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Milk production systems in Southern Brazil

TIAGO S. TELLES, MATHEUS D. BACCHI, GUSTAVO V. DA COSTA &
AMANDA M.S. SCHUNTZEMBERGER

Abstract: The aim of this study was to verify the dynamics of milk production in Southern Brazil, analyzing the spatial distribution, evolution and structure of bovine milk production systems in the dairy-specialized microregions. To this end, annual data from 2000 to 2015 are drawn from the Municipal Livestock Survey, reported by the Instituto Brasileiro de Geografia e Estatística, and the Programa Nacional de Fortalecimento da Agricultura Familiar, reported by the Banco Central do Brasil. Location quotient analyses, principal component analyses and clustering analyses are applied. Results of the location quotient analysis indicate that, of the 94 microregions in Southern Brazil, 36 are specialized in milk production. Two principal components were identified (mechanized production and family production) capable of explaining 78.3% of the variation in the data. Among microregions specialized in milk production, cluster analysis identifies four groups that are differentiated by productivity levels and predominance of family versus commercial production. Furthermore, results reveal that there is substantial heterogeneity among microregions specialized in bovine milk production in Southern Brazil.

Key words: animal production, spatial analysis, agricultural economics, regional development.

INTRODUCTION

Bovine milk production is of major importance for agrobusiness in Brazil. The milk production is characterized by a number of noteworthy features: (i) production is scattered throughout the country and (ii) there is no nationally standardized system of production. Brazil's small family farms are responsible for 58% of the total milk supply for consumption (Honorato et al. 2014). While milk production occurs throughout Brazil, there are regions where this activity is especially concentrated, with high technological level.

Brazil's Southern Region is the largest producer of milk in the country (Costa et al. 2018). In 2016, Southern Brazil produced 12.45 billion liters of milk, constituting 37% of national production (IBGE 2018). Nonetheless, in terms of productivity and production processes, high levels of heterogeneity persist among Southern states and microregions specialized in dairy activities, with locations differentiated to the greatest degree by levels of technological intensity in milk production (Fernandes et al. 2004, Telles et al. 2017).

The dairy production chain has experienced considerable technological, operational, and institutional transformations, especially from the end of the 1990s onwards. All of these transformations have provoked reactions and adaptations along the production chain, with direct effects on commercialization and the

organizational structure of the Brazilian dairy sector (Oliveira & Silva 2012).

Heterogeneity in milk production in Southern Brazil is the result of both climatic differences between microregions and differences in the interests of the agents involved. Among these differences, some of the most important are relate to traditions of beef production, which are often responsible for low adoption of dairy-related technologies (Fernandes et al. 2004). In other words, microregion-level variation is not the result of physical-geographic characteristics alone, but rather is a function of the technological development and agrarian structure of each microregion. Furthermore, it is important to note that there are many specialized milk producers coexisting alongside agents producing milk as a secondary product either for subsistence or supplementary income (Lemos et al. 2003, Telles et al. 2008).

In Southern Brazil, despite the availability of data on milk production, productivity, and other variables relevant to dairy activity, data on the specialization and spatial distribution of milk producing regions is scarce. Furthermore, data is lacking on levels of technology adoption by producers. There are few studies that attempt to describe milk production and its spatial distribution in this region of the country (Fernandes et al. 2004, Marion-Filho et al. 2011, 2015, Lange et al. 2016, Telles et al. 2017, Bánkuti et al. 2017).

The description and mapping of dairy activity are important inputs for planning and policymaking in the agrobusiness sector. In consideration of the diversity and heterogeneity of milk production in terms of spatial organization and production techniques, there is a need for constant updating and analysis of information. This information is useful for the planning and definition of public policies focused on regional development, as well as for the determination of the allocation of resources such as rural credit (Telles et al. 2017). It is, therefore, of policy-relevance to identify regions specialized in milk production, as well as indicators of regional concentration and evolution.

In this context, the aim of this study was to verify the dynamics of milk production in Southern Brazil, analyzing the spatial distribution, evolution and structure of bovine milk production systems in the dairy-specialized microregions.

MATERIALS AND METHODS

Data from the years 2000 to 2015 cover the 94 microregions of Southern Brazil, as defined by Instituto Brasileiro de Geografia e Estatística (IBGE) of which 39 are in Paraná, 20 in Santa Catarina, and 35 in Rio Grande do Sul. Data were analyzed using location quotient analysis (LQ), principal component analysis (PCA) and clustering.

