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The importance of institutions in agricultural productivity in municipalities of Southern Brazil

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Abstract
This study correlates institutions with productivity in the agricultural sector in municipalities in the southern region of Brazil. The argument is based on the institutionalist approach, considering institutions as actors that can impact the economy. The methodology includes the elaboration of a productivity indicator using the fuzzy logic and we evaluated this indicator through the cluster analysis and the linear regression using data from 2006 Agricultural Census. The cluster analysis showed that part of the municipalities in southern Brazil presents low agricultural productivity based on variables of technical assistance, association, qualification, and teaching institutions as proxies. However, the regression analysis indicated a positive interaction between institutions and productivity in almost all regions. The main explicative variable was technical assistance, possibly due to a greater diversity of institutions that provide this service and because it generates more immediate results to production factors.
Keywords: Institutions. Agriculture and Livestock Productivity. Southern Region. Fuzzy logic.

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1 Introduction

Crop farming has historically played an important role in the Brazilian economy, as Brazil's economy has relied almost solely on the export performance of agricultural commodities from the colonial times through the imperial period to the republic. Data from the Ministry of Agriculture and Livestock show that products from various agribusiness sectors had a major contribution to the Brazilian trade balance in 2022, accounting for 47% of the country's total exports in the same year, and 25% of which came from the southern region of Brazil (Ministério da Agricultura e Pecuária [MAPA], 2023).

In 2022, the agribusiness sector accounted for 25% of the country's Gross Domestic Product (GDP), 18% of which came from agriculture and 7% from livestock. Considering only the primary sector in this scenario, agriculture contributed to 4.3% of Brazil's GDP in 2022, while livestock contributed to 2.6% (Centro de Estudos Avançados em Economia Aplicada [CEPEA], 2023).

These results reflect the growing productivity of the agricultural sector. For five decades, productivity of Brazilian agriculture has been on an upward trend, registering an average annual growth rate of 2.03% between 1970 and 2017. During this period, productivity accounted for 63.1% of the increase in the sector output (Gasques, Bastos, Bacchi, Vieira Filho, & Valdes, 2023).

This increase of agricultural productivity is attributed mainly to investments in research by public institutions, such as Embrapa (Brazilian Agricultural Research Corporation), federal and state universities and institutes, as well as public policies aimed at the sector (Gasques, Bastos, & Bacchi, 2008; Gasques, Bastos, Bacchi, & Valdes, 2010; Gasques et al., 2023).

Thus, public policies and private initiatives, supported by various institutions, usually focus on agricultural productivity due to the important role of agriculture to the Brazilian economy. In this sense, the literature argues that research agencies closely linked to agriculture enable partnerships, co-operation and consequently knowledge transfer (Dossa & Segatto, 2010), which can significantly improve agricultural productivity in Brazil (Felema, Raiher, & Ferreira, 2013). Therefore, the influence of interaction and co-operation between institutions and productivity of the agricultural sector needs further investigations to validate this argument, more specifically for agricultural productivity in the southern region of the country. We also investigated which institution (educational, research and extension) has greater contribution to increase productivity in the agricultural sector in the region under analysis, as well as in which state in the southern region of Brazil these institutions play a more prominent role in the dynamics of agricultural productivity. Here, we analysed the relationship between institutions of agricultural support in southern Brazil and their role in productivity of the sector.

The analysis encompassed municipalities in the southern region of Brazil and the theoretical discussion framework is based on the institutionalist school, which assumes that institutions can influence the techno-productive knowledge of the agricultural sector, affecting its technological trajectory and thus its productivity. At the time of the research, the data available for analysis was from the 2006 Agricultural Census, which is still relevant to evaluate public policies in the sector, given the stability of institutions over time.

This study is organized into five sections, including this introduction. Section 2 provides a theoretical overview of the main institutionalist currents and the relationship between the concepts presented and the agricultural sector. Section 3 presents the methodological procedures used, leading to the results in section 4. Final considerations are presented in section 5.

2 Institutions and agriculture

2.1 Theoretical aspects

According to the institutionalist school, the economy relates to politics, sociology, laws, customs, and ideologies. It should therefore be analysed as a whole and not in small isolated parts, due to the existence of collective action patterns that are greater than the individual behaviour of the parts. The institutionalist school can be divided into three main currents: old institutionalists, neo-institutionalists, and New Institutional Economics (NIE). Veblen (1983), a representative of old institutionalism, argues that society evolution is a process of mental adaptation of individuals under pressure of circumstances that no longer allow for mental habits formed from past circumstances. Thus, today's habits tend to remain indefinitely, except when

circumstances force a change. For the author, forces that lead to the readjustment of institutions are almost entirely economic mainly in the case of the modern industrial community.

The Veblen's line of reasoning allows to analyse productivity of agricultural workers. Many producers have changed their working techniques due to the growth of the agricultural sector and because of changes in consumer demands. How many producers manage to adapt to the new scenarios? How many are displaced to other activities? These are valid questions when considering the possible conservative nature of the sector. Production techniques in agriculture are commonly handed down from a generation to another; nevertheless, producers who opt for conservatism to the detriment of adaptations to a new environment may not survive in the market. Moreover, producers who do not integrate into the agribusiness environment may be driven away to other activities, due to inefficiency to compete in this scenario.

Commons (2003) follows the same institutionalist lines, which prescribe that an institution is a collective action that controls, liberates, and expands individual action. Collective actions include everything from unorganised customs to the various interests at work, such as family, corporation, the union, and the state. Based on the "various interests at work" of Commons (2003), farmers can choose to be part of a group to protect themselves against market fluctuations through easier access to credit, better conditions to negotiate with suppliers and purchasers, certifications, knowledge and information gathering, as well as and assurance of rights.

The neo-institutionalist current emerged in the 1960s, continuing the line of thinking of American institutionalism. Hodgson (2001) is among the most prominent authors, who defines institutions as lasting systems of social rules that structure social interaction, namely currency, laws, a system of weights and measures, enterprises, and other organisations. The market is also an institution that involves social norms, customs, established exchange relationships, and information networks. Based on Hodgson's ideas, Belik, Reydon, Neto, and Guedes (2007) state that corporate organisations are characterised as an instrument of social control, as they are institutions formed by individual interests, which are also influenced by group interests. Neo-corporatism suggests that group interests are based on the function of their members in the social division of labour rather than their position in the social class. This approach depicts the interaction of public agencies and group interests on a sectoral basis without aggregating broad class interests.

