



Regional inequalities in a learning economy: the case of Brazilian bioethanol production

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Resumo

O objetivo do artigo é analisar as desigualdades regionais na produção de bioetanol, tendo como foco o aprendizado e a geração de conhecimento. O artigo tem dois pressupostos centrais: primeiro, aprendizado é um recurso chave no capitalismo moderno; segundo, esse atributo é desigualmente distribuído no espaço. Para capturar esse fenômeno na produção de bioetanol, dividimos a região Centro-Sul em três: as regiões tradicionais de produção do Estado de São Paulo; as novas regiões de expansão do Oeste Paulista; e as regiões complementares a São Paulo em outras unidades federativas. Dividimos o conhecimento e o aprendizado em três dimensões: a experiência dos trabalhadores, o grau educacional e a pesquisa acadêmica sobre cana-de-açúcar. Os resultados indicam o avanço da acumulação de experiência e do nível educacional da mão-de-obra no Oeste Paulista e nas regiões complementares, mas uma concentração da pesquisa acadêmica nas regiões tradicionais.

Palavras-chave: Economia do aprendizado; Desigualdades Regionais; Setor sucroenergético

Abstract

This paper aims to analyze the regional inequalities of bioethanol production, focusing on learning and knowledge creation. The papers have two central assumptions: first, learning is the key resource in modern capitalism; second, it is unevenly distributed in the space. For capturing this phenomenon in bioethanol production, we divided the Center-South region into three: the traditional regions of production in the State of São Paulo; the new expansion regions in the western of São Paulo; and the complementary regions in other federative units. We divided the knowledge and learning in three dimensions: the worker experience, the worker educational degree, and the academic research about sugarcane. The results show the growth of the accumulation of experience and the improvement of labor education in the western of São Paulo and the complementary regions, but a concentration of academic publications in the traditional regions.

Keywords: Learning Economy; Regional Inequalities; Sugar-Energy Sector

Área 4 - Redes e sistemas urbanos, regionais e nacionais

4.2. Economias Regionais e Urbanas

Códigos JEL: R11, O13, J43, J43.

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1. Introduction

The introduction of flex-fuel vehicles in the Brazilian domestic market (FURTADO; SCANDIFFIO; CORTEZ, 2011) and the projections that the country could satisfy a future global demand of biofuels (CERQUEIRA LEITE et al., 2008) boosted bioethanol market in the 2000s and the beginning of 2010s. New sugarcane mills were created. International and national companies invested in biofuels production (PIETRAFESA; PIETRAFESA, 2016). Logistic infrastructures for bioethanol distribution were improved or began to be constructed (OLIVEIRA, 2015). The agricultural area with sugarcane increased (CASTILLO, 2015). Brazilian national economic crises, after 2015, and the specific crises of sugar-energy sector, deaccelerated this process and put doubts about the capacity of Brazil to face bioeconomy challenges (SALLES-FILHO et al., 2017). However, the point is that the growth of the 2000s changed the dynamic of the sugar-energy sector⁴ in Brazil.

It is worth mentioning that this was not the first period of bioethanol increasing. There was a moment in the 1970s, influenced by the National Alcohol Program (PROALCOOL), a program implemented by the National State to reduce the use of gasoline in a context of international oil crisis (MORAES; ZILBERMAN, 2014). The new phase of bioethanol growth in the 2000s has its particularities about sustainability and the environmental question (GOLDEMBERG; COELHO; GUARDABASSI, 2008), the regulation of market economy (MORAES; ZILBERMAN, 2014), and the new agriculture and industrial technologies (BUENO; SILVEIRA; BUAINAIN, 2018). It also has particularities in its territorial dimension, which will be the focus of this paper. The growth of bioethanol demand in the 2000s took place in a moment that the traditional regional of São Paulo were dealing with problems with competition for sugarcane, what rose the prices of land and acquisition of raw material (BELIK et al., 2017). Therefore, new investments in bioethanol prioritized zones where sugarcane was not a relevant activity, like the western region of São Paulo, the south of Goiás, the triangle of Minas Gerais, and southwest of Mato Grosso do Sul (ROSENDO; MATOS, 2017; PIETRAFESA; PIETRAFESA, 2016; LOURENZANI; CALDAS, 2014).

This geographical dispersion of bioethanol production brought a debate in the national and international literature whether this activity could be a viable alternative to regional development. Comparing ethanol and oil activities, Moraes et al. (2011), pointed out that bioethanol has a higher potential to improve regional development insofar the production is spread throughout several states and regions, improving jobs and income creation. Using data of GDP per capita, Chagas, Toneto Jr & Azzoni (2011) conclude that the agricultural regions where sugarcane grew had more advantages compared to the regions where that did not happen. Brinkman et al. (2018) made a comparative study of the bioethanol production in three regions: Piracicaba, Presidente Prudente, and South West of Goiás. Their results show that the first region has a well-developed sector; while in the second and the third regions, the reduction of economic impacts is a consequence of the displacement of other agricultural activities. Brinkman et al. (2018) brought an important contribution to the discussion of regional implications of bioethanol production, showing that its socio-economic benefits depend on characteristics of the region itself. It means that the effects of bioethanol production are heterogeneous in regions.

Although the literature does not neglect the capacity of bioethanol to induce regional development, little debate was made about its potential to improve knowledge and learning in regions. These are the crucial resources for the economy and society in modern capitalism (FORAY, 2004; LEE, 2009; LUNDVALL, 2016). Knowledge “may appear both as an input (competence) and output (innovation) in

⁴ We will use the term sugar-energy sector in reference of bioethanol, energy, and sugar production.



the production process” (LUNDVALL; JOHNSON, 2016, p. 134). We argue that identifying the geography of knowledge is a key-point for contemporary analysis of regional development insofar as different regions have different competencies.