The LQ was computed using data on gross value of production (GVP) from the Municipal Livestock Survey (Pesquisa Pecuária Municipal – PPM) and Municipal Agricultural Survey (Produção Agrícola Municipal – PAM), both reported by the IBGE. Based on the average GVP (over the sample period), the LQ was utilized to assess microregions specialization in milk production in the Southern Brazil. Specialization is computed as the proportion of GVP for milk over GVP for agriculture, as defined in Lemos et al. (2003) and Telles et al. (2017). Microregions are considered "specialized in milk production" if their LQ ≥ 1, and "not specialized in milk production" if LQ < 1.

PCA was conducted based on average milk productivity (the ratio of quantity of milk produced over number of milk cows, both variables drawn from the PPM), average

GVP, average value of the Programa Nacional de Fortalecimento da Agricultura Familiar (PRONAF), and the LQ. Average value of PRONAF is computed as the sum of program resources destined to expenses and investment in each microregion. Data on PRONAF are reported by the Banco Central do Brasil.

PCA is applied subsequently to those microregions in Paraná identified as "specialized in milk production" by the LQ. In accordance with Fávero et al. (2009), PCA considers total variance in the dataset and finds a linear combination of observed variables that maximizes total explained variance. If the variables are highly correlated, they are combined into a factor, or component, that can explain a larger portion of the variance in the sample. The second component will explain the second largest amount of variance and will be uncorrelated with the first, and so on.

To identify groups showing similar behavior, the PCA was subjected to a hierarchical cluster analysis using Ward's linkage. It was used a cutoff Euclidean distance of 5. Cluster analysis is applied to microregions, with clustering based on degrees of similarity. Clustering is a statistical technique that allows the grouping of variables into homogeneous groups based on defined parameters, in accordance with a measure of similarity or distance (Fávero & Belfiore 2015).

Monetary values are in US dollars (US$) of June 2018. Data analysis was conducted using the software package SPSS 21, and mapping was conducted using ArcGIS 10.2.

RESULTS AND DISCUSSION

Table I shows the statistics on quantity of milk produced, number of milk cows, productivity and gross value of production for the states of Southern Brazil. The evolution of dairy activity in the state of Paraná is noteworthy, since it rises from second-largest milk producer in the Southern region between 2000-2014 to the largest producer in 2015. Despite becoming the largest milk producer in Southern Brazil only in 2015, Paraná already had the largest number of milk cows since 2009, with 42.1% growth in number of milk cows over the 2000 to 2014 period. In Paraná, the progress in milk production is associated with public policies to encourage the development of new areas of production, which was one of main factor for the development of the region called "milk corridor", located in the south of the state (Bánkuti et al. 2017). In relation to the quantity of milk produced, the state of Santa Catarina presented the highest cumulative growth rate (205%) over the 2000 to 2015 period, followed by Paraná with a growth rate of 159% and Rio Grande do Sul with a growth rate of 118.8%. Until 2014, the state of Rio Grande do Sul was the largest producer of milk in the Southern region; however in 2015 the state experienced a reduction in both the number of milk cows and volume of milk produced. Despite this reduction in herd size and production, Rio Grande do Sul nonetheless enjoyed the highest levels of productivity among Southern states, producing 3.07 thousand liters of milk per cow per year. In terms of GVP, Santa Catarina stands out since, despite being the smallest of the three states in absolute terms, it experienced the highest growth rate in productivity between 2000 and 2015 (330.6%), followed by Paraná (250.7%) and Rio Grande do Sul (201.7%).

Based on the calculation of LQ for each microregion, 36 microregions throughout the Southern Region were identified as specialized in milk production (Figure 1). It is noteworthy that, despite substantial heterogeneity in milk production throughout the Southern Region, several of the regions classified as specialized in

Table I. Evolution of milk production, number of milk cows, productivity and gross value of production for states in Southern Brazil.