As for the new institutionalists, the New Institutional Economics (NIE) also advanced from the 1960s onwards and Douglass North is among its main authors. North (1991) highlights the importance of institutions to determine a country's economic performance. In a well-structured way, the author distinguishes two types of institutions: formal institutions, represented by laws and regulations, and informal institutions, such as social norms and practices. From this perspective, according to the author, institutions determine the economic performance of a country or region with a direct influence. In addition, formal institutions provide economic agents with a degree of stability and predictability, which in turn stimulates investment, innovation and, consequently, higher productivity. Informal institutions, on the other hand, which also play an important role in the society, change people's behaviour just as significantly or even more than formal institutions. According to North (1991), these are social norms and cultural values that can influence individual choices and, in turn, affect the functioning of the market and the economic development of a society. In this context, the author emphasises that the concept of path dependence refers to the idea that current and future results are conditioned by past decisions and events.

In another more specific study, North (1990) states that organisations include political bodies (political parties, parliaments, and regulatory agencies), economic bodies (companies, unions, cooperatives, and family farming), social bodies (churches and athletic associations) and educational bodies (schools and universities). For the author, organisations emerge due to opportunities that arise from the set of constraints and represent agents of change by trying to achieve their objectives. As for restrictions, the author highlights informal restrictions (sanctions, taboos, customs, traditions, and codes of conduct), which reflect the characteristics of a society and affect the dynamics of the innovation process. On the other hand, enforcement situations generally act in a positive sense, that is, they are formal rules which require compliance of certain measures by force of law.

According to North (1991), the concept of enforcement relates to the role of institutions to guarantee and apply the rules and norms that govern economic activities. Institutions shape the behaviour of agents through enforcement, which is crucial to ensure the proper functioning of markets and economic stability. In addition, the quality of enforcement has significant implications for the economic development of a country or a region, while its effectiveness stimulates investment, innovation, and economic growth. Generally speaking, the concept of enforcement plays a central role in understanding how institutions shape the economic behaviour, structure the institutional environment in which organisations operate and influence the development of societies.

According to Zylbersztajn (2000), organisations adapt to or modify the institutional environment to suit their interests. From this perspective, organisations within institutional environments are the determining actors in the productive dynamics of any economic activity. Therefore, according to Saes (2000), the result of interaction between individuals representing organisations allows for more efficient decisions to achieve common objectives.

In this context, corroborating the analyses of North (1991), Zylbersztajn and Sztajn (2005) state that rules of conduct shape interpersonal relationships and the institutional environment. Thus, institutions impact and are impacted by the law, the economy, and organisations.

Regarding the institutional environment of the agricultural sector, cooperatives and associations are organisations that consist of different individuals coming together to achieve a common goal (Saes, 2000), while educational institutions and research and extension institutions involve defining the kind of knowledge to be developed and transmitted, determining the short- and long-term results of techniques and inputs used.

In addition, organisations with which rural producers have direct contact in their search for knowledge also need to be taken into account in this context. Educational institutions and research and rural extension agencies, as well as agricultural co-operatives, are capable of guiding producers' learning towards specific techniques, products, processes, and even forms of marketing. These organisations can also develop projects to help producers seek out knowledge thus contributing to their informational independence. In addition, producers with a lower level of formal education may find it more difficult to learn new techniques, adopt management measures, or even make decisions on their own. Therefore, information that producers receive and interpret is a relevant factor in their decision-making process, as it impacts the evolution of the sector historical trajectory (Dosi, 1982).

2.2 Empirical evidence

In this institutional context, agricultural technology is considered multidisciplinary and its convergence is not a fully coordinated process. For Possas, Salles-Filho and Silveira (1994), technological sources change in agriculture can be analysed internally and externally. The internal analysis concerns innovation sources in the sector, such as public and private institutions, non-profit organisations, and the production unit itself, while the external analysis refers to agricultural policies, environmental pressures, advances in biology, and new consumption patterns.

In the context of internal analysis, Dossa and Segatto (2010) investigated the partnership between Embrapa and educational institutions in Brazil and highlighted some results of these cooperations for innovation of products and processes, the learning and accumulation of experiences, the development of new projects, the optimization of resources, and the reduction of risks and time spent. Likewise, in view of the importance of knowledge in productivity, Dill et al. (2015) concluded that access to the internet, participation in producer associations, and technical assistance can have a positive impact on results in the agricultural sector.

Felema, Raiher and Ferreira (2013) showed that agriculture in the southern and southeastern regions of Brazil has higher productivity in terms of land and labour than the other regions and that most Brazilian municipalities have a low productivity index. Agricultural inputs and mechanization have an influence on the sector performance in most Brazilian states and access to knowledge by workers can have a positive effect on the country's agricultural productivity. These results corroborate Gasques, Bastos, and Bacchi (2008) and Gasques, Bastos, Bacchi, and Valdes (2010).

Felema and Spolador (2023) observed an increase in Total Factor Productivity (TFP), mainly due to the expansion of the agricultural frontier based on the decomposition of TFP. The authors also reported that technical efficiency was positively related to the rise in TFP, along with the adoption of new technologies, facilitated by spatial proximity (neighbourhood). In this same line of analysis, Gasques, Bastos, Bacchi, Vieira Filho, and Valdes (2023) also showed that TFP was higher in Brazil than the world average (3.31% against 1.12% per year, respectively) over a longer period (46 years). According to the authors, this performance is associated to prices received and paid by producers, rural credit, and investments in research.

Torres (2023) analysed different studies on investments in research and productivity in Brazilian agriculture and found a strong convergence on the high returns from agricultural research and its positive impact on the productivity of the sector. On the other hand, Aragão (2023) analysed the national agricultural research system and underscored weaknesses in its implementation, mainly in terms of the inability to integrate and coordinate public agricultural R&D organizations, notably Embrapa, as well as the instruments to coordinate the system as a whole. Several studies have been conducted on this inability; however, few works have investigated the importance of institutions linked to agriculture, mainly in a segmented and regionalised way, in the sector productivity performance. Thus, the present study is relevant and adds new findings to the existing literature.

