 DV_t + \alpha_6 T + e_t, \quad (1)$$

where

ECH_t is the natural logarithm of Pará's cattle herd from 1995 to 2019.

PFC_{t-1} is the natural logarithm of the real price of fat cattle in Pará from 1995 to 2019, lagged by one period and expressed as R$/@.

RC_t is the natural logarithm of the amount of rural credit obtained for cattle raising in Pará from 1995 to 2019, expressed as R$.

DRM_{t-2} is the deforestation rate from 1995 to 2019, lagged by two periods and expressed as a percentage.

RS_{t-1} is the natural logarithm of the rural salary rate from 1995 to 2019, lagged by a period and expressed as R$/day. It was used to capture how the cost of labor affects cattle ranching.

DV_t is a dummy variable illustrating the effect of the creation of the ADEPARÁ on cattle ranching in Pará. It equals zero in the period 1995–2002 and one in 2003–2019.

T is a trend variable representing technological advances in cattle ranching between 1995 and 2019. Finally, e_t is the random error term.

The coefficient of determination (R^2) was used to express the variance of independent variables explaining the dependent variable in a percentage form. Gujarati and Porter (2012) assert that values closer to 1 indicate a better goodness-of-fit. Furthermore, the Durbin-Watson test was employed to check for autocorrelation. This statistic tests the dependence between the successive values of the residuals in the OLS regression. The

presence of multicollinearity, that is, correlation between several independent variables, was checked using the Variance Inflation Factor (VIF).

Based on the economic theory, the coefficients of PFC_{t-1}, RC_t, DRM_{t-2}, DV_t, and T should be greater than zero, and the coefficient of RS_{t-1} should be less than zero.

The increased rural credit and the creation of ADEPARÁ is expected to yield a positive result, considering that both would encourage investments in livestock projects and, consequently, herd expansion. Similarly, the price of fat cattle should directly influence cattle production because it would have a straight impact on the cost of breeding, rearing, and fattening other categories of cattle. The variable representing the deforestation rate is delayed by at least two years (Rivero et al., 2009). It should be directly related to herd growth because, initially, deforestation provides wood-based products and, later, it paves the way for growing pastures, ultimately bolstering livestock production. Finally, the correlation between the rural salary rate and the growth of cattle should be negative, given that it is a component of production cost.

3. Results and Discussion

The results from the econometric model are presented in Table 1. The F-test was significant at the 1% level, and the coefficient of determination indicates that 97.8% of the total variation in herd growth was due to the variations in independent variables. Furthermore, there were no autocorrelation concerns among the residuals, as shown by the Durbin-Watson test. In addition, multicollinearity was not an issue as the VIF of all independent variables was less than 10. All coefficients were significant at either the 1% or 5% level based on Student's t-test.

Table 1. Results of employing the econometric model in Equation 1

Variable	Coefficient	Standard error	t-Test
Intercept	9.5444*	1.1900	8.0206
PFC_{t-1}	0.2831**	0.1157	2.4462
RC_{t-1}	0.1406*	0.0395	3.5625
DRM_{t-2}	0.2740*	0.0540	5.0763
DV_{1t}	0.1562**	0.0652	2.3946
RS_t	-0.0541*	0.0177	-3.0538
Trend (T)	0.0400*	0.0063	6.3161
F-test	134.0256*		
R^2	0.9781		
R^2 adjusted	0.9708		
Durbin-Watson - *d*	1.9967		

Note: (*) and (**) indicate significance at the 1% and 5% levels, respectively.

Source: Research data estimates using GRETL (Free Software Foundation [FSF], 2020).

The model was estimated from the Napierian logarithms of variables. Therefore, their coefficients can be interpreted as elasticities. Notably, the price-elasticity coefficient was

0.2831, suggesting that the cattle herd increases by 2.831% at every 10% increase in the price of fat cattle (lagged by one period). This result holds when *ceteris paribus*, that is, all other variables remain constant. Conclusively, the supply of cattle is price inelastic.

The coefficient of rural credit-elasticity was 0.1406. That is, every 10% increase in credit supply induces a 1.406% increase in the herd, *ceteris paribus*. This finding indicates that the supply of cattle is inelastic to rural credit.

The elasticity coefficient concerning the deforestation rate was 0.2740. It suggests that a 10% increase in deforestation, lagged by two time periods, results in the cattle herd growing by 2.740% in the present time. Put simply, deforestation positively influences the increase in the cattle herd. This finding corresponds to those in Neves et al. (2014) and Santos, Lourenço-Júnior, et al. (2019).