UF[1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Milk Production (millions of liters)																
PR[2]	1,799	1,890	1,985	2,141	2,395	2,568	2,704	2,701	2,828	3,339	3,596	3,816	3,969	4,347	4,541	4,660
SC[3]	1,003	1,076	1,193	1,332	1,487	1,556	1,710	1,866	2,126	2,218	2,381	2,531	2,718	2,918	2,983	3,060
RS[4]	2,102	2,222	2,330	2,306	2,365	2,468	2,625	2,944	3,315	3,400	3,634	3,879	4,049	4,509	4,687	4,600
Number of milk cows (thousands of cows)																
PR	1,155	1,151	1,187	1,206	1,305	1,362	1,383	1,352	1,332	1,489	1,550	1,589	1,616	1,716	1,726	1,641
SC	577	599	612	643	695	722	784	804	900	934	979	1,022	1,078	1,133	1,107	1,111
RS	1,165	1,204	1,186	1,182	1,202	1,204	1,239	1,325	1,419	1,457	1,496	1,530	1,517	1,555	1,544	1,497
Productivity (thousands liters)																
PR	1.56	1.64	1.67	1.78	1.84	1.89	1.95	2.00	2.12	2.24	2.32	2.40	2.46	2.53	2.63	2.84
SC	1.74	1.80	1.95	2.07	2.14	2.15	2.18	2.32	2.36	2.38	2.43	2.48	2.52	2.58	2.69	2.75
RS	1.80	1.84	1.96	1.95	1.97	2.05	2.12	2.22	2.34	2.33	2.43	2.54	2.67	2.90	3.04	3.07
Gross Value of Production (in millions of US$[5])																
PR	405	393	472	530	644	668	673	763	776	937	1,049	1,186	1,266	1,462	1,487	1,422
SC	208	216	247	325	370	372	429	514	564	583	680	784	845	996	940	897
RS	459	472	524	562	622	593	623	808	900	918	1,010	1,136	1,216	1,486	1,505	1,383

[1]UF: Federal Unit (Unidade da Federação). [2]PR: Paraná. [3]SC: Santa Catarina. [4]RS: Rio Grande do Sul.
[5]Monetary values are in US dollars of june 2018.

milk production by LQ analysis are geographically clustered near each other.

In Rio Grande do Sul, of the 35 existing microregions, 14 were classified as specialized, with 11 of these located in the Northwest Rio-Grandense mesoregion. The remaining three are Gramado-Canela, in the Metropolitan of Porto Alegre mesoregion, Lajeado-Estrela in the Mid-East Rio-Grandense mesoregion, and Guaporé in the Northeast Rio-Grandense mesoregion.

Our results corroborate Marion-Filho et al. (2011), who identify the microregions of Santa Rosa, Três Passos, Cerro Largo, Passo Fundo and Guaporé as those specialized in milk production in Rio Grande do Sul in 2008 according to criteria of productivity growth rates, specialization and concentration of production. Departing from this base, we have made two observations: (i) there was an expansion of dairy activity in the state over the study period and (ii) considering the LQ analysis of the Southern Region as a whole, a larger number of Southern microregions were considered specialized in milk production based on high GVP.

In the state of Santa Catarina, of the 20 existing microregions, 12 were classified as specialized in milk production. All five microregions in the West Catarinense mesoregion, and 3 microregions in the Great Florianópolis mesoregion were identified as specialized. Of the remaining four, Blumenau, Itajaí and Rio do Sul are located in the Vale do Itajaí mesoregion, and Tubarão is located in the South Catarinense mesoregion.

The West Catarinense mesoregion is characterized by agricultural and agroindustrial