This paper aims to analyze the regional inequalities of bioethanol production, focusing on learning and knowledge creation. Is there a regional division of labor where the knowledge is generated in the traditional regions of São Paulo, and only the production moves into the countryside? Alternatively, is there a growth of both production and knowledge in the new regions of expansion?

The paper focuses on the Center-South region of Brazil⁵. For the analysis, we divided this region into three parts: the traditional regions of productions; the expansion regions in the state of São Paulo; and the complementary regions in other federative units. To shed light into the questions raised, the paper makes use of two Brazilian databases: the Annual Relation of Social Information (RAIS) to obtain data related to the workers qualification in these regions; and the Brazilian Lattes Platform to obtain regional data about the number of publications and research efforts and build proxies for knowledge generation.

This study is in line with the idea that “Brazil’s success with sugarcane cannot be understood solely as deriving from a natural comparative advantage. Above all, it is the result of a virtuous trajectory of technological learning strongly based on incremental innovations” (FURTADO; SCANDIFFIO; CORTEZ, 2011, p. 156). Our analysis can contribute to understanding the spatial dimension of the innovation process in the sugar-energy sector and provide ideas that can support investigations about the limits and potential that bioethanol has for regional development.

The paper is divided into more four parts besides the introduction. The first one is a theoretical discussion about the idea of regional development based on agricultural production in a learning economy. The second one presents the methodology to justify the regionalization and the data we used. The third shows the results. Finally, the last section presented our conclusions.

2. The geography of knowledge in agricultural and agroindustrial systems

There is a classical discussion in the economic literature about the potentialities of agriculture to induce regional development. In the historical debate, there are both a group of authors who associate agricultural growth with underdeveloped structures (FRANK, 1969; FURTADO, 1972; MYRDAL, 1957) and authors who defended that, under certain conditions, agriculture can be a prime influence for regional economic growth, inducing external economies, urbanization, and industrial development (NORTH, 1959).

Walker (2004) presented a contemporary perspective of this discussion in studies about the agricultural zone of California. Page & Walker (1991) analyzed the agro-industrialization as a motor of regional development in the American Mid-West region (PAGE; WALKER, 1991). These studies showed how agricultural growth could create a complex *social division of labor*. These are cases where the region economy increased as a result of a combination of local interactions of farming production, processing and input industries, and universities that develop scientific research according to the local demands. In this context, according to Walker (2004, p. 15), modern agriculture “requires, above all, human knowledge and practical labor skills, and advances in technology are commonly made through human learning.”

The sentence is in line with the perspective that knowledge is a crucial resource in modern capitalism (LUNDVALL, 2016). Sustained growth depends on the creation of local capabilities. As Lee (2009, p. 1) pointed out: “without a certain critical degree of capabilities, growth, which is based on lower wage rates

⁵ This region concentrates the highest percentage of Brazilian sugarcane and ethanol production. In the harvest of 2017/2018, the Center-South had 93.6% of the ethanol production in Brazil and 93.0% of the sugarcane (UNICA, 2019).



or simple price competitiveness, tends to be short-lived.” We follow the idea of Lundvall and Johnson (2016) that more than a knowledge-based economy, we live in a learning and dynamic economy.

The learning economy is a characteristic of a period of capitalist development that emerged in the 1970s with the information and communication technological revolution⁶ (PEREZ, 2009). Lundvall and Johnson (2016) define the changes at this moment with three interconnected phenomena. The first is related to the radical innovations of information paradigm – personal computers, software services, telecoms, and the internet (PEREZ, 2009, p. 189). On the one hand, it “has drastically reduced the costs of handling, storing and moving information” (LUNDVALL; JOHNSON, 2016, p. 109). Nevertheless, the efficient use of information remains a costly process that depends on learning. The second is the change from a Fordism to a flexible specialization model. It increases the possibilities of the division of labor. Therefore, it also increases the necessities for communication and cooperation among firms, universities, and even competitors. The third phenomena are the changes in the innovation process that demand a continuing and incremental advance that emanate more interactive learning (LUNDVALL, 1988) for the survival of firms.

A combination of long-distance and proximity relations defines the geography of knowledge and learning in the technological paradigm of information (STORPER, 2013). Proximity relations are associated with the tacit dimension of scientific knowledge (POLANYI, 1966) and the necessity of face-to-face interaction (STORPER; VENABLES, 2004). It leads to a spatial concentration of sophisticated knowledge (BALLAND; RIGBY, 2017). Long-distance relations, on the other hand, are complements to absorb external and codified knowledge. It is a mechanism to diversify the knowledge base and avoid the risk of local lock-in (BOSCHMA, 2005).

The approach of regional innovation systems combines interactive learning and proximity relation (ASHEIM; GERTLER, 2006; ASHEIM; SMITH; OUGHTON, 2011; COOKE; URANGA; ETXEBARRIA, 1997). According to Asheim & Gertler (2006, p. 299), “the regional innovation system can be thought of as the institutional infrastructure supporting innovation within the production structure of a region.”. Among the main interactions able to create and induce the abortion of knowledge in regions, we highlight the relationship between firms, universities, and research centers (LESTER, 2005). These interactions are central in the creation of human capital and to transform traditional agriculture into a modern activity (SCHULTZ, 1965).

According to Perez (2010), one of the effects of a technological paradigm is its “capacity to transform profoundly the rest of the economy (and eventually society).” Therefore, it is essential to understand agriculture in the information era and within a learning economic context as changes in the techno-economic paradigm enter in different spheres of agricultural production. The use of information technologies in agriculture dates from the 1980s. Tractors using Global Positioning System (GPS) became available at the beginning of the 1990s, making possible the use of precision agriculture. This method was fundamental to manage the use of fertilizers, pesticides, and water in agriculture (BÓGEL, 2017). The adoption of this technology is almost simultaneous in Brazil (CASTILLO, 1999). Besides the use of technology to improve the knowledge about natural conditions, information technologies created the possibility of processing and storage data, also enhancing the management and technical decisions of farmers.