Several key policies concerning animal health protection were initiated owing to the creation of ADEPARÁ. These policies bolstered the growth of the cattle herd, as evidenced by the dummy variable's positive coefficient (Table 1). It shows that the growth of the cattle herd is related to the evolution of Pará's beef and live cattle exports.

The cost-elasticity coefficient is -0.0541. It indicates that the cattle herd reduces by 0.541% every time the salary of rural workers increase by 10%, *ceteris paribus*. That is, rural workers' salaries exert a negative impact on the cattle herd.

The coefficient of the trend variable was positive and statistically significant. The cattle herd grew from 8.058 thousand heads in 1995 to 20.881 thousand heads in 2019, showing a 159.14% increase during this period. The average carcass weight at slaughter was 15.39 arrobas for fat cattle and 12.29 arrobas for cows in the early 1997s, which grew to 19.32 arrobas for fat cattle and 13.49 arrobas for cows in 2020. Therefore, productivity also increased between 1995 and 2019 (IBGE, 2019b).

3.1 Beef Arroba Price

Based on the law of supply, an appreciation in the price per arroba stimulates production and investment in the entire livestock market because ranchers anticipate more profits. Consequently, the cattle herd grows. Therefore, producers start retaining matrices on properties, reducing the participation of dams in total cattle slaughter. This movement of retention bolsters the birth of calves, and the bovine numbers at the rearing and fattening stages increase in the following season.

3.2 Rural Credit

The FNO supplied more credit for cattle raising than for agricultural operations in Pará. From 1999 to 2019, the credit provided for livestock operations amounted to R$ 12.6 billion in deflated values. Of this amount, R$ 9.0 billion were contracted for investment, R$ 3.3 billion for funding, and R$ 200 million for commercialization.

Figure 1 shows the three distinct phases of rural credit allocation for livestock activities: the growth period from 1999 to 2006, the stagnation and sudden increase from 2007 to 2012, and

the declining period from 2013 to 2019. The supply of rural credit for livestock operations grew from the late 1990s to the mid-2000s, as did the cattle herd in Pará (Figure 2). However, the cattle herd continued to grow, while the rural credit fluctuated significantly until 2013.

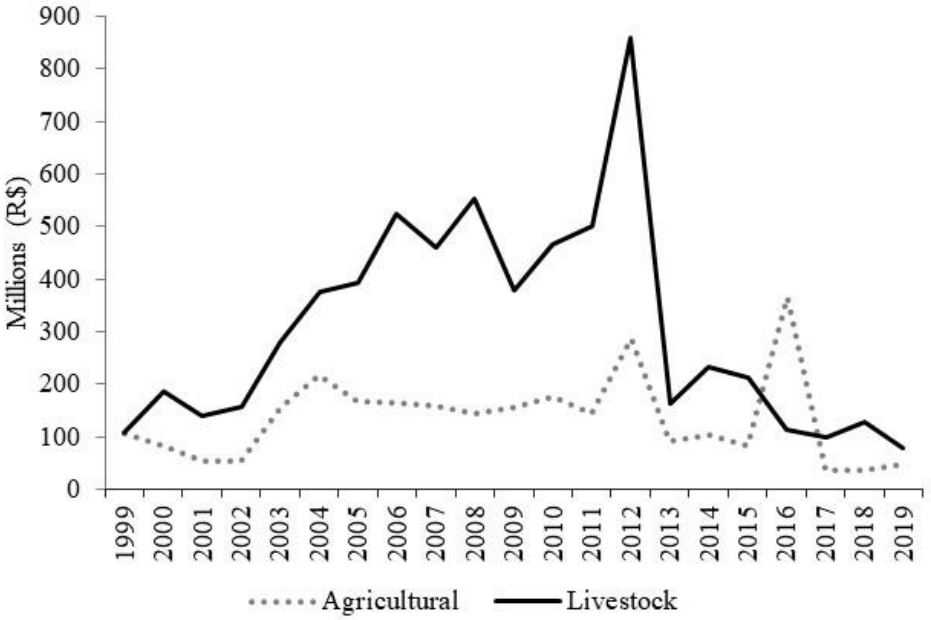

Figure 1. Evolution of the value of rural credit supply for agricultural and livestock operations in Pará from 1999 to 2019. Source: Research data

The relationship between the growth of the cattle herd and rural credit is not positive when we only observe their variations over time. However, rural credit policies increase the cattle herd as they facilitate acquisition of animals for reproduction, investment in pasture management and recovery, and implementation of intensive systems. Particularly, these policies aid the South and Southeast regions, which hold most of the cattle in Pará (Santos et al., 2012; Instituto de Pesquisa Ambiental da Amazônia [IPAM], 2019).