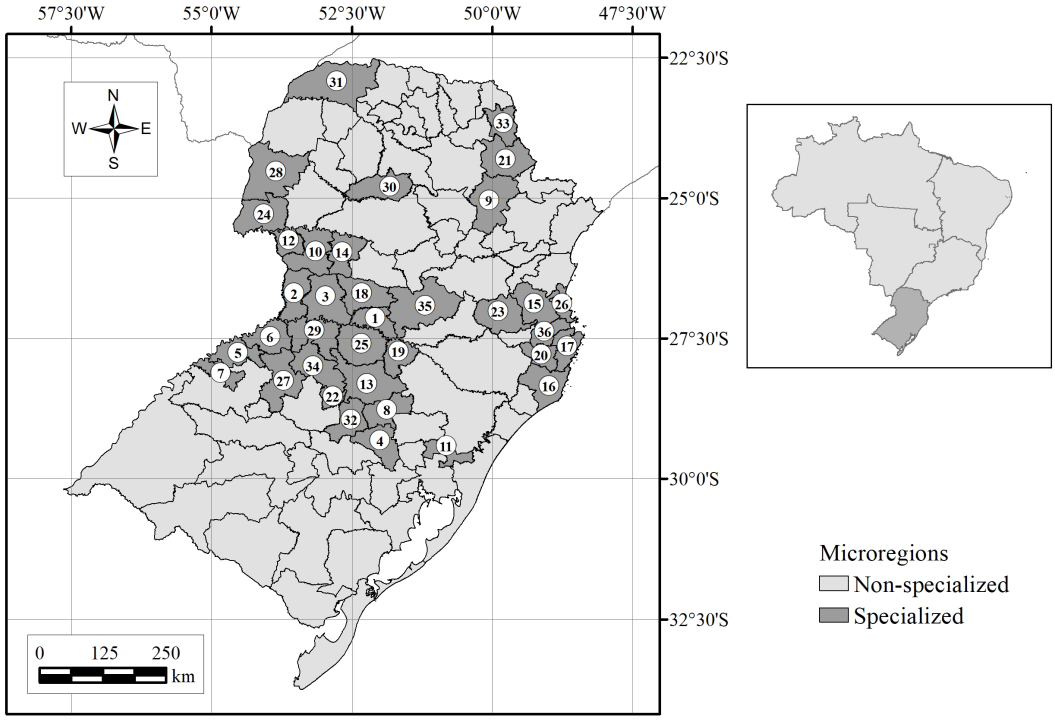

Figure 1. Microregions specialized in milk production in Southern Brazil. Notes: 1. Concórdia. 2. São Miguel do Oeste. 3. Chapecó. 4. Lajeado-Estrela. 5. Santa Rosa. 6. Três Passos. 7. Cerro Largo. 8. Guaporé. 9. Ponta Grossa. 10. Francisco Beltrão. 11. Gramado-Canela. 12. Capanema. 13. Passo Fundo. 14. Pato Branco. 15. Blumenau. 16. Tubarão. 17. Florianópolis. 18. Xanxerê. 19. Sananduva. 20. Tabuleiro. 21. Jaguariaíva. 22. Não-Me-Toque. 23. Rio do Sul. 24. Foz do Iguaçu. 25. Erechim. 26. Itajaí. 27. Ijuí. 28. Toledo. 29. Frederico Westphalen. 30. Pitanga. 31. Paranavaí. 32. Soledade. 33. Wenceslau Braz. 34. Carazinho. 35. Joaçaba. 36. Tijucas.

activities, especially the production of grains and bovine milk and meat production. These activities are dominated by enterprises of 100 hectares or less, with the majority of milk cows concentrated on enterprises of 2 to 5 hectares (Fischer et al. 2011).

In the state of Paraná, of 39 existing microregions, 10 are classified as specialized in milk production. Considering the Southern Region as a whole, Paraná is the state with the greatest heterogeneity, given that microregions classified as specialized in milk production belong to half of all mesoregions in the state: Mid-East, Mid-South, Northwest, Pioneer North and Southwest. This last mesoregion exhibits the most advanced levels of organization and performance of the milk production system in the state, which may be attributed to the intensification and divulgation of technical assistance programs for producers, high levels of training and management, credit incentives for investments in sectoral improvements, and knowledge exchange among producers focused on achieving economies of scale, especially among small producers (Parré et al. 2011).

Based on the PCA, we identified two components that explain 78.33% of variation in the dataset (Figure 2). Component 1 explains 57.5% of the variability and is positively correlated with the variables PRONAF-Investment, GVP, PRONAF-Expenses and LQ, and is composed of microregions that are highly mechanized,