In order to discuss the agriculture and agro-industrial systems in the learning economy, we use the distinction of Lundvall and Johnson (2016) of four types of knowledge: know-what, know-why, know-

⁶ Following Perez (2009, p. 190) “a technological revolution can be seen more generally as a major upheaval of the wealth-creating potential of the economy, opening a vast innovation opportunity space and providing a new set of associated generic technologies, infrastructures and organizational principles that can significantly increase the efficiency and effectiveness of all industries and activities”.



how, and know-who. Table 1 presents the original definition of Lundvall (2016) and our proposal to apply this perspective on agriculture.

Chart 1: Types of knowledge in agricultural and agroindustrial systems

Types of knowledge	Definition (LUNDVALL; JOHNSON, 2016)	Use in agroindustrial systems
Know- what	Knowledge about facts. Similar to information.	Information about natural conditions (soil, climate). Market and political information.
Know- why	Knowledge about principles and laws of nature, the human mind, and society. Science-based knowledge.	Agrarian sciences knowledge. General university valuable knowledge to agriculture.
Know-how	Refers to skills. Experience-based learning, Learning-by-doing.	The experience acquired on the farming — specialized knowledge created about a specific crop in the region.
Know- who	Information about who knows what and who knows what to do. Ability to cooperate and communicate.	The capability of identifying the leading agents and their competences in the agricultural innovation system.

Source: Org. by the authors

As we may conclude from Chart 1, although all types of knowledge are combined in the process of innovation, we argue that some of them are more critical to regional development. The know-what and the know-who are more equivalents to reproducible information. Nevertheless, the use of information and the capacity of regions to create and absorb scientific knowledge depends on the know-why and know-how. It is essential for more autonomy of a region to execute innovation efforts. In agriculture, know-why is central to adapt the production to the regional particularities regarding both natural and economic conditions. The know-how complements this capacity. It shows how a region develops its abilities and expertise in agricultural production through new methods, practices, and organizational dynamics. It is an essential dimension for the creation of tacit knowledge in the regions.

Thus, in order shed light on the question raised in the Introduction about knowledge generation and learning capabilities and how they unevenly distributed in the territory, we will focus on the know-why and know-how associated with sugar-energy sector.

3. Methodology

3.1. Regionalization of the sugar-energy industry in Brazilian Centre-South

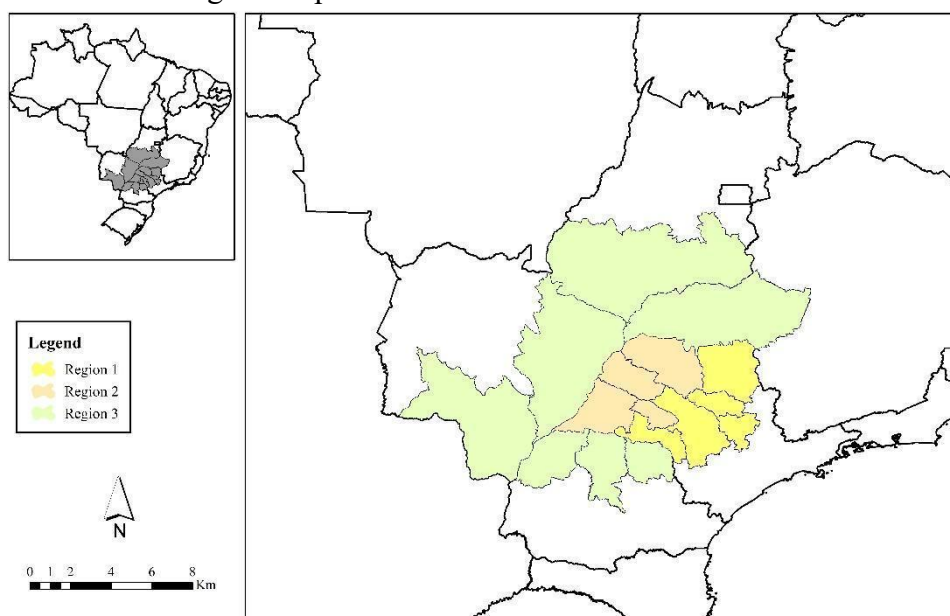
The first step to analyze the regional capabilities of knowledge creation in the sugar-energy productive system was to propose a regionalization of sugarcane production in the Brazilian Centre-South area. We used a group of meso-regions, defined by the Brazilian Institute of Geography and Statistics (IBGE), to create our regionalization.

We considered three groups of regions using as the main condition the historical moment of sugarcane growth. The region 1 is the traditional regions of São Paulo, being the group of Piracicaba, Ribeirão Preto, Araraquara, Bauru, and Assis. Region 2 is the western region of São Paulo, being the group of Araçatuba, São José do Rio Preto, Presidente Prudente, and Marília. Region 3 is the complementary region of sugarcane expansion. It means the group of the South of Goiano, in the state of Goiás; the



Triângulo Mineiro/Alto Paranaíba, in the state of Minas Gerais; East de Mato Grosso do Sul, and the Southwest of Mato Grosso do Sul in the state of Mato Grosso do Sul; and the Northwest Paranaense, Center-North Paranaense, and Pioneer North Paranaense in the State of Paraná. Map 1 presents the regionalization used for the data analysis.

Map. 1: Regional division of sugarcane production



Source: Org. by the authors

3.2. The analysis of the sugar-energy sector: measuring the know-why and know-how

Based on Belik, Perosa & Fredo (2014), we focused our attention on the sugar-energy sector as the sum of four sectors at a 4-digit level of disaggregation from the National Classification of Economic Activities (CNAE 2.1)⁷: sugarcane crop (0113), sugar production (1071), sugar refining (1072), and ethanol production (1913). The first is agricultural production. The others refer to the milling. This choice allows us to capture direct and indirect effects on the regional occupational structures.