3.3 Deforestation Rate

Figure 2 shows a significant reduction in the area of deforestation between 1988 and 1994. This period may be related to the economic recession in Brazil and thus, resulted in a lack of financial resources to invest in opening new areas (Carrero & Fearnside, 2011). Hyperinflation in that period also contributed as land value rose in the Amazon. Therefore, land speculations could prove more profitable than cattle raising or other activities in that period (Hecht, 1993).

With the initiation of the Real Plan, the expectations of economic recovery were high in 1995. The deforestation rate increased by 83.1% from the previous year, reflecting low land value and capitalization of ranchers. This indicates the strong role of land speculation as a factor in land use change (Bowman et al., 2012).

From 1998 onwards, the dynamics of deforestation intensified until 2004. This period culminated in the agro-industrial expansion in the Brazilian Amazon (Santos et al., 2018).

Prices in international agricultural commodity markets rose, as did the price indices of cattle. The period also witnessed technological advances that allowed the mechanization of large areas.

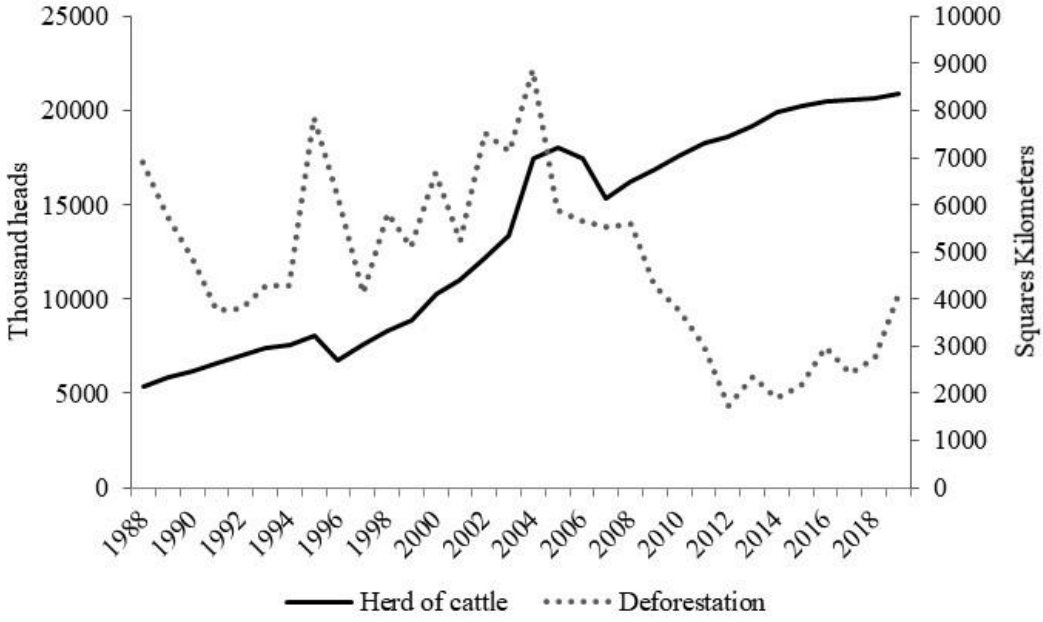

Figure 2. Evolution of the cattle herd and deforested areas between 1988 and 2019. Source: Research data

Deforestation rates in the Amazon were high in the 2000s, with a large chunk in Pará. Therefore, the Federal Public Ministry (MPF) of Pará initiated an investigation and found that the meat production chain is linked to deforestation (Armelin et al., 2019). Based on this finding, policy actions focused on combatting deforestation (Assunção et al., 2015). Particularly, this emphasis started after the creation of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon in 2004. This Plan was initiated under the supervision of the Environment Minister at the time, Marina Silva (2003–2008). She aimed to reduce deforestation rates by 80.0% by 2020.