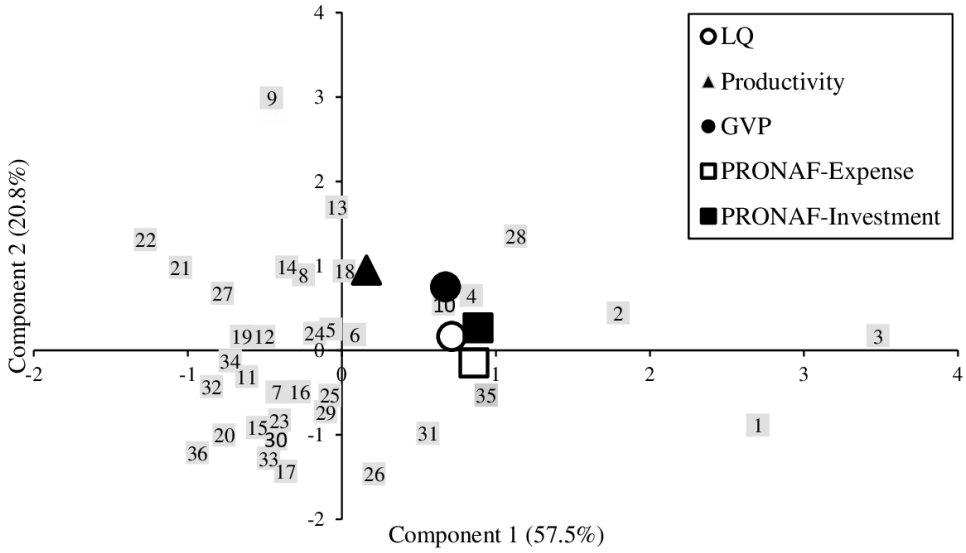

Figure 2. Principal Component Analysis (PCA) of microregions specialized in milk production in Southern Brazil. Notes: LQ: Location Quotient. GVP: Gross Value of Production. PRONAF: National Program to Strengthen Family Agriculture. 1. Concórdia. 2. São Miguel do Oeste. 3. Chapecó. 4. Lajeado-Estrela. 5. Santa Rosa. 6. Três Passos. 7. Cerro Largo. 8. Guaporé. 9. Ponta Grossa. 10. Francisco Beltrão. 11. Gramado-Canela. 12. Capanema. 13. Passo Fundo. 14. Pato Branco. 15. Blumenau. 16. Tubarão. 17. Florianópolis. 18. Xanxerê. 19. Sananduva. 20. Tabuleiro. 21. Jaguariaíva. 22. Não-Me-Toque, 23. Rio do Sul. 24. Foz do Iguaçu. 25. Erechim. 26. Itajaí. 27. Ijuí. 28. Toledo. 29. Frederico Westphalen. 30. Pitanga. 31.Paranavaí. 32. Soledade. 33. Wenceslau Braz. 34. Carazinho. 35. Joaçaba. 36. Tijucas.

productive and specialized. Component 2 explains 20.83% of the variation, is positively correlated with the variable productivity, and is composed of microregions that, in relative terms, do not exhibit high levels of production or specialization, though they present high levels of productivity.

Along these lines, the microregions of Chapecó, São Miguel do Oeste and Toledo are far from the center and strongly associated with the variables PRONAF-Investment, LQ, GVP, and PRONAF-Expenses. The microregions of Lajeado-Estrela and Francisco Beltrão stand out due to their proximity with variables LQ, GVP, and PRONAF-Investment. The microregion Xanxerê, in turn, stands out for its proximity with the variable productivity.

Based on cluster analysis, we identified four clusters (Figure 3). Cluster 1 is composed of the microregions Concórdia and Chapecó, both located in the West Catarinense mesoregion and characterized by high levels of mechanization. Despite exhibiting lower levels of productivity relative to other microregions, both exhibit elevated LQ values and possesses high number of family establishments.

Group 2 is composed of four microregions, all highly productive, with elevated GVP and predominantly family establishments. These microregions are located in the mesoregions West Catarinense, Mid-East Rio Grandense, Southwest and West Paranaense. This area is characterized by increasing levels of modernization of dairy activity. The area has experienced profound structural modification, departing from rudimentary, small-scale production dependent on manual inputs and evolving toward larger scale production systems

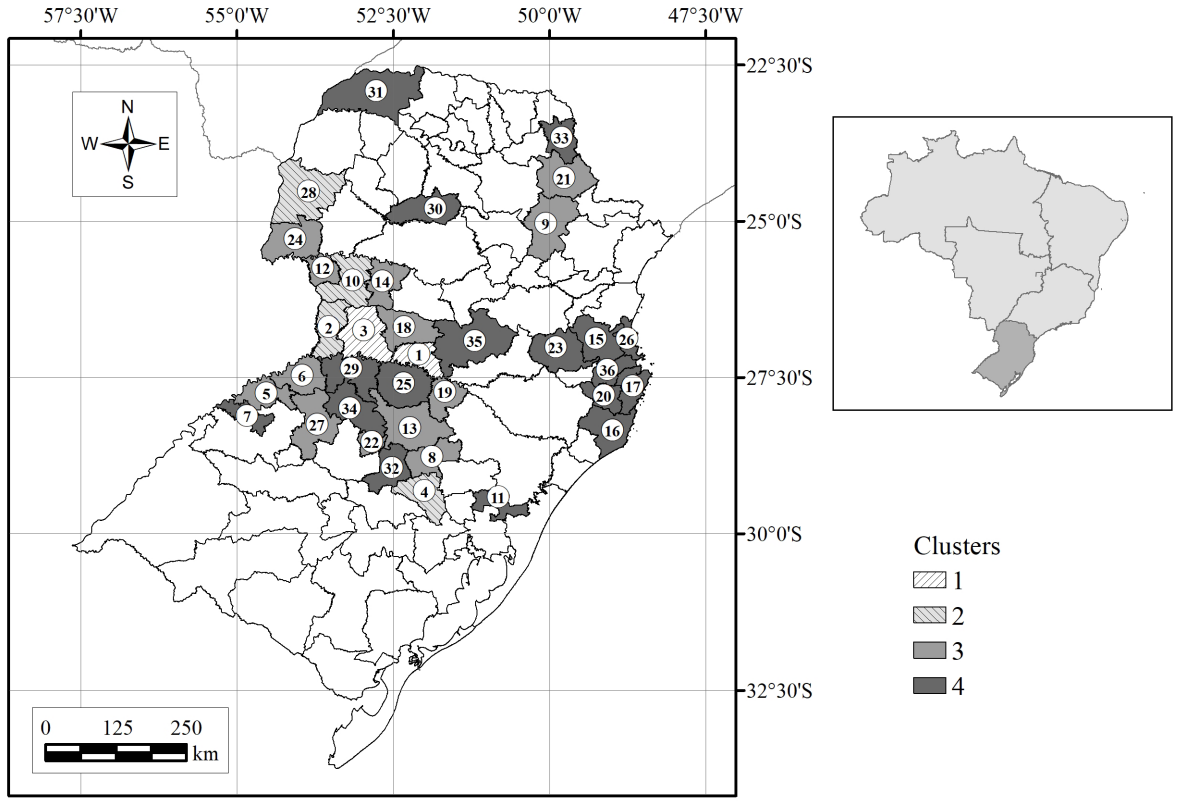

Figure 3. Clustering of microregions specialized in milk production in Southern Brazil. Notes: 1. Concórdia. 2. São Miguel do Oeste. 3. Chapecó. 4. Lajeado-Estrela. 5. Santa Rosa. 6. Três Passos. 7. Cerro Largo. 8. Guaporé. 9. Ponta Grossa. 10. Francisco Beltrão. 11. Gramado-Canela. 12. Capanema. 13. Passo Fundo. 14. Pato Branco. 15. Blumenau. 16. Tubarão. 17. Florianópolis. 18. Xanxerê. 19. Sananduva. 20. Tabuleiro. 21. Jaguariaíva. 22. Não-Me-Toque, 23. Rio do Sul. 24. Foz do Iguaçu. 25. Erechim. 26. Itajaí. 27. Ijuí. 28. Toledo. 29. Frederico Westphalen. 30. Pitanga. 31.Paranavaí. 32. Soledade. 33. Wenceslau Braz. 34. Carazinho. 35. Joaçaba. 36. Tijucas.

with modern technological inputs such as mechanical milkers (Schmitz & Santos 2013).

Group 3 is composed of microregions that possess the highest levels of productivity but few family establishments. These microregions are located in the mesoregions Northwest and Northeast Rio-Grandense, Mid-East and Southwest Paranaense, and West Catarinense. Group 4 is composed of microregions that exhibit lower levels of specialization, productivity, mechanized inputs, and gross value of production relative to the other groups.

It is important to note the proximity between those microregions that exhibit the highest degrees of specialization. These results are similar to those presented in Fernandes et al. (2004), with the exception of microregions in Santa Catarina. This divergence may result from the use of different data series in the two studies.

These microregions form a belt of dairy activity, and the similarity of these microregions may be explained by the presence of spillover effects (Capucho & Parré 2012). In general, our results indicate that, although the Southern Region is the largest milk producer in Brazil, regional disparities are considerable, even among specialized microregions. Considering

just those microregions identified as specialized, there are those characterized by: (i) elevated productivity and predominance of commercial producers; (ii) elevated productivity and predominance of family producers; (iii) lower levels of productivity and predominance of commercial producers; (iv) lower levels of productivity and predominance of family producers. Beyond this typology, it is possible to identify substantial gaps between different regions within Southern Brazil, especially in relation to productivity levels, GVP and LQ. Our results show that a standardized milk production system does not exist in Southern Brazil.

We may conclude that there are no defined patterns of dairy production across the diverse microregions included in this analysis, since these include establishments ranging from subsistence production to highly mechanized, large-scale enterprises (Zoccal & Gomes 2005).

The same demands driving increases in milk production and productivity also create new problems or accentuate old ones related to the production chain, some of which fall within the institutional sphere. These problems, both new and old, generate distrust along the supply chain relating to regulation and quality control (Oliveira & Silva 2012). Nevertheless, organizational changes have occurred that increasingly allow small cooperatives to create competitive advantages and enable increases in production and living standards for family farmers (Schubert & Niederle 2011).

Among the factors fostering synergies in milk production in the region, it is important to highlight optimization of a labor force specialized for the dairy sector, favorable climatic conditions, the predominance of populations with European heritage, appropriate nutritional inputs for herd health, and the cooperative production structure (Capucho & Parré 2012, Lopes Junior et al. 2012). Further improvements in productivity could be gained from genetic improvements in livestock, improved livestock feeds and care, and other production-enhancing technological inputs (Fischer 2011).

Considering the spatial distribution of the clusters, it is important to note that the climatic conditions and restrictions into which each microregion specialized in milk production is inserted are important explanators of cluster formation. Furthermore, technologies adopted for milk production in each locality are developed in consonance with the physical-geographic characteristics and agrarian structures of the locale. Given these complex biophysical, technical, and social interactions, it is natural that high levels of heterogeneity persist.

Nevertheless, regional inequalities may be minimized through the design and application of public policies focused on overcoming production bottlenecks within each microregion, with the objective of generating gains in milk production and productivity in Southern Brazil (Costa et al. 2013). Along these lines, investments should be directed toward regions that already exhibit relative levels of specialization, allowing spillovers to occur naturally and fortifying the broader adoption of efficient production systems.

A well-structured productive cluster requires less incentive for development, since to expand regionally new areas for herd, financial incentives are needed to improve infrastructure, logistics and adaptation to environmental issues thus, it demands a good public policy and that restrict the migratory phenomenon (McManus et al. 2016).

CONCLUSIONS

We were able to apply three stages of analysis. Firstly, the LQ analysis reveals that 36 of 94

microregions in Southern Brazil are specialized in milk production, then, using PCA, we identified two components that were capable to explain 78.3% of the variability observed in the dataset. The first component consists in microregions with high specialization, high GVP and utilization of rural credit from PRONAF for both investment and expenses, on the other hand, the second one consists in microregions with elevated levels of productivity. The last stage, based on cluster analysis, we identified four clusters. The first one is composed in microregions of Concórdia and Chapecó, which stand out for their high levels of specialization, that is, the high level of absolute and relative importance of bovine milk production for these locations. The second one is composed of microregions with high levels of mechanized production. The third one contains microregions characterized by high levels of productivity and low proportions of family establishments and the fourth clusters miroregions stand out for their proximity to more specialized microregions illustrating spillover effects. Thus, we demonstrated that Brazil's Southern Region is characterized by accentuated heterogeneity in milk production, even among microregions specialized in this activity.

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TIAGO S. TELLES[1]
https://orcid.org/0000-0001-5817-3420

MATHEUS D. BACCHI[2]
https://orcid.org/0000-0001-7510-7695

GUSTAVO V. DA COSTA[3]
https://orcid.org/0000-0002-1115-3892

AMANDA M.S. SCHUNTZEMBERGER[4]
https://orcid.org/0000-0002-7627-2091

[1]Instituto Agronômico do Paraná, Rodovia Celso Garcia Cid, Km 375, Gleba Fazenda Palhano, 86047-902 Londrina, PR, Brazil

[2]Departamento de Economia, Administração e Sociologia, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Av. Pádua Dias, 11, São Dimas, 13418-900 Piracicaba, SP, Brazil

[3]Departamento de Agronomia, Universidade Estadual de Londrina, Rodovia Celso Garcia Cid, Km 380, 86057-970 Londrina, PR, Brazil

[4]Departamento de Zootecnia, Universidade Estadual de Londrina, Rodovia Celso Garcia Cid, Km 380, 86057-970 Londrina, PR, Brazil

Correspondence to: **Tiago Santos Telles**
E-mail: telles@iapar.br

Author contributions

TST and MDB conceived the study conceptualization. TST, MDB and GVC conducted the data curation, methodology, formal analysis, and writing, review and editing. AMSS collaborated in the writing. TST performed the project administration. All authors reviewed the manuscript.