Extended abstract submitted to 62st ERSA Congress to be hold at Alicante, Spain, August 28th thru September 1st, 2023

Spatial changes in dairy cattle productivity among Brazilian states

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Introduction

Milk production, including the one from bovine dairy farming, is very important for developing countries, since this production provides essential food for their inhabitants (ZOCCAL; GOMES, 2005).

Bovine milk consumption provides important nutrients for humans, such as: lipids, proteins, amino acids, vitamins, minerals, immunoglobulins, hormones, growth factors, cytokines, nucleotides, peptides, polyamines, enzymes, fatty acids and other bioactive peptides (HAUG; HØSTMARK, HARSTAD, 2007).

Brazil was the fifth largest world's producer of bovine milk in 2018, just behind of the USA, India, China and Russia. Dairy cattle farming answered for 5.6% of Brazil´s farming gross value in 2016.

Brazilian milk production has been increasing since the middle of the 1970s and the productivity enlargement has played a key role for the country´s milk production growth. However, the Brazilian dairy cattle productivity is still lower than the ones reached by the largest milk producing countries. For example, in 2017, US dairy productivity was 10.415 tons per cow while the Brazilian productivity was only 1.33 tons per cow. Moreover, there are huge heterogeneity among and within the Brazilian states concerning their dairy cattle productivity.

There are several works dealing with Brazil´s milk production and its evolution, most of them were written in Portuguese, such as Gomes (1991, 1995, 2001 and 2002), Maia *et al* (2013), Embrapa (2015), Vilela *et al* (2017), Martins (2004) and Vilela & Resende (2014), for example. Also, there are works concerning to the technological disparities among dairy farmers, such as Zoccal & Gomes (2005) and Jank & Galan (1999), for instance. However, little is known about the spatial association among municipalities concerning to their dairy farming productivity.

The production of bovine milk is taking place in almost all Brazilian municipalities. However, it happens differently among municipalities and dairy farmers. This production heterogeneity affects the average productivity by municipalities, however, we little know about the spillover effect from this productivity. For example, can the surge of a technical school teaching farmers how to improve their milk production in one specific city the power to generate spillover effect on surrounding cities? Has the presence of a milk processing mill only onsite impact or does it have spillover effects among neighboring municipalities?

Given the importance of productivity to enable the expansion and competitiveness of dairy cattle farming, this paper aims to evaluate the differentiated evolution of the dairy cattle productivity among and inside the Brazilian municipalities and regions, willing to unveil some spatial associations.

Methodology and dataset

We consider the Brazilian Institute of Geography and Statistics´ dataset about the milk production in each Brazilian municipalities and their bovine herd. The productivity is measured as liters of milk per cow.

The Brazilian Institute of Geography and Statistics assembles Brazil´s 27 states and its over 5,600 municipalities into five regions: North (where most of the Brazilian Amazon forests lies), Northeast (which is partially dominated by semi-arid climate), Central-West (a larger

soybean, corn and cattle producer), Southeast and South. The last two are the richest Brazilian regions and they hold most of the agricultural technical schools, research centers and universities.

Because the number of Brazilian municipalities has change over the time, we aggregated our information in Comparable Minimum Areas (CMA) what surges as the reassembling of current split cities into their original city.

Also, we base our study in the exploratory spatial data analysis (ESDA) and calculate Local Moran´s I index for each Brazilian municipalities, what allows us to estimate clusters throughout the Brazil. According to Aurin Portal (2022) **"**Local Moran's *I* is a local spatial autocorrelation statistic that identifies local clusters or local outliers to understand their contribution to the 'global' clustering statistic. It was developed by *Anselin (1995)* as a class of local indicators called Local Indicators of Spatial Association (LISAs). The local Moran's I statistic offers insight into the behavior of data at local levels, by providing a decomposition of the Moran's I global statistic into the degree of spatial association associated with each observation. LISAs serve two purposes in exploratory spatial data analysis (ESDA): they indicate local spatial clusters and they perform sensitivity analysis (identify outliers)".

The formula to estimate Local Moran´s I index is:

$$I_i = z_i \sum_{j=1}^{J} \boldsymbol{w_{ij}} z_j \quad (1)$$

Where: z_i and z_j are the deviation values of milk productivity to the national average in cities *i* and *j*, respectively; and w_{ij} is the spatial weight matrix element, what is the 5 nearest neighboring cities in our study. Positive values of I_i suggest high-high or low-low clusters and negative values of I_i indicate a spatial cluster with dissimilar values of dairy productivities.

Results

Figure 1 shows the evolution of Brazil´s milk production from 1974 thru 2016, what jumped from 3.4 million liters to 7.1 million liters, respectively, more than doubled. This production has a steady increase until 2014, and it had slightly decreased in the following two years.