From 2005 to 2012, deforestation rates dropped significantly, followed by stable rates until 2015. The Meat Adjustment Agreement between the Pará State Government and meat industry businessmen in 2009 aimed to reduce illegal deforestation. This initiative was adopted because the MPF exerted pressure and discouraged acquiring meat from companies in Pará. This is because the suppliers were accused of environmental violations or making laborers work in conditions analogous to slavery (Barreto & Gibbs, 2015).

In 2012, the Government of Pará committed to achieve Zero Net Deforestation by 2020 in the Rio+20. However, this commitment was not fulfilled, and in the following years and post-creation of the New Brazilian Forest Code, deforestation rates rose again in Pará. They soared from 1.7 thousand km^2 in 2012 to 4.1700 thousand km^2 in 2019, growing annually by 10.0%. Moreover, they also rose in 2016, increasing by 39.4% between 2016 and 2019.

One factor that has led to the increase in deforestation rates in recent years is the federal government's actions. The current Ministry of the Environment has reduced the budget for environmental public policies, relaxed inspections, and suspended fines on illegal deforestation. These measures have weakened the actions of Brazilian environmental agencies. Furthermore, they show that the government does not prioritize the fight against illegal deforestation, paving the way for environmental degradation.

Pará's cattle herds grew in number from 1995 to 2019, similar to the trajectory of deforestation rates until 2005. Probably, this continuous growth was largely sustained by the economic stabilization effected by the Real Plan. During this period, the cattle herd grew sharply, particularly enlarging from 13.4 thousand heads to 17.4 thousand heads between 2003 and 2004.

From 1995 to 2019, the pasture area increased from 7.2 to 17.5 million hectares, showing a significant increase until the end of the 2000s. Despite the deceleration in the expansion of pasture areas in the second half of the decade, the pastures grew at an annual growth rate of 6.2%. This finding aligns with that in Dias-Filho (2012). The researcher asserts that the increase in the pasture occupation rate relates to the increase in livestock productivity in the Amazon. He suggests reusing pastures before opening new pastures by restoring the degraded ones. From 2010 to 2019, the annual growth rate of pastures was only 0.6%.

Between 2005 and 2007, the Pará bovine herd reduced by 15.0%, while the national bovine herd shriveled by only 3.6%. This reduction in the bovine herd is probably related to the outbreak of the foot-and-mouth disease in Mato Grosso do Sul and Paraná in 2005. It also induced a drop in beef exports to several countries, especially Brazil's primary export market–Russia (International Federation for Animal Health [IFAH], 2012).

This outbreak severely impacted the Brazilian economy, depreciating domestic and international sales revenues. There was an excess supply of animals, and the arroba prices of cattle dropped (Figure 3).

Figure 3. Evolution of the arroba price of live cattle and the total cattle slaughter between 1997 and 2019. Source: Research data

This discouraged cattle raisers, who started to offer more cattle for slaughter. With fewer resources, ranchers invested less in pasture and seeds, reduced production, or migrated to more financially-rewarding activities. In addition, there was a greater supply of bovine females for slaughter, including future dams. Consequently, it reduced the supply of calves and, ultimately, the number of herds. The cattle herd and the export market later recovered in 2009.

3.4 Dummy Variable (ADEPARÁ)

The meatpacking industry in the Amazon region has expanded in recent decades, increasing the rate of inspected slaughters. With this feat, the quality of meat improved substantially in the domestic and export markets (Santos, Lourenço-Júnior, et al., 2019).

This improvement was brought about by the positive impact of animal health policies on beef production in Pará. Put simply, the sanitation policy provided favorable conditions for growing the cattle herd and expanding slaughterhouses. Consequently, the beef market grew and new markets opened up, both nationally and internationally.

After the creation of ADEPARÁ in 2002, the state leveraged beef production and changed its status as a meat importer to a meat exporter. This was possible due to the nationwide implementation of animal health policies, in accordance with the guidelines provided by the World Organization for Animal Health. Programs such as the National Program for the Eradication and Prevention of Foot-and-Mouth Disease and the National Program for the Control and Eradication of Brucellosis and Animal Tuberculosis also contributed to this achievement.

Diseases such as the foot-and-Mouth disease, brucellosis, and animal tuberculosis

significantly damage animal production. This is because ranchers incur direct losses in providing clinical treatments (Souza et al., 2013; Piva Filho et al., 2017). Particularly, the foot-and-mouth disease disturbs trade relations the most as its incidence restricts exports and weakens the economy (Garcia et al., 2015; Mocci et al., 2015). Evidently, animal health protection holds a great and direct influence on the dynamics of the export market.