3 Methodology

In this study, a productivity indicator was developed for agriculture in the southern region of Brazil using the fuzzy logic. This indicator was then analysed using the cluster analysis and the multiple linear regression. The data used to create the productivity indicator as

well as the data used in the regressions refer to the 2006 Agricultural Census[1] and were obtained from the IBGE Automatic Retrieval System (SIDRA, 2020).

3.1 Fuzzy logic

Many studies have used the fuzzy logic to evaluate the performance of the agricultural sector, such as Khatchatourian and Treter (2010), Lima, Abreu, Santos, and Massruhá (2012), Bagolin, Souza, Mattos and Gautério (2013), and Conde, Rodriguez, Paes-de-Souza, and Souza Filho (2014). The fuzzy logic shows some advantages, as it does not depend on values from past years, unlike TFP, it allows more variables to be added in addition to factors of production, and it allows to classify individuals observed in a comparative way within the group. According to Simões and Shaw (2007), the real world is not bivalent and thus the aim of the fuzzy logic is to capture different degrees of truth, working with uncertainties in a systematic and rigorous way.

The fundamental property of the fuzzy logic is that the pertinence function has all values within the interval [0, 1], which means that an element can be a partial member of a set, represented by a fractional value. The fuzzy logic is based on the fact that sets have imprecise boundaries, where the transition from non-pertinence to pertinence is gradual (Simões & Shaw, 2007).

In the present study, the fuzzy logic was used to resolve the ambiguity between "more productive" and "less productive", considering the agricultural activity of the municipalities analysed. It is understood that municipalities can have different productivity degrees rather than a division into two clear groups. Therefore, once the term has been quantified, it assumes a degree of computational usefulness, moving from indistinct to diffuse (COX, 1994)

As described by Atanassov (2017), in 1965, Zadeh introduced the concept of the fuzzy sets, which became established as a method to evaluate objects and processes in nature and society. In this context, the fuzzy sets became the subject of extensions and, more recently, some authors introduced the term "type 1 fuzzy set" (T1FS) to refer to Zadeh's fuzzy set, used in this work. According to Zadeh (1965), a fuzzy set is characterised by a function that assigns each object a membership grade that varies between 0 and 1. If X is a space of points (objects), with a generic element of X denoted by x, then X = {x}. A fuzzy set (class) A in X is characterised by a function fA(x), which associates to each point in X a real number in the interval [0, 1] with the value of fA(x), where x represents the membership degree of x in A. Thus, the closer the value of fA(x) is to 1, the greater the pertinence degree of x in A.

The pertinence functions assume that the variables are equidistant from each other and assume direct proportionality between the elements of the domain and with the adherence degree. In this context, there are two main classes of linear representations. Firstly, the trapezoidal specification postulates the choice of two threshold values greater than the minimum value of x and lower than the maximum value. Secondly, the basic linear function depends exclusively on the extreme values of variable x (Lelli, 2001).

In this study, we decided to develop an agricultural productivity indicator using the fuzzy logic to analyse each municipality in the southern region of Brazil. To this end, the basic linear representation described by Lelli (2001) was used, according to Equation (3.1).

[1] Data available at the time of writing, although data from the new Agricultural Census is expected to be available soon. Still, it is assumed that the results will not be affected, as institutions have a certain "rigidity" over time (North, 1990 and 1991; Hodgson, 2001). Furthermore, these results can be compared with the results of future research from the same perspective.

$$|x_{ij}| = \begin{cases} 0 & \text{se } a = a_{min} \\ \frac{a - a_{min}}{a_{max} - a_{min}} & \text{se } a_{min} < a < a_{max} \\ 1 & \text{se } a = a_{max} \end{cases} \quad (3.1)$$

Where: xij is the productivity index of municipality i in attribute j; a is the productivity of municipality i in attribute j in absolute terms; amin is the lowest value and amax the highest productivity value in attribute j, in absolute terms, in the set of municipalities analysed. In other words, productivity of the agricultural production factors (land, capital, and labour) in the municipalities under analysis constitutes the domain of the fuzzy set. The lower and upper limits of the domain are considered the lowest and the highest productivity values found, respectively.

To construct the productivity indicator for each municipality (yi), three agricultural productivity proxies were used, representing three attributes (j): land income, capital income, and labour income. Land income was obtained by dividing the value of municipality agricultural production by the area of establishments in hectares. Capital income was obtained by dividing the production value by the value of "real estate" (buildings, real estate, and other improvements) and "other assets" (vehicles, tractors, machinery, and implements) in agricultural establishments, according to the classification of the Brazilian Institute of Geography and Statistics (IBGE). Labour income was calculated by dividing the value of agricultural production by the Economically Active Population (EAP) in the sector.

Cox (1994) emphasises that the fuzzy models allow to weight the importance of variables by providing a weight multiplier, which concentrate the set strength, according to the defined weighting. For Lelli (2001), the notion of frequency is also considered useful to define adherence degrees in relation to the distribution of elements in the population analysed. One way of applying this notion of frequency is to take into account the deprivation degree of the attribute analysed and derive a group of weighted average operators. Thus, the lower the presence of a given characteristic in the units analysed, the greater its weight (w) in the indicator formulation, since the unit that possesses this characteristic is comparatively above the others. Thus:

$$w_j = -\ln\left[\frac{1}{n}\sum x_{ij}\right] \quad (3.2)$$

Where: wj is the weight of the attribute analysed and n is the number of observations.

The productivity indicator for each municipality considering all the attributes is given by Equation (3.3), which represents an average weighted by the weights.

$$y_i = \sum x_{ij} w_j / \sum w_j \quad (3.3)$$

Where: y_i is the fuzzy productivity indicator for each municipality i. Therefore, y_i varies between 0 and 1, and the closer it is to 1, the higher the agricultural productivity of the municipality in question (i). The aggregate productivity indicator for each state or even for the entire southern region can be analysed by taking the arithmetic average of the indicators for its member municipalities.

3.2 Cluster analysis

The cluster analysis involves techniques and algorithms to find and separate objects into g groups (clusters), given a sample of n objects, each measured in p variables (Favero, 2009;

Corrar, Paulo, & Dias Filho, 2012). In this study, the Euclidean Squared Distance was used as a measure of similarity, which consists of the distance between two observations (i and j) corresponding to the sum of the squares of differences between i and j for all p variables (Favero, 2009).

The clustering algorithm used the hierarchical procedure, the agglomerative method, with the Average Linkage or Between Groups method to form clusters. Hierarchical procedures consist of building a tree-like hierarchy. In the agglomerative method, each observation consists of a group initially, combining with other groups in the following stages. The method Between Groups treats the distance between two groups as the average distance between all pairs of their elements, seeking to agglomerate clusters with the lowest average distance. This technique has the advantage of using all the elements in the set rather than a single pair of extreme values (Favero, 2009). One option for the stopping rule used in this work consists of observing the successive values of the distance measure. When a large increase occurs, the previous solution is selected based on the logic that the last combination caused a substantial decrease in similarity (Corrar et al., 2012).

3.3 Multiple linear regression

The multiple linear regression model is used to study the relationship between a dependent variable (Y) and one or more independent variables (X). In this study, in order to assess the role of institutions in agricultural productivity, the regressions relate the productivity of the agricultural sector (y_i) as the dependent variable of the variables listed in Table 1. The idea is to capture the effects of institutions on agricultural performance, since these institutions involve services to improve technological efficiency, such as teaching, research, extension, technical assistance and associations. Two regressions were estimated for each state and for the southern region as a whole, one included co-operatives in the provision of technical assistance, while the other did not.

Activities of universities regarding research, teaching, and extension are often not restricted to their home municipality; therefore, neighbouring municipalities that had higher education courses on agriculture in 2006 also received a value of 1 for the "D_ens" variable, while the other municipalities received a value of 0. Information on higher education courses was obtained from the E-Mec portal (E-MEC, 2023) and refers to the following courses: Agronomy, Agricultural Engineering, Aquaculture Engineering, Fisheries Engineering, Forestry Engineering, Veterinary Medicine, and Animal Science.

The "Finan" and "Insum" variables were included to the model as control variables to avoid parameter bias due to the variables omitted. Regarding the expected signs based on the literature, it is assumed that more efficient production factors require fewer inputs for a good yield. In this case, the relationship is expected to be inverse between input expenditure and productivity. The parameters of the other variables are expected to show positive signs, indicating that the greater their presence, the greater the agricultural productivity. This result corroborates the hypothesis that agricultural institutions make a positive contribution to the sector performance in the southern states of Brazil.

Table 1
Description of the explanatory variables

Variable	Description	Representation	Expected sign	Reference authors
Assis	Percentage of agricultural establishments in the municipality that received technical assistance, regardless of the service source.	X_{2i}	+	Dossa and Segatto (2010); Dill et al. (2015).
Assis'	Percentage of agricultural establishments in the municipality that received technical assistance, except for cases where it was provided by cooperatives.	X_{2i}'	+	
Assoc	Percentage of agricultural establishments in the municipality where the producer was a member of a cooperative or trade organisation.	X_{3i}	+	Dill et al. (2015).
Qualif	Percentage of people employed in agricultural establishments in the municipality with professional qualifications.	X_{4i}	+	Dossa and Segatto (2010); Felema, et al. (2013); Dill et al. (2015).
D_ens	Binary variable indicating the municipalities that had a higher education course related to agriculture in 2006, as well as their neighbours.	D_{1i}	+	
Finan	Percentage of agricultural establishments in the municipality that obtained funding.	X_{6i}	+	Gasques et al., (2010; 2023).
Insum	Ratio of input expenses to the value of the establishment production.	X_{7i}	–	Felema et al. (2013).

Two binary variables were also included to the equations estimated for the southern region in Brazil: one for municipalities of Santa Catarina (D2i) and another for municipalities of Rio Grande do Sul (D3i), while the state of Paraná was the reference category. The dependent and independent variables were logarithmised to improve the fit of the model and to analyse the relationships in percentage terms. The parameters were considered statistically significant at 10%. Thus, the regression models (OLS) estimated for the southern region were:

$$y_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 D_{1i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 D_{2i} + \beta_9 D_{3i} + u_i \quad (3.6)$$

$$y_i = \beta_1 + \beta_2 X_{2i}' + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 D_{1i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 D_{2i} + \beta_9 D_{3i} + u_i \quad (3.6')$$

The regressions using the productivity indicator calculated on the basis of information from the municipalities in each state [y(e)] are described in Equations 3.7 and 3.7':

$$ye_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 D_{1i} + \beta_6 X_{6i} + \beta_7 X_{7i} + u_i \quad (3.7)$$

$$ye_i = \beta_1 + \beta_2 X_{2i}' + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 D_{1i} + \beta_6 X_{6i} + \beta_7 X_{7i} + u_i \quad (3.7')$$

4 Results and discussion

Table 2 shows the descriptive statistics for the production factors and the productivity indicator for each state (y(e)) and for the southern region as a whole (y), after excluding outliers. When considering the productivity indicator for the southern region as a whole (y), Paraná State showed the highest average (y) (0.1737), followed by Santa Catarina (0.1730), which were above the regional average (0.1684). Both the minimum value (0.0030) and the maximum value (0.7176) of y belong to Paraná State, which justifies its higher standard deviation (0.1023).

Table 2

Descriptive statistics for the land (S), capital (K) and labour (L) income variables, productivity (y) for the southern region and estimated productivity for the states [y(e)]

		S income	K income	L income	y	y(e)
PR	Mean	1.205,02	0,90	17.213,74	0,1737	0,1897
	Median	1.011,36	0,73	13.406,22	0,1478	0,1640
	Minimum	18,76	0,07	548,48	0,0030	0,0000
	Maximum	5.068,87	5,87	81.572,17	0,7176	0,7969
	Standard deviation	804,76	0,69	12.325,31	0,1023	0,1123
	n = 394					
SC	Mean	1.761,02	0,68	14.825,77	0,1730	0,2418
	Median	1.477,22	0,58	12.540,59	0,1536	0,2176
	Minimum	55,15	0,03	1.815,50	0,0154	0,0165
	Maximum	6.275,22	2,63	64.597,11	0,5731	0,8039
	Standard deviation	1.207,98	0,39	9.421,18	0,0938	0,1330
	n = 289					
RS	Mean	1.512,33	0,62	15.674,31	0,1616	0,2065
	Median	1.250,00	0,56	11.706,67	0,1389	0,1786
	Minimum	92,23	0,06	1.009,51	0,0178	0,0190
	Maximum	6.898,93	2,48	80.388,10	0,5620	0,7363
	Standard deviation	1.087,56	0,32	12.391,41	0,0825	0,1072
	n = 489					
South	Mean	1.470,34	0,73	15.982,59	0,1684	-
	Median	1.207,01	0,61	12.390,01	0,1459	-
	Minimum	18,76	0,03	548,48	0,0030	-
	Maximum	6.898,93	5,87	81.572,17	0,7176	-
	Standard deviation	1.056,54	0,50	11.743,12	0,0925	-
	n = 1172					

Paraná State displayed a better performance in the productivity indicator which is the result of its income from capital and labour, as these variables received the greatest weight in

the calculation of y. The fuzzy logic weights its indicator according to the relative scarcity of the items analysed; thus, capital and labour income proved to be scarcer than land income in the southern region. Paraná State performed better in these factors and showed higher productivity than the other states in the region, corroborating Gasques et al. (2010; 2023) in that the increase in productivity in Brazilian agriculture is associated to an increase in labour productivity due to better qualified rural workers. Dossa and Segatto (2010) also underscored that knowledge and experiences have a positive impact on agricultural productivity. Felema et al. (2013) analysed access of producers to knowledge and also reported the importance of human capital in agricultural productivity.

The use of the basic linear representation in the fuzzy logic required the exclusion of municipalities with outlier values to allow for the analysis of the indicator. This exclusion provide more homogeneous and unbiased productivity results. In turn, the use of scarcity-weighting was interesting to compare productivity between the different production factors.

The cluster analysis was carried out to check for significant differences among municipalities in the southern states in terms of the agricultural productivity level and to better visualise the geographical distribution of y values. The results showed the formation of four clusters (Table 3).

Table 3
Characterisation of productivity clusters (y) for the southern region in Brazil

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Nº. of municipalities	180	950	39	3
Average productivity (y)	0.2832	0.1330	0.4613	0.6770
Average technical assistance (%)	58.08	49.73	53.83	40.06
Average associations (%)	57.16	54.89	53.58	33.01
Average financing (%)	34.90	35.50	30.53	27.58
Average qualification (%)	7.09	4.86	6.57	4.61
Average inputs (%)	21.71	31.95	23.09	25.30

Cluster 2 had the largest number of municipalities (950), accounting for 81% of the sample, and also the lowest average productivity indicator (0.1330). Cluster 1 was second in terms of the number of municipalities (180) and productivity, in the ascending order, followed by Cluster 3 with 39 municipalities, and Cluster 4 with only three municipalities. These results converge with those found by Felema et al. (2013) in that most Brazilian municipalities have a low agricultural productivity index, possibly attributed to the difficulties to implement and coordinate agricultural research, as cited by Aragão (2023). This could be a sign of problems in the institutional environment (Zylbersztajn; Sztajn, 2005) with weak enforcement effectiveness (North, 1991) as well as a slow readjustment of institutions in the absence of circumstantial pressures, as predicted by Veblen (1983).

In addition, the concentration of the largest number of municipalities in two clusters reflects the relative homogeneity in the productivity indicator. Nevertheless, the cluster analysis allowed to distinguish statistically distinct groups of municipalities, showing that that the fuzzy logic was effective to define the pertinence between clusters.

Based on the analyses of Dill et al. (2015), Felema and Spolador (2023) and Torres (2023), the hypothesis is that institutions contribute to increasing the agricultural productivity indicator. Thus, it is expected that the higher the average productivity in the cluster, the higher

the average of the variables related to technical assistance, associations, financing and qualifications, and the lower the average of the variable inputs. Cluster 2 was therefore expected to have the lowest values for the proxy variables of institutions and financing, and the highest percentage use of inputs. Similarly, Cluster 4 was expected to have the highest values for the proxy variables of institutions and financing, and the lowest value for the percentage use of inputs. However, the results were different from expected[2].

Figure 1 was drawn to geographically demonstrate the distribution of productivity indicator clusters, illustrating municipalities associated to the clusters found. Since Cluster 2 had the lowest average productivity, it was considered better to illustrate it in a lighter colour for didactic purposes. Figure 1 also shows municipalities that had a decentralised Embrapa unit or a higher education course related to agriculture in 2006. The units of state institutions focused on agriculture, such as technical assistance and research companies and cooperatives, were not illustrated because they are present in almost every municipality in the region, which would hinder the visual analysis.

Figure 1
Geographical distribution of productivity clusters (y)

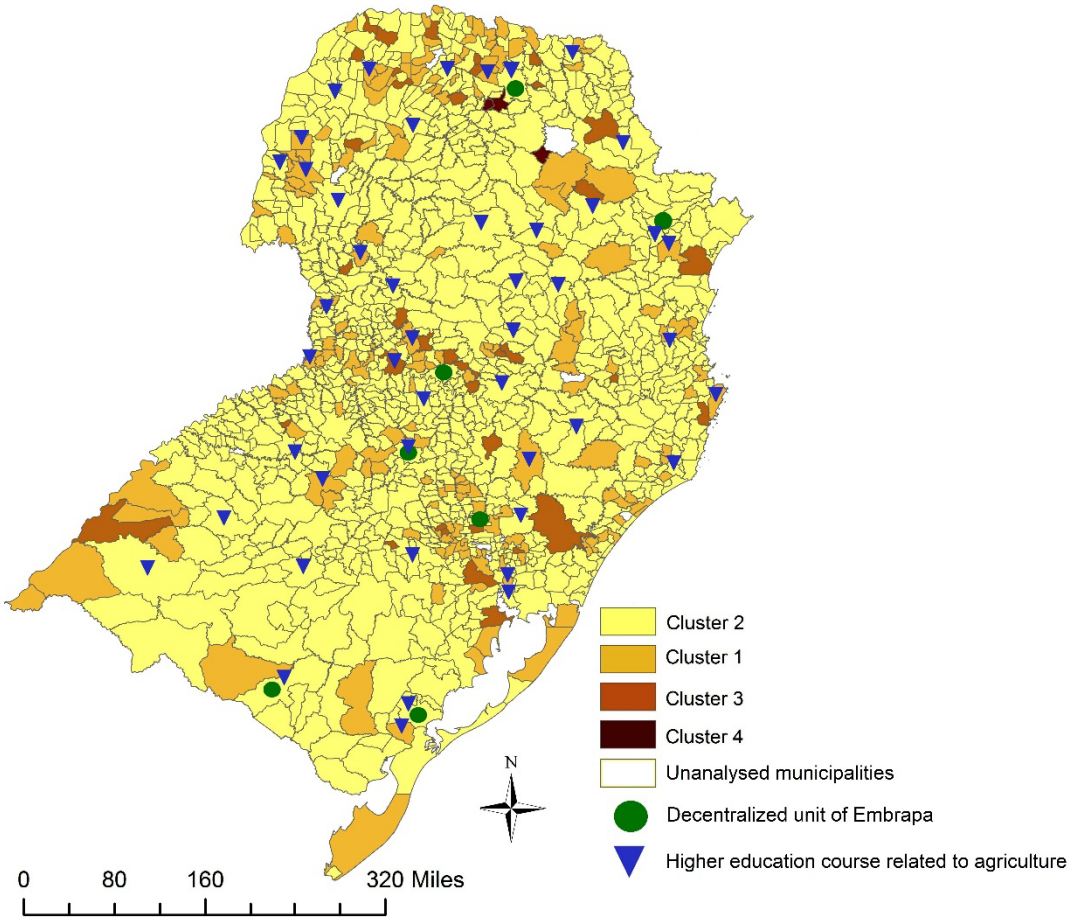

Figure 1 shows that clusters 1, 2, and 3 have representatives in the three Brazilian southern states. However, municipalities that comprise Cluster 4 are all from Paraná State:

[2] It should be noted, however, that the results in the estimated regressions were as expected according to the literature.

Imbaú, Marilândia do Sul, and Rio Bom. Most municipalities in the southern region are in Cluster 2 with the lowest average productivity indicator. Municipalities in Clusters 1 and 3 are dispersed, with no concentration in a specific region[3].

In the southern region of Brazil, Embrapa had seven decentralised units in 2006, four in Rio Grande do Sul, two in Paraná, and one in Santa Catarina. Figure 1 shows that most municipalities that had a decentralised Embrapa unit or a higher education course on agriculture in 2006 are in Cluster 2, which has the lowest average productivity indicator. However, almost all decentralised units are neighbours of municipalities in clusters with higher productivity indicators, which possibly indicates that benefits to agricultural productivity from these institutions are captured by neighbouring municipalities, since rural areas may be close to each other or to large urban centres, which generally have strong research and extension institutions, may not have a large rural area to apply their experiments. This effect of spatial proximity corroborates the findings of Felema and Spolador (2023).

Cluster 4 shows that the municipality of Imbaú in the central-eastern region of Paraná State had 89% of its agricultural production value from forestry in 2006, possibly because of the municipality relationship with a pulp and paper mill with a production unit in the neighbouring municipality of Telêmaco Borba (outlier excluded). According to information released by the Imbaú municipal government (Imbaú, 2017), in 2010, 70% of the municipality forestry production was sent *in natura* to the pulp and paper mill, which owned 31% of the municipality land area.

The municipalities of Marilândia do Sul and Rio Bom in the central-northern region of Paraná State have roughly 65% of the value of their agricultural production from soybean crops. In addition, both are neighbours of the municipality of Londrina, which, despite being in Cluster 2, had a higher education course on agriculture and a decentralised Embrapa unit (Embrapa Soya) in 2006. Londrina also houses the headquarters of the Paraná Institute for Agricultural Research (IAPAR).

A linear regression was estimated for each state and for the southern region as a whole to further investigate agricultural productivity with institutions. The regressions for each state were carried out using the state productivity indicator [y(e)] and the number of observations varied according to the availability of data on explanatory variables. The main results of this model can be found in Tables 3 to 6.

The variable associativism (Assoc) is not statistically significant at 10% when considering agricultural farms that received technical assistance, regardless of the source of this service, that is, including cooperatives (Assis in Equation 1) (Table 4). However, all variables are statistically significant at levels below 1% in the equation in which farms that received technical assistance from cooperatives are excluded from the group (Assis' in Equation 2). This indicates that the main effect of associativism on agricultural productivity occurs through the technical assistance services offered by these institutions. According to Equation 1, when the percentage of establishments that receive technical assistance increases by 1%, productivity of agriculture and livestock increases by 0.36% in the municipality. These relationships corroborate the conclusions of Dossa and Segatto (2010), Felema et al. (2013), Dill et al. (2015) and Gasques et al. (2023) in that cooperatives, technical assistance, and knowledge exchange between institutions and producers can have a positive impact on agricultural results.

[3] The municipalities that appear blank on the map are outliers or were excluded from the sample because there were no data available to calculate y.

Table 4
Results of regressions relating productivity (y) and institutions in the southern region

	Const	Assis	Assis'	Assoc	Qualif	D_ens	Finan	Insum	D_SC	D_RS
(Eq. 1)	-2.78	0.36	-	0.08	0.053	0.06	0.06	-0.33	-0.13	-0.14
p-valor	0.000	0.000	-	0.109	0.000	0.036	0.037	0.000	0.001	0.000
VIF	-	1.44	-	2.65	1.19	1.14	2.64	1.68	1.56	2.09
	n = 1159				R^2 = 0.268			Prob. F = 0.000		
(Eq. 2)	-2.46	-	0.11	0.16	0.08	0.06	0.14	-0.29	-0.13	-0.19
p-valor	0.000	-	0.000	0.005	0.000	0.051	0.000	0.000	0.002	0.000
VIF	-	-	1.27	3.10	1.12	1.13	2.41	1.58	1.78	2.33
	n = 1159				R^2 = 0.194			Prob. F = 0.000		

The "Qualif" and "Finan" variables have their parameters increased from Equation 1 to Equation 2, indicating that the explanatory power of cooperatives in technical assistance may have been distributed among other variables than only associations. In any case, the qualification variable (Qualif), along with the dummy that indicates the municipalities with higher education courses on agriculture and their neighbours (D_ens), showed a low parameter relationship with the sector productivity, indicating that producer qualification and higher education, as well as research and extension of these institutions had little effect on the sector productivity in 2006; still, this effect was positive. Higher education institutions are usually located in larger and more urbanised municipalities; however, their effects can spill over to neighbouring municipalities even those with a more rural base.

The dummies identifying the states of Santa Catarina (D_SC) and Rio Grande do Sul (D_RS) show that municipalities in these states had lower agricultural productivity than those in Paraná State. Municipality in Santa Catarina State show a decrease of 0.13% in agricultural productivity compared to municipalities in Paraná State. Similarly, municipalities in Rio Grande do Sul State show a decrease in agricultural productivity by 0.14% (Equation 1) or 0.19% (Equation 2) also in relation to Paraná State. This result was expected, given the y averages shown in Table 2.

Furthermore, all estimated parameters showed the expected sign. The negative sign of the variable "Input" indicates that the higher the proportion of expenditure on inputs in relation to the production value, the less productive the municipality agriculture sector, that is, the application of inputs yield less in terms of production value. The variable "Insum" showed the highest modulus value in Equation 2 and the second highest in Equation 1, indicating that it has greater power to explain productivity than the other variables in the model. This corroborates the characterization of the clusters described in Table 3 in which inputs were the only variable with the expected behaviour, indicating that the group of municipalities with the lowest average productivity index showed the lowest return in terms of production value on input expenses.

Considering the productivity indicator calculated individually for each southern state in Brazil, the same behaviour towards the presence of cooperatives in the technical assistance variable was repeated for Paraná State (Table 5). When cooperatives provide technical assistance (Assis in Equation 3), associationism (Assoc in Equation 3) is not statistically significant. However, when technical assistance from cooperatives is disregarded (Assis' in Equation 4), associationism is statistically significant (Assoc in Equation 4), indicating that cooperatives have a greater impact on productivity through the provision of technical assistance. For Paraná State, this behaviour is also observed for the financing variable. These facts, along with the increase in the modulus value of almost all the parameters when moving from Equation 3 to Equation 4, may indicate that the explanatory power of technical assistance

by cooperatives is distributed among the other variables, but this transmission is not complete since the coefficient of determination (R^2) between the equations decreases by 14.4pp.

Table 5
Results of regressions relating productivity [y(e)] to institutions in Paraná State

	Const	Assis	Assis'	Assoc	Qualif	D_ens	Finan	Insum
(Eq. 3)	-3.34	0.50	-	0.03	0.07	0.08	0.03	-0.27
p-valor	0.000	0.000	-	0.553	0.002	0.093	0.572	0.000
VIF	-	1.95	-	1.53	1.25	1.06	1.70	1.26
	n = 391			R^2 = 0.358			Prob. F = 0.000	
(Eq. 4)	-2.91	-	0.11	0.18	0.13	0.10	0.11	-0.20
p-valor	0.000	-	0.017	0.000	0.000	0.045	0.045	0.001
VIF	-	-	1.22	1.55	1.11	1.05	1.70	1.27
	n = 391			R^2 = 0.214			Prob. F = 0.000	

The other variables analysed for Paraná State show the same behaviour as those for the southern region as a whole. In Paraná, a 1% increase in technical assistance (Equation 3) represents a variation of 0.50% in y, while it represents a variation of 0.36% (Equation 1) for the southern region as a whole, indicating the importance of this variable for agricultural productivity in Paraná State.

In Santa Catarina, the removal of the participation of cooperatives in technical assistance (Assis' in Equation 6) does not make the parameter associativism statistically significant (Assoc in Equation 6), unlike the results for the southern region and Paraná State (Table 6). Conversely, the variable technical assistance is no longer significant, which indicates that cooperatives are the main source of impact on productivity from technical assistance services and that technical assistance no longer affects productivity. This prominent role of associations in agricultural productivity corroborates the results of Dill et al. (2015) and supports the reports of Hodgson (2001), Commons (2003) and Belik et al. (2007) in that individual interests can be converted into collective interests in an institutional context.

Table 6
Results of regressions relating productivity [y(e)] to institutions in Santa Catarina State

	Const	Assis	Assis'	Assoc	Qualif	D_ens	Finan	Insum
(Eq. 5)	-2.00	0.27	-	0.01	0.03	0.05	0.21	-0.48
p-valor	0.000	0.001	-	0.903	0.224	0.447	0.001	0.000
VIF	-	1.50	-	2.15	1.10	1.14	2.90	1.32
	n = 287			R^2 = 0.269			Prob. F = 0.000	
(Eq. 6)	-1.55	-	0.10	0.03	0.04	0.03	0.25	-0.46
p-valor	0.000	-	0.133	0.708	0.114	0.672	0.000	0.000
VIF	-	-	1.06	2.27	1.10	1.10	2.63	1.22
	n = 287			R^2 = 0.242			Prob. F = 0.000	

The variable financing for Santa Catarina was higher than for the southern region and Paraná State, indicating that producers in Santa Catarina seek to direct their financing towards investments that increase productivity of production factors, such as technical innovations. On the other hand, the variables of education (Qualif and D_ens) were not statistically significant in any of the equations for Santa Catarina State, which may indicate that their effects on

agricultural activities are not captured by y or that they do not translate into increased productivity. Finally, the variable "Insum" played a more pronounced role to explain productivity than the average for the region, indicating that municipalities in Santa Catarina need to overcome inefficiencies in the use of inputs more than other states to have a positive return on factors of production.

For Rio Grande do Sul State, similarly to Santa Catarina State, the removal of the participation of cooperatives in technical assistance (Assis' in Equation 8) does not make associativism statistically significant for agricultural productivity (Assoc in Equation 8) (Table 7). In addition, removing this group reduces the parameter of technical assistance, showing that the impact of technical assistance on agricultural productivity comes mainly from cooperatives.

Table 7
Results of regressions relating productivity [y(e)] to institutions in Rio Grande do Sul State

	Const	Assis	Assis'	Assoc	Qualif	D_ens	Finan	Insum
(Eq. 7)	-1.67	0.21	-	-0.05	0.05	0.06	0.12	-0.34
p-valor	0.000	0.000	-	0.563	0.004	0.261	0.031	0.000
VIF	-	1.47	-	1.45	1.29	1.22	2.34	2.08
	n = 480			R^2 = 0.211			Prob. F = 0.000	
(Eq. 8)	-1.52	-	0.07	-0.03	0.06	0.06	0.18	-0.32
p-valor	0.000	-	0.037	0.720	0.000	0.245	0.000	0.000
VIF	-	-	1.14	1.62	1.28	1.22	2.23	2.09
	n = 480			R^2 = 0.187			Prob. F = 0.000	

Although the variable "D_ens" was not statistically significant, the qualification of producers showed a positive relationship with productivity. In other words, every 1% increase in "Qualif" results in a 0.06% (Equation 8) increase in productivity. Financing and inputs also showed the expected relationship, that is, for every 1% increase in financing, y(e) increases by 0.12% (Equation 7) and 0.18% (Equation 8), and for every 1% increase in the proportion of production value spent on inputs, y(e) decreases by 0.34% (Equation 7) and 0.32% (Equation 8).

The results presented show that institutions affect agricultural productivity to some extent when the analysis is carried out at a municipal level, although it is not a behaviour observed in the groups (clusters). The quantitative analysis carried out by regressions showed a greater explanatory power than the descriptive analysis given by the clusters, since the former has a larger sample and allows each municipality to be analysed separately.

The results of the regression analysis showed that technical assistance was statistically significant and competed in terms of parameter size with costs of inputs in all states under analysis, indicating the importance of institutions to agricultural productivity. The relationship observed between technical assistance and associations shows that the former is offered by different institutions, not only public ones. Moreover, activities of technical assistance have a greater effect on production factors than associations, qualifications, and higher education courses on agriculture, which indicate the effects of technical assistance on productivity are more immediate. The greater prominence of technical assistance in relation to the other proxies of institutions was expected, based on the results presented by Dill et al. (2015) and Felema and Spolador (2023), representing the description of internal sources of technological change by Possas, Salles-Filho and Silveira (1994).

Although the parameters of qualification were low, their positive relationship shows the importance of investing human capital in the agricultural sector. As for higher education courses on agriculture, the direct effect was not confirmed for the states of Santa Catarina and Rio Grande do Sul; nevertheless, their effect in Paraná State was considered significant for the southern region. The analyses by state reduce the number of observations compared to regional analysis, which can affect the results by restricting the sample. Furthermore, the performance of the agricultural sector can be affected by factors not captured in this study, due to the data nature and specificity of the sector, which can provide basis for future works.

5 Final remarks

This study investigated the relationship between agricultural institutions and agricultural productivity in the southern region of Brazil, aiming to highlight relationships of association and complementarity. Institutions, as a theoretical basis, can be formal or informal rules and customs, organisations or markets, subject to external pressures and pecuniary interests that can define future trajectories. Organisations can be considered institutions as they involve conflicts of interest and decisions that affect the institutional environment and are characterised as agents of change, based on their path of dependence. In this study, organisations involved in the agricultural sector in southern Brazil were considered institutions that provide technical assistance, rural extension, teaching, research and association services involved in "formal (enforcement) and informal restrictions", which can influence the performance of the agricultural sector since they define partnerships, research, fields covered, techniques, and knowledge transmission.

The methodology used the fuzzy logic, which allowed to bring together different production factors into a single productivity indicator, with gradual variation in the degrees of pertinence. The cluster analysis and the linear regressions seemed homogeneous, as they vary over a small range; nevertheless, they showed that the construction of the indicator using the fuzzy logic was effective to characterise and differentiate municipalities in terms of their agricultural productivity, as reported by Khatchatourian and Treter (2010), Lima et al. (2012), Bagolin et al. (2013), and Conde et al. (2014). Furthermore, the use of weighting by scarce factors allowed for an additional comparison between the situations of the states analysed. Therefore, this tool proved to be a viable alternative for the analysis, mainly when data from subsequent years is not available, which is necessary to calculate TFP, for example.

The cluster analysis based on the agricultural productivity indicator showed that most municipalities perform poorly in this field and that there is no evidence of the role of institutions in characterising the groups within the clusters formed. On the other hand, the regression analysis indicated a positive determination between institutions and agricultural productivity in almost all the cases analysed, for instance, the percentage of agricultural farms that received technical assistance. This result may be a consequence of the larger number of institutions providing this service (public institutions, private companies, and cooperatives), revealing enforcement mechanisms as well as informal rules in routines of farmers (informal restrictions). Technical assistance also generates more immediate results in terms of the performance of production factors, whereas research and the formation of human capital can take several years to have a positive impact on productivity (Gasques et al., 2008; Felema et al. 2013), which can also be observed in associativism. The contribution of technical assistance has been positive (Hodgson, 2001; Commons, 2003; Belik, Reydon, Neto, & Guedes, 2007; Dossa & Segatto,

2010; Felema et al., 2013; Dill et al., 2015; Gasques et al., 2023), indicating that the other benefits of membership do not have an immediate effect on increased productivity.

The institutions analysed here have fields of activity that do not always coincide with their municipalities of location (Felema & Spolador, 2023). This may limit the more incisive relationship expected between institutions and agricultural productivity, which does not mean that these institutions are unimportant, but that it is difficult to process the data to confirm these events. Overall, the results found here for the agricultural sector corroborate the arguments of the institutionalist approach, confirming its importance in the process of economic development and that the decisions made within organisations have an impact on agricultural productivity. Our findings also converge with the results presented by other authors, relating better performance in agriculture to associations, technical assistance, teaching, research, and extension (Gasques et al., 2023; Torres, 2023; Dill et al., 2015; Felema et al., 2013; Gasques et al., 2010; Dossa & Segatto, 2010; Gasques et al., 2008).

In this study, we used a cross-section analysis, meaning that the quantitative results found do not allow for conclusions about the spread of these effects over the years, which is a limiting factor. Another limitation is the access to more recent data on Brazilian agriculture at municipal level. However, changes that may have occurred, along with the high response lag, which is characteristic of institutional stability, minimise possible distortions in the results found here. Therefore, incentive policies, mainly those related to learning and knowledge dissemination gradually over time, are valid in cooperative environments, as reported by Commons (2003). Therefore, policy makers need to consider that current decisions can create development trajectories - similar to the contributions of Dosi (1982), North (1991) and Zylbersztajn and Sztajn (2005) - that have long-term effects. However, possible limitations of this study can mean opportunities for future research to deepen the knowledge of trajectories in relationships between institutions and agriculture to drive agricultural evolution to a more productive path.

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