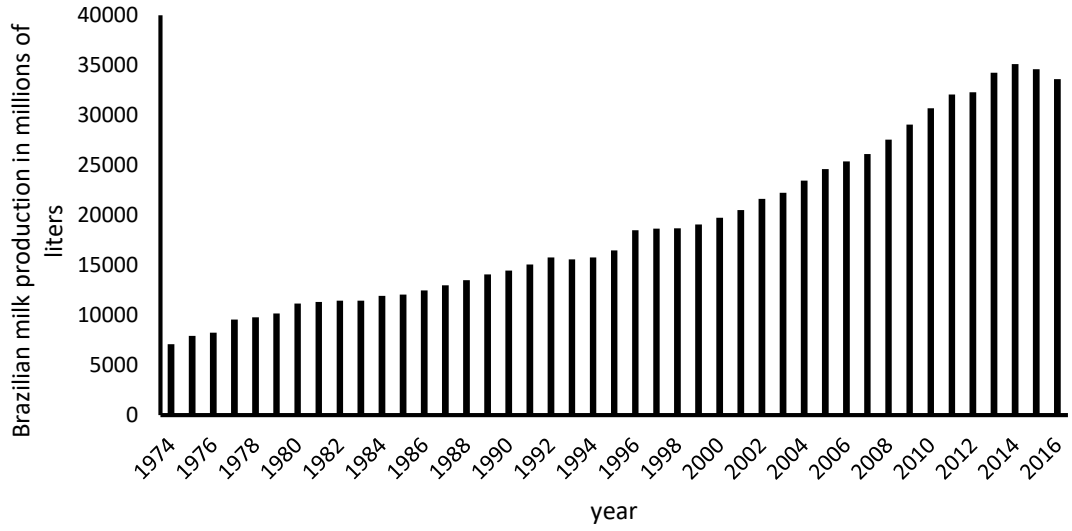

Figure 1 – Evolution of Brazil´s bovine milk production from 1974 thru 2016
Source: Brazilian Institute of Geography and Statistic.

In 1974, in average, milk productivity in Brazilian CMA was 635.92 liters per cow, and ¾ of the Brazilian CMA hold productivity below the national average. In 2016, national productivity was 1,423.97 liters per cow (an increase of 124% in relation to 1974 figure) but 80.64% of the Brazilian CMA hold productivity below national average.

Figure 2 shows how milk productivity is spread over the Brazilian CMA. Clearly, milk farmers located at the Brazil´s North and Northeast regions (which are the poorest regions in Brazil) have the lowest productivity and the ones located at Southeast and South regions (the richest regions in Brazil) have the highest productivity. And those differences have enlarged from 1974 to 2016.

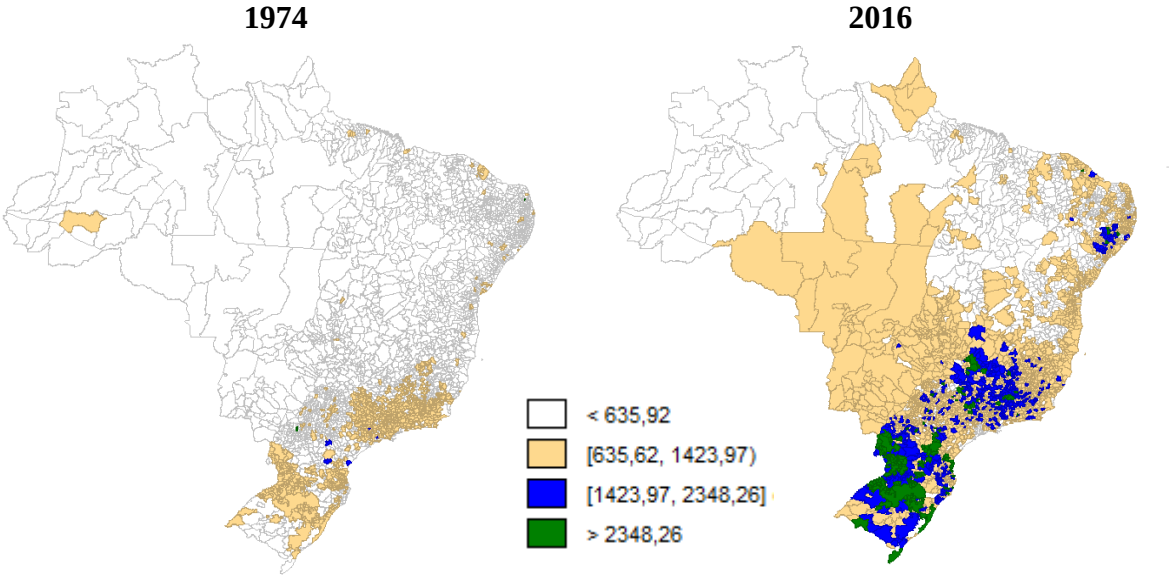

Figure 2 - Dairy productivity by Brazilian cities (considering liters of milk per cow)
Source: Brazilian Institute of Geography and Statistic.

Figure 3 shows the spatial clusters of dairy farming productivity. Comparing figures 2 and 3 we easily find out that cities located at the Brazilian North and Northeast regions hold lower dairy productivity and there is low-low cluster in those regions, that is to say, one city with low dairy productivity is surrounding for cities with lower dairy productivity. Also, dairy productivities are higher and enlarged, from 1974 to 2016, in cities located at Central-West, Southeast and South regions (especially in the last two regions, see Figure 2) and high-high clusters have taken and enlarged in Southeast and South regions (see Figure 3).

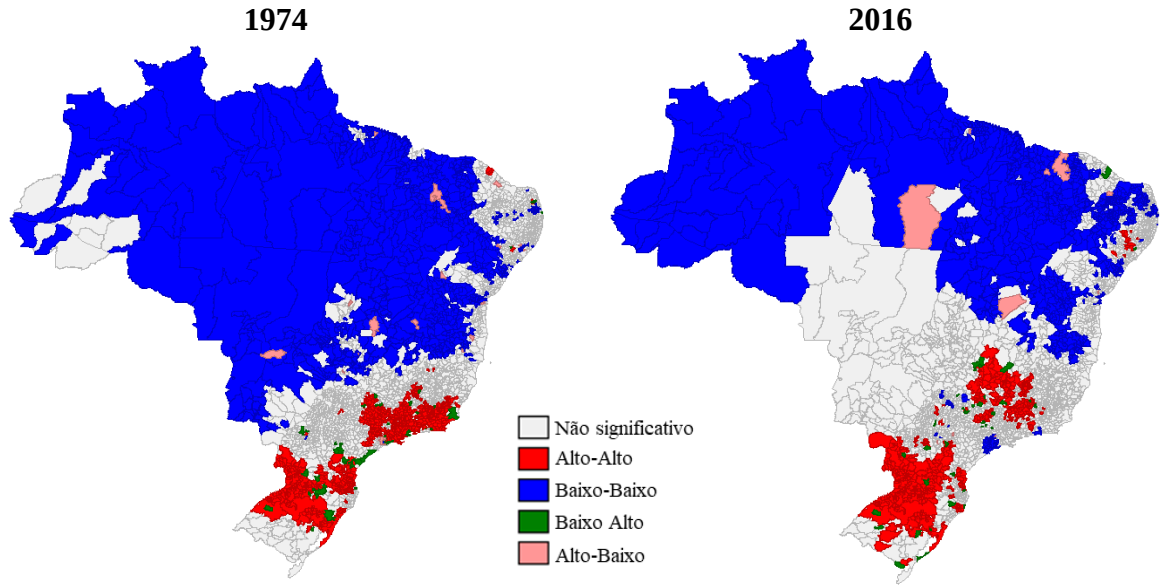

Figure 3 – *Clusters* of dairy production in the years of 1974 and 2016. “Alto” indicates high and “Baixo” indicates low.
Source: elaborated by the authors

It is clear after analyzing Figures 2 and 3 that we have different milk cattle systems throughout Brazil and some policies can be draft to try both improve and homogenize those systems.

Some policies could reduce the heterogeneity of production systems and, consequently, contribute to reducing the dairy productivity disparities among the Brazilian cities and regions. Among those policies we can suggest: creation of technical schools and centers for teaching animal science in regions with lower productivity; and incentives for private institutions to grant and/or increase the amount made available for rural credit for livestock. Offering short term courses about management of animals and pastures, about animal diseases and health as well as teaching good milking practices in some regions can generate spillover effects on neighboring cities; and paying differentiated prices according the milk quality can stimulate dairy farmers to adopted modern technology. Moreover, credit can be allocated in order to allow Northern and Northeastern farmers to acquire new technologies. However, in order to link faraway producing regions to urban markets, the improvement and development of new milk transport network need to be addressed.

Conclusion

Brazil´s milk production increased significantly from 1974 through 2016. The country ranks as one of the world's largest producers of bovine milk; however, its productivity (measured in milk liters per cow) is below the figures achieved by other major milk producing countries. Moreover, Brazilian regions hold huge disparities about their dairy farming productivity and those differences have enlarged over the time.

Trying to better evaluate this phenomena, this paper analyzed the differentiated evolution of dairy cattle productivity among and inside the Brazilian regions, trying to unveil spatial associations among Brazilian municipalities concerning to their dairy farming productivities. Time period from 1974 through 2016 as well as minimum comparable areas (MCA) are taken into consideration. E*xploratory spatial data analysis* confirmed the existence of spatial autocorrelation of milk productivity, indicating that dairy cattle productivity in one MCA is linked to the productivity reached on its neighboring MCA. Over the analyzed period low-low clusters of dairy productivities have predominated inside the Brazilian North and Northeast regions, which are the poorest regions in Brazil and have held few technical researching centers, technical middle schools and universities dealing with this subject as well as credit for improving their milk production. High-high clusters show up into the Brazilian Southeast and South regions, which are better attended by researching and teaching institutions and rural credit. The configuration and geographic location of these clusters have changed during the studied period. In order to reduce those disparities, at least, improving researching and teaching about milk production and rural credit availability at the Brazilian North and Northeast regions could have spillover effects and led their farmers to increase their dairy farming productivities. However, in order to allow the faraway milk production to reach the consuming markets also a new transportation network would be addressed.

Biography

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