Pará has been a foot-and-mouth disease-free zone since 2014, according to Normative Instruction 16/2014, which allowed the transit of animals in ports of countries with the same health status. In 2018, the state of Pará was internationally recognized as an area 100% free of foot-and-mouth disease, depicting more progress (Agência de Defesa Agropecuária do Estado do Pará [ADEPARÁ], 2020). These advances were effected by initiating the Animal Health Defense Service and the Regionalization Process in the fight against the foot-and-mouth disease.

Resultingly, the number of establishments to be subjected to inspection increased, especially those to be subjected to federal inspections. These establishments authorize beef exports for international markets. They also check compliance with specific slaughtering requirements based on religious beliefs to cater to new markets. Hong Kong, Egypt, China, Israel, the United Arab Emirates, and Saudi Arabia are some countries that import beef from Pará. Moreover, Turkey, Egypt, Lebanon, Jordan, Iraq, and Saudi Arabia are some countries that import live cattle, with Saudi Arabia being the most recent importer (MDIC, 2020).

Pará began exporting live cattle in 2003, and currently, it is the largest Brazilian exporter of live cattle. From 2004 to 2010, cattle exports increased considerably (Figure 4) and, the revenue from these exports rose from US$ 729 thousand in 2003 to US$ 641 million in 2010 (MDIC, 2020). Cattle exports decreased in the following two years and increase again in 2013, generating an export revenue of US$ 531 million. In 2007, Pará exported 97% of Brazilian live cattle (MDIC, 2020). This shows the strength of this sector in the socioeconomic development of Pará. Furthermore, the revenue from this sector can be used to diversify services and inputs and generate investment and employment. Particularly, the input industry is stimulated from the boost in the export sector, and it generates wealth for Pará. This sector includes the production of seeds, fertilizers, medicines, animal feed, machinery, and equipment.

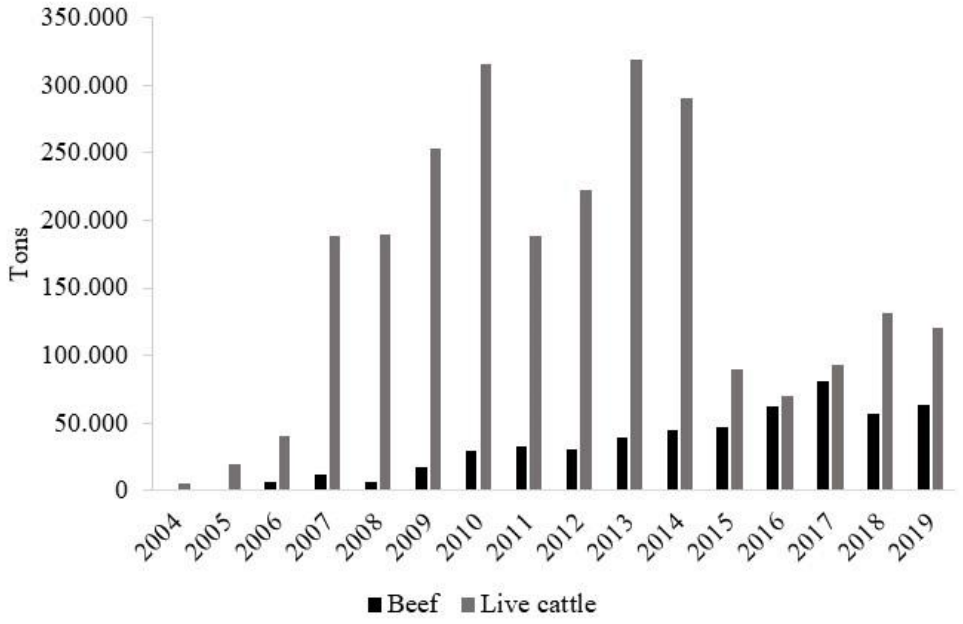

Figure 4. Evolution of exports of beef and live cattle between 2004 and 2019. Source: Research data

Haidar Beirut, a ship transporting live cattle, sank in 2015. This ship was heading to Venezuela via Vila do Conde, a port in Barcarena, Northeast Pará. The sinking of this ship suspended exports and exerted a negative and immediate impact on Pará's socioeconomic profile. Moreover, it adversely affected the environment, particularly the local community, which suffered from pollution owing to oil spills, decomposition of dead animals, and other residues (Ministério Público Federal [MPF], 2015).

Owing to the embargo on the movement of live cargo through Vila do Conde, the export of live cattle dropped by 80% in 2016 (G1.Globo.com, 2016). This exacerbated the financial crisis in Venezuela, which was the largest importer in this niche market. Then, exporting activity was initiated from other states that could export, such as Maranhão and Bahia. In addition, the weakness of the security protocols followed by the company that operated Vila do Conde was evident. The lack of concern for animal welfare and the lack of a Risk Management Plan were also apparent.

3.5 Rural Salary

Generally, cattle raising is practiced in extensive and semi-intensive systems, which do not require highly trained labor. Notably, the shortage of workers in rural areas is increasing. This is mainly due to technological advances that simplify and reduce daily activities in agriculture production processes (Grossi & Silva, 2006). For instance, an agricultural establishment occupied 4.54 people, on average, in 1980. In 1985, this number rose to 4.78, but it fell to 4.38 in 1996. In 2006, it reduced to 3.57 and 3.49 in 2017 (IBGE, 2017). This downward trend has continued in recent years.

The devaluation of rural workers results in the existing labor working for long hours and

being exploited in terms of remuneration. Therefore, many workers end up working without a registration or employment relationship. They are deprived of their rights as citizens and subjected to work conditions analogous to contemporary slavery, which is considered an act of denying the dignity of individuals and forcing them to remain in degrading conditions for the use of their work (Silva & Jacob, 2017). Unfortunately, this practice is still prevalent in several productive and economic sectors in Brazil. Its structural causes include the poverty of rural workers and the economic and political power of farmers (Girardi et al., 2014).

Cattle ranching in Pará still bears some relation to this issue based on the 1995–2019 data of the Observatory for the Eradication of Slave Labor and Trafficking in Persons, which is maintained by the Public Ministry of Labor. For instance, in the municipalities of São Félix do Xingu, Santana do Araguaia, Marabá, Pacajá, Itupiranga, Redenção, and Ulianópolis, 3.5 thousand workers in cattle breeding were rescued from work conditions similar to slavery (SMARTLAB, 2020). Furthermore, 67.2% of such occurrences belong to the municipalities in the Southeast Pará mesoregion, which holds more than 60% of the state's cattle herd.

3.6 Trend

Table 2 shows that the total pasture area grew by 125.9% from 1996 to 2019. In the same period, the bovine herd grew by 209.3%, and the average stocking rate increased from 0.65 to 0.89 animal units, increasing by 37.0%.

Table 2. Pasture areas, cattle herd, and stocking rate in the state of Pará

Variables	Year				Rate of variation (%) (1996–2019)
	1996	2006	2017	2019	
Pasture (ha)	7 749 457	15 159 049	17 355 736	17 500 356	125.9
Bovine herd (heads)	6 751 480	17 501 678	20 585 367	20 881 204	209.3
Animal Unit (ha)	0.65	0.87	0.89	0.89	37.0

Source: Research data.

On average, the Brazilian Amazon has the potential of livestock intensification of 2.13 animal units ha^{-1} (Arantes et al., 2018). This potential is associated with the rainfall regime of the Amazon. It is also encouraged by the Term of Adjustment of Conduct (TAC) of meat, which is the commitment of many slaughterhouses to not obtain animals from the properties associated with deforestation in the Amazon and those that do not comply with environmental and social laws (Gibbs et al., 2015).

The stocking rate can indicate the efficiency of livestock activity. However, it can be associated with overcrowding, which generally degrades the soil and pastures and reduces

productivity and profitability (Valentim & Andrade, 2009).

The intensification of beef production systems is a salient factor in livestock expansion. It balances the increasing demand for beef with the environmental and social issues in production systems.

4. Conclusion

The growth of the cattle herd is inelastic to prices and rural credit. Rural credit supply and animal health policies vitally supported the development of regional cattle ranching.

The creation of the ADEPARÁ in 2002 was a major advance in the institutional sphere. This is because it promoted the implementation of animal health policies and programs, contributing to the expansion of investments in cattle production. It also opened the gates to new marketing opportunities, both national and international.

Deforestation rates are directly associated with the growth of the cattle herd. Furthermore, the decrease in the supply of rural labor negatively affects the herd growth. Increased stocking rate and increased carcass yield in male and female cattle resulted in productivity gains.

Future research efforts should include different socioeconomic and environmental variables to complement the present study and facilitate a deeper understanding of the dynamics of herd growth in Pará.

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