We used the public version of the Annual Social Information Report (RAIS). This database considers microdata on formal employment, but, as the levels of formality in this sector are increasing, we can consider that our sample is representative enough.

In order to analyze the know-how in the sugar-cane sector using RAIS, we will use the worker experience in months within the firm. In the sugar-energy sector, it shows the creation of specific skills and capabilities of producing sugarcane according to local conditions. Each local has its particularities in terms of climate, soil, and the interaction of sugarcane variety with the environment (MESQUITA, 2016). Therefore, if the workers are keeping more time in the mill, it is assumed that this type of knowledge, essential for sugarcane productivity, is increasing.

To analyze the know-why in sugar-energy sector, we aim to discuss how scientific knowledge is created and applied to the sector. One of the central agents for this is universities (FURTADO; SCANDIFFIO; CORTEZ, 2011). As Garcia et al. (2014) pointed out, universities are essential agents for

⁷ Compatible with the International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4.



the innovation process due to two fundamental roles: the training of the labor force and the creation of new knowledge in the research activity. Therefore, we divided the know-why capacity into these two categories.

For the labor qualification, we analyze, from RAIS, the evolution of schooling or level of formal education. We divided the data into five groups: illiterate, up to elementary school completed, up to high school completed, college incomplete, and at least college completed (which include workers with MSc. and Ph.d. titles).

To analyze research knowledge created about sugarcane, we use the Lattes Platform. To obtain all papers about sugarcane, we filtered the papers that have the following words in the title: cana-de-acucar or cana de acucar or sugarcane.

At first, it showed a total of 6,340 paper and 7,229 authors (including also co-authors). However, excluding the authors who did not identify their professional address, we reached a total of 5,369 papers and 4,193 authors. This data was combined with our regional division using the researchers' professional address. We also arranged the top universities in sugarcane research.

The analysis is carried out in the years of 2003, 2010, and 2017. It allows showing two different periods in sugar-energy dynamics. The period of 2003 to 2010 is a moment of growth and optimism while the period of 2010-2017 is a moment of crisis and reduction of investments.

4. Regional inequalities in the sugar energy sector: the know-how and know-why dimensions

4.1. General characteristics of region 1, 2 and 3

Before analyzing the regional differences related to knowledge production, this item aims to present a general view of the sugar-energy sector in Regions 1, 2, and 3. Table 1 shows different data related to these regions in the years of 2003, 2010, and 2017.

Table 1: Share in Brazilian GDP, employment and sugarcane harvested area in Region 1, 2 and 3

	Region 1			Region 2			Region 3		
	2003	2010	2017	2003	2010	2017	2003	2010	2017
Share in Brazil's GDP* (%)	4.2	3.9	4.1	1.9	1.7	1.9	4.5	4.2	4.9
Employment in Sugar-energy Sector	41,567	141,635	125,579	6,373	78,882	73,122	20,195	114,842	109,431
Share of employment in the sum of Region 1, 2 and 3 (%)	61.0	42.2	40.8	9.4	23.5	23.7	29.6	34.2	35.5
Total of sugarcane area (in millions of hectares)	2.0	2.8	3.1	0.6	1.8	2.2	0.7	1.9	2.6
Share of sugarcane area in the sum of Region 1, 2 and 3 (%)	60.7	43.3	39.0	18.5	28.1	28.2	20.8	28.5	32.8
Share of sugarcane in total agriculture area in the region (%)	54.2	69.4	68.0	40.8	77.7	79.8	7.0	16.9	17.1

Source: Org. by the authors. Database: IBGE-PAM; IBGE-GPD of municipalities; RAIS.

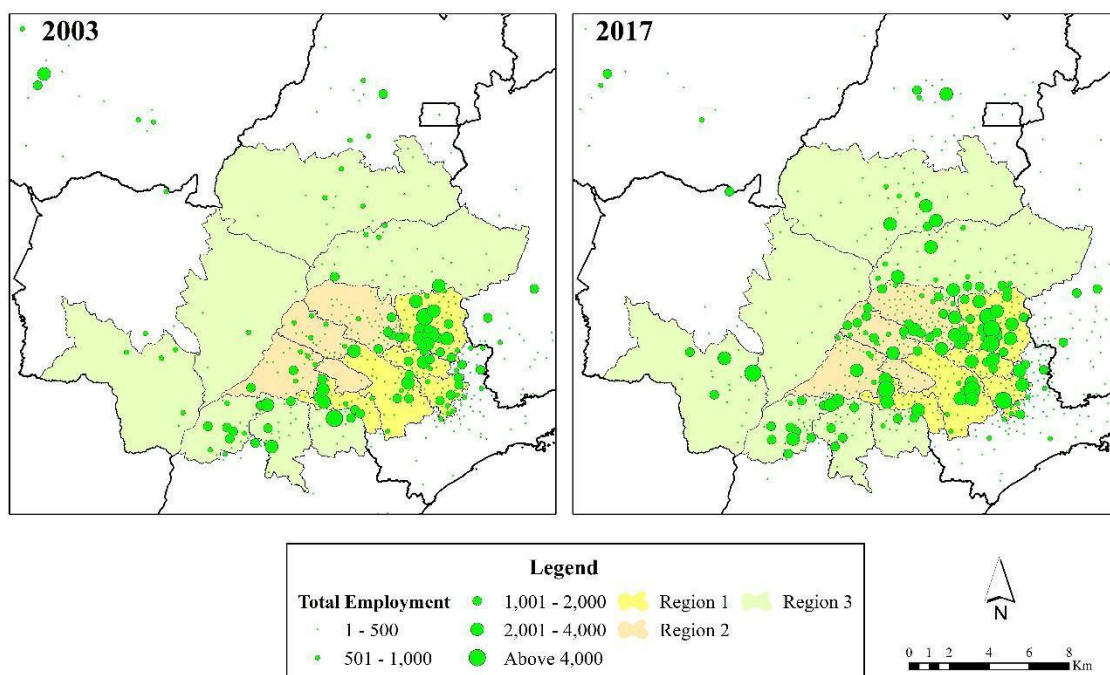
* The year of GDP data is 2016, not 2017.



The only one of the three regions to increase its participation in the Brazilian GDP between 2003 and 2017 was Region 3 that passed from 4.5% to 4.9%. About the total employment in the sugar-energy sector, all the three regions have a similar behavior: a significant growth between 2003 and 2010 and a reduction between 2010 and 2017. Baccarin, Alves & Gomes (2008) discussed two effects in the employment in the sugar-energy sector: a composition and technological effects. The composition effect is a result of the growth in employment caused by the increase of production in the context of steady technology. The technological effect is associated mainly with the mechanical technologies. The growth of employment between 2003 and 2010 is a consequence of the increase in the number of mills and, on some level, by the composition effect. The reduction of employment between 2010 and 2017 can be more directly associated with the technological effect. It is a result of policies stipulated by the state of São Paulo for a new regulatory framework since 2007, establishing the end of the burning of straw in the sugarcane harvest. It is important to highlight in Table 1 that despite the reduction in employment, the total of sugarcane area kept growing in all regions (especially region 3) during all the periods. In region 1, the sugarcane area increased 44,4% from 2003 to 2010 and 9,0% from 2010 to 2017. In region 2, sugarcane area grew 207,7% from 2003 to 2010 and 21,7% from 2010 and 2017; in region 3, sugarcane area increased in 178,2% from 2003 to 2010 and 39.2% from 2010 to 2017.

Considering the sum of region 1, 2 and 3, Table 1 also indicates geographical deconcentration of sugar-energy sector in these regions both in employment and sugarcane area. It shows that the traditional region is reducing its share compared with the new regions of production in west São Paulo and the frontier regions of the state. Map 2 illustrates this process considering the total employment within the sugar-energy sector by the municipality.

Map 2: Employment in the sugar-energy sector in 2003 and 2017



Source: Org. by the authors. Database RAIS.



Although this data indicates a dispersion of production and employment, the knowledge and learning process follows a different geography.

4.2. Regional inequalities: the “know-how” dimension

We used the worker experience as a proxy for absorptive capability and tacit knowledge. While the first one is necessary for learning, the second one is the output of the learning-by-doing process, and time plays a central role in this process of experience accumulation. Figure 1 shows a kernel density estimation of the distributions of workers experience in months, for every macro-region (red) and the sugar-cane-sectors (blue). Median values are represented by the vertical lines, respectively. Horizontal axes are in \log_{10} for a better visualization.

As observed for 2003, median time experience is around 24-25 months ($10^{1,37} - 10^{1,39}$), with a higher concentration of workers to the left for region 1 and to the right for region 3, which also presents a strong bimodality. Mean values are also close among regions, with approximately 60, 56, and 46 months on average for regions 1, 2, and 3, respectively. Thus, the skewness of the distributions and central statistics put in evidence the presence of workers with very high experience⁸.

In 2010, the sector in region 1 presented a shift to the right, which implies a higher survival rate of workers, which is also reflected in the central moments of the distribution. A bimodal pattern also appears in regions 1 and 2 although there was no positive change on the means and averages of the sectoral distributions of regions 2 and 3. On the contrary, dispersion raised in region 1 and decreased in regions 2 and 3. With all this and considering that we are working only with what we defined as permanent workers, we can infer the emergence of two workers profiles: the first as the one settling at the sector and the second one as the most experienced.

In 2017, we observed a shift to the right of the sectoral distributions and the weakness of the bimodal pattern. Means and medians had a significant increase in all the regions, with region 1 leading (mean 86 and median 58), followed by region 2 (mean 66 and median 49) and region 3 (mean 59 and median 47), which also puts in evidence a path-dependence effect in the sense that regions 2 and 3 are the “new” ones in the expansion process. Together with better qualification and a demand for less manual activities, we expect a positive impact on sectoral performance. The horizontal axis is in \log_{10} for better visualization of the tails. It is also important to notice the higher medians of the sugar-energy industry if compared to the median worker experience within the regions. Overall and differently from the sectoral dynamic, region 2 is the one who presents a higher mean and median worker experience among the three regions.

⁸ Central moments and other statistics may be provided upon request.



IV ENEI

Encontro Nacional de Economia Industrial e Inovação

Inovação, Produtividade e os Desafios do Crescimento

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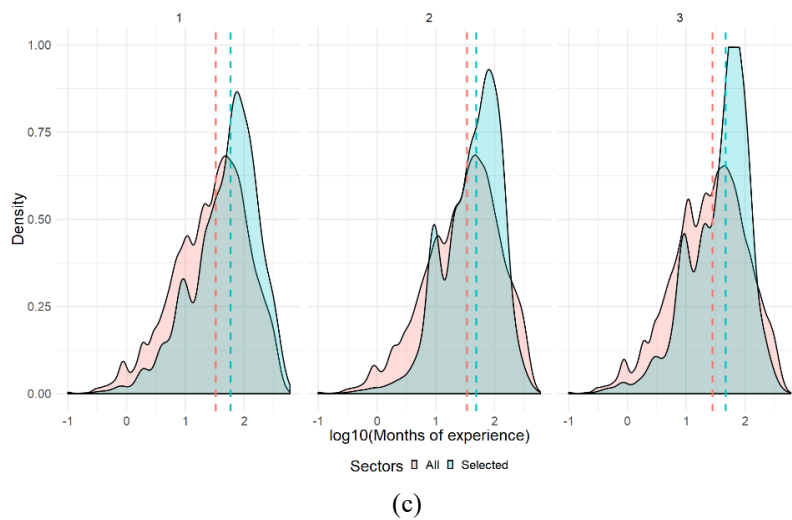
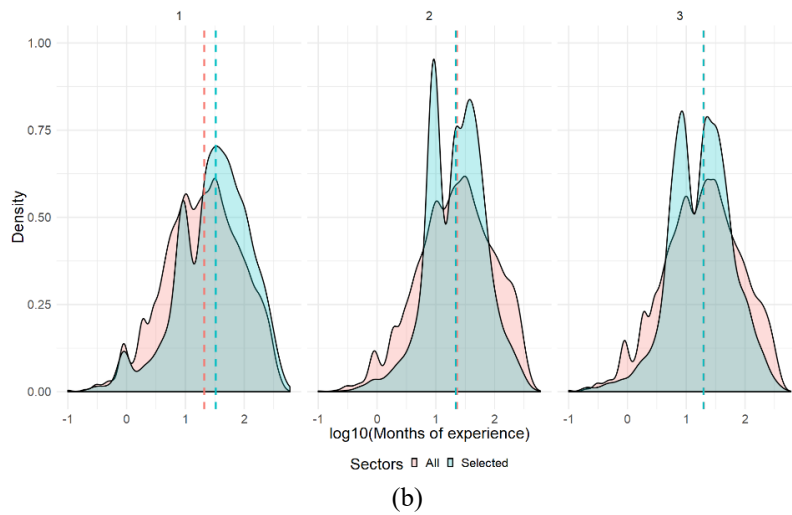
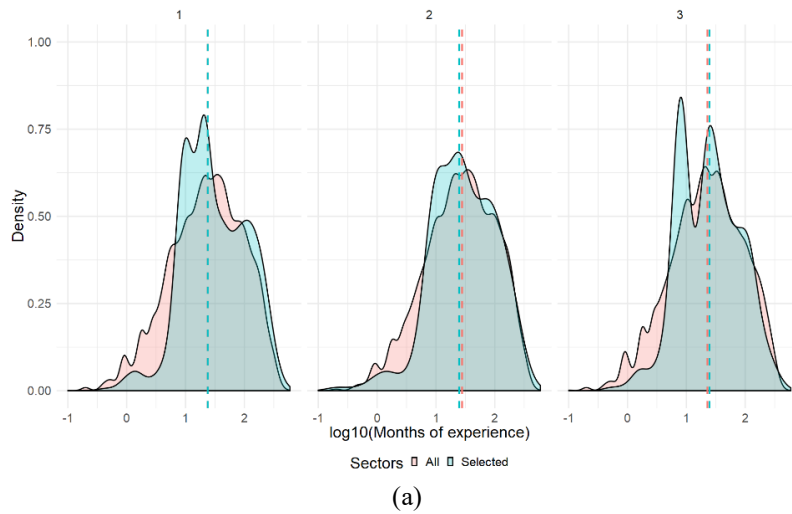


Figure 1: Distribution of workers experience within for (a) 2003, (b) 2010, and (c) 2017. The horizontal axis is in \log_{10} for better visualization of the tails.



4.3. Regional inequalities: the know-why dimension in the labor force

Table 2 shows the composition of the labor force within the regions and the sugar-energy sector by the level of formal education (schooling). The percentage of illiterates is diminishing consistently in region 3, although the sector presents a higher share of illiterates if compared with the regions. From the three regions, it is region 2 that appears with the higher percentages of formal workers that at least completed high school or have at least college in every year analyzed. On the other hand, the share of more qualified workers within the sector is lower than the ones observed in the respective regions. Notwithstanding, there is a change in the sectoral occupational structure once there is a constant increase in the participation of higher qualified workers. It certainly brings benefits to the performance of the sector given that there is a whole set of capabilities that can be acquired only by formal education and that are also central in the process of knowledge generation, the development of absorptive capacities and innovation.

Table 2: Distribution of workers per level of formal education.

Education	% of total employees (2003)					
	Region 1		Region 2		Region 3	
	All	Selected	All	Selected	All	Selected
Illiterate	0.7	1.8	0.5	0.7	1.0	1.8
Up to elementary school completed	49.2	71.8	45.1	56.8	48.9	68.8
Up to high school completed	36.5	20.9	40.0	33.6	37.6	20.1
College incomplete	2.8	1.6	2.9	2.2	3.2	1.2
College completed+*	10.8	3.8	11.6	6.7	9.4	8.0
	% of total employees (2010)					
	Region 1		Region 2		Region 3	
	All	Selected	All	Selected	All	Selected
Illiterate	0.3	1.6	0.3	0.9	0.5	1.4
Up to elementary school completed	32.1	62.9	28.8	57.9	34.8	60.0
Up to high school completed	51.9	29.4	53.8	35.4	48.3	32.7
College incomplete	3.3	1.7	3.4	1.6	4.0	2.0
College completed+*	12.4	4.3	13.7	4.2	12.4	3.8
	% of total employees (2017)					
	Region 1		Region 2		Region 3	
	All	Selected	All	Selected	All	Selected
Illiterate	0.2	0.9	0.1	0.4	0.4	0.7
Up to elementary school completed	21.9	49.8	19.0	47.0	23.8	43.8
Up to high school completed	58.0	40.2	60.5	44.0	54.7	46.5
College incomplete	3.2	1.9	2.9	1.8	3.9	2.5
College completed+*	16.7	7.2	17.4	6.9	17.3	6.5

Source: Org. by the authors. Database RAIS.

*College, MSc, Ph.D.

Table 3 reinforces what we observed in Table 2, in the sense that it highlights the changes in the demand for more qualified occupations. More specifically, it shows a higher demand for professionals within the Exact and Biological Sciences (that include engineers and agronomists, for example). Indeed, even though the shares appear to remain equal or even diminishing over time, the increase in absolute values is significant and higher than the increasing pattern observed within the regions. For example, in region 1, while the raise on the demand of these occupations is about 87% from 2003 to 2017, the rise observed within the sector is about 249% for the same period. Region 2 presents a raise of 83% while the sector within that region presents a raise on this demand of around 452%. Finally, the change in the same demand within the sugar-energy industry is around 684% against the 160% observed within the region.

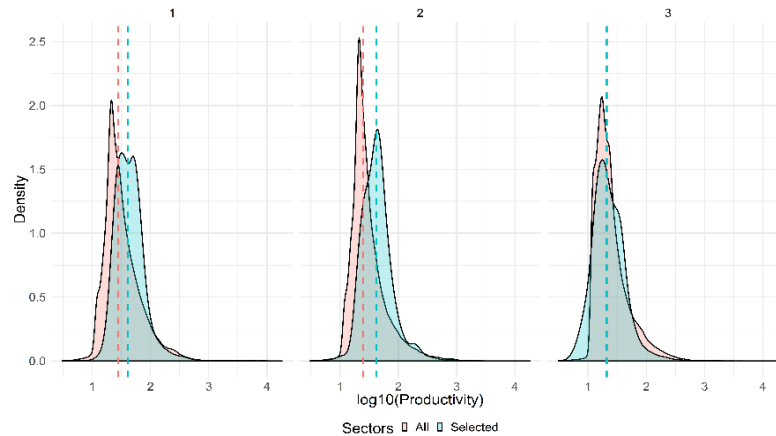


Table 3: Evolution of the number occupations in Exact and Biological Sciences.

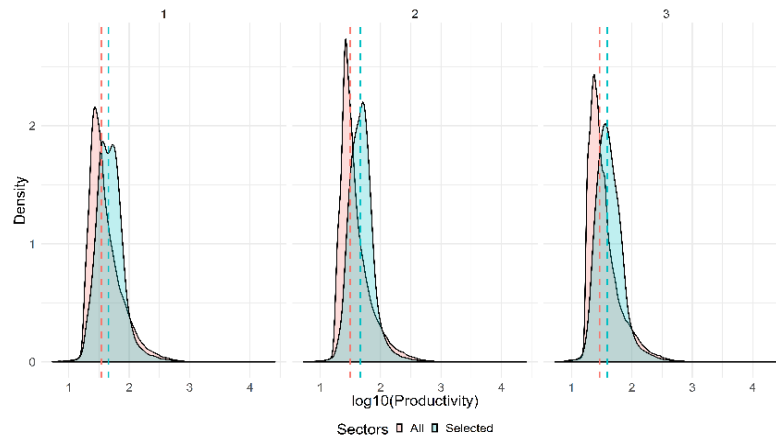
Region	Sector	2003		2010		2017	
		n	%	n	%	n	%
1	All	24,329	2.4	32,819	2.0	45,714	2.6
	Selected	403	1.0	1,262	0.9	1,408	1.1
2	All	12,299	2.5	15,903	2.1	22,550	2.7
	Selected	126	2.0	665	0.8	695	1.0
3	All	18,389	1.8	28,425	1.7	47,944	2.4
	Selected	114	0.6	900	0.8	894	0.8

Source: Org. by the authors. Database RAIS.

Finally, we believe that it brings evidence in favor of a structural change within the sugar-cane industry. However, if this change is positive for the sector and the region, it should be reflected in the sectoral performance. For capturing this, we observe the average wage per hour worked, which is presented in Figure 2. The kernel density estimations for regional labor productivity is depicted in blue, whereas the sectoral estimates are in red. Horizontal axes are in log 10 for better visualization of the tails.



(a)



(b)

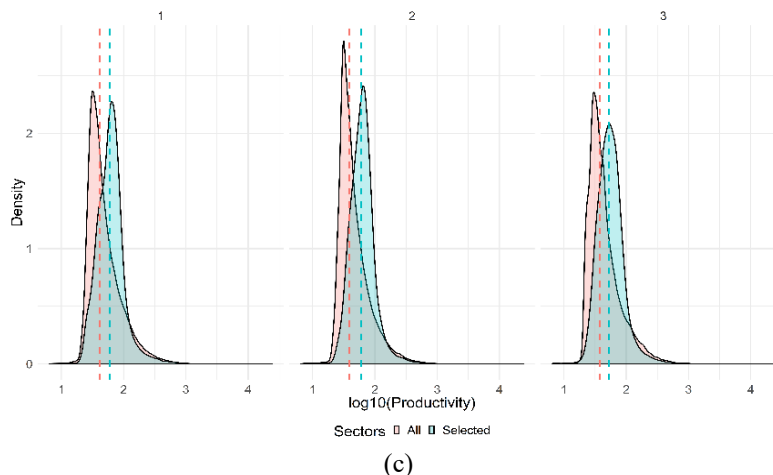


Figure 2: Distribution of labor productivity for (a) 2003, (b) 2010 and (c) 2017. The horizontal axis is in log10 for better visualization of the tails.

Region 1 has the higher average wage per hour worked (45, 53 and 62 approx. in 2003, 2010 and 2017, respectively), followed by region 2 (40, 48 and 57) and 3 (35, 45 and 56), although variability appears higher in regions 2 and 3.

The sugar-energy sector has a higher average wage per hour worked in regions 1 and 2 if compared with the whole region. Asymmetric distributions show the heterogeneity, with a right fat tail indicating that there is a significant part of workers year with productivity lower than the average and some with higher productivity. For example, if we consider 2017, and a confidence interval of plus/minus one standard deviation, we notice that the higher productivity observed is 247, 10 and 17 times higher than the lower one observed within the sector. Also, in 2017, the sector presents its median productivity shifted to the right in all the regions. Social and economic benefits will be higher in region 3 given that we are working with wages that affect the welfare of the families directly and that it was that region that presented the major increase on average values, going from 28 reais per hour to 62 on average.⁹

To finish our analysis let us observe another dimension of the know-why, this time more related to the knowledge generation and research activities.

4.4. Regional inequalities: the know-why dimension in research activities

The publications evolution about sugarcane, under regional and temporal perspectives, allows a stratified understanding of the generation of knowledge in the sector. According to Table 4, of the total of 5,639 publications on sugarcane, approximately 60% of the publications occurred between 2011 and 2017, which indicates a significant expansion of the publications in the second period. Even though the distribution of publications between regions still shows small changes in the share of each region over the total published over the years. Evidence suggests that there were no significant changes in the participation of each region in the generation of knowledge about sugarcane in Brazil.

⁹ Statistics can be provided upon request.



Table 4: Publications evolution by regions and years

Region	until 2003	%	2004-2010	%	2011-2017	%	Total
Region 1	219	19.09%	171	14.24%	420	13.90%	810
Region 2	5	0.44%	24	2.00%	50	1.66%	79
Region 3	63	5.49%	86	7.16%	186	6.16%	335
Other SP*	470	40.98%	464	38.63%	1,258	41.64%	2,192
Other Brazil**	390	34.00%	456	37.97%	1,107	36.64%	1,953
Total	1,147	100.00%	1,201	100.00%	3,021	100.00%	5,369

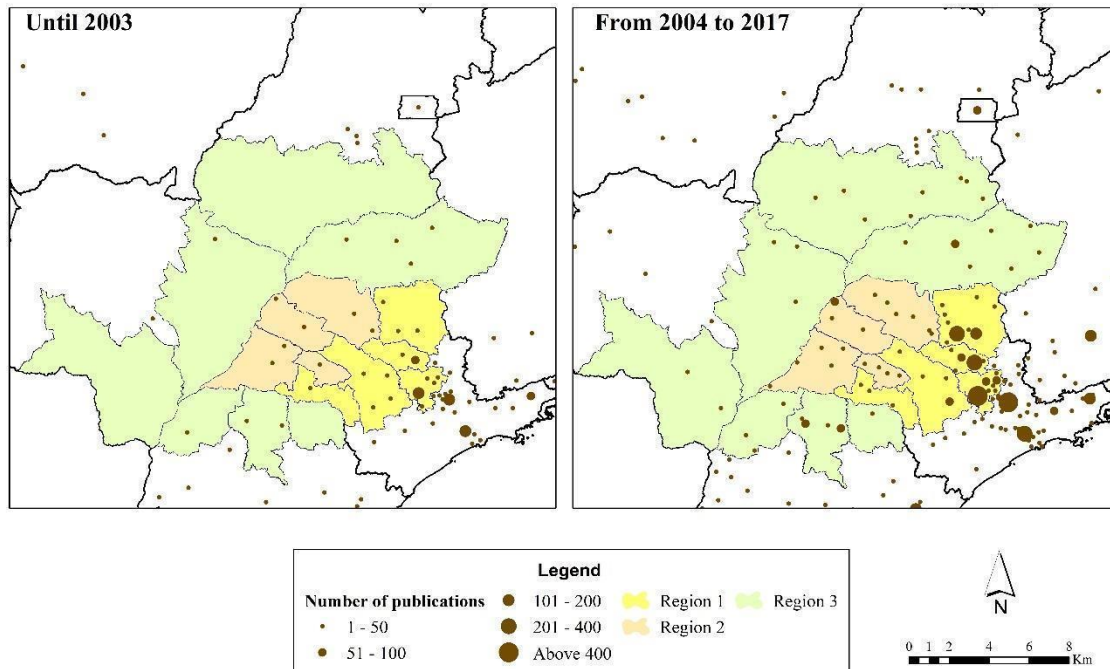
Source: Org. by the authors. Database Lattes Platform

* São Paulo state disregarding regions 1 and 2.

** Brazil is disregarding São Paulo state and region 3.

However, Map 3 shows the beginning of the contribution of universities, between the years 2004 and 2017 that were not part of the map of the scientific production on sugarcane.

Map 3: Publications about sugarcane



Source: Org. by the authors. Database: Lattes Platform

The concentration of the scientific production presented in Table 4 is a result of the size of the universities where papers authors work. As Table 5 shows, the universities of the state of São Paulo appear among the institutions with the most significant number of publications, reinforcing the importance of the state for the generation of knowledge about sugarcane.



Table 5: Publications by university or research institution

University of Research Institution*	Brazilian State	Publications
UNIVERSIDADE DE SAO PAULO	São Paulo	871
UNIVERSIDADE ESTADUAL PAULISTA JULIO DE MESQUITA FILHO	São Paulo	741
ESCOLA SUPERIOR DE AGRICULTURA LUIZ DE QUEIROZ	São Paulo	640
UNIVERSIDADE ESTADUAL DE CAMPINAS	São Paulo	552
EMPRESA BRASILEIRA DE PESQUISA AGROPECUARIA	Multi State	417
UNIVERSIDADE FEDERAL DE SAO CARLOS	São Paulo	257
CENTRO NACIONAL DE PESQUISA EM ENERGIA E MATERIAIS	São Paulo	202
UNIVERSIDADE FEDERAL DE VICOSA	Minas Gerais	195
INSTITUTO AGRONOMICO DE CAMPINAS	São Paulo	186
UNIVERSIDADE FEDERAL DO RIO DE JANEIRO	Rio de Janeiro	183

* The number of articles of each university is calculated considering if there is at least one author of such university. Thus, an article with more than one author from the same university does not duplicate the number of articles in that university.

In region 1, it is important to highlight the role of Escola Superior de Agricultura Luiz de Queiroz (ESALQ) located in Piracicaba, the Universidade Federal de São Carlos - headquarter of the (Inter-University Network for the Development of Sugarcane Industry – Ridesa, in São Paulo, located in Araras, and the Instituto Agrônômico de Campinas, mainly because of the Center of Cana located in Ribeirão Preto. Region 1 also benefits for its geographical proximity with the Universidade de São Paulo, Universidade de Campinas and the Centro Nacional de Pesquisa em Energia e Materiais (CNPEM). The data of Universidade Estadual Paulista Julio de Mesquita Filho is aggregated, which makes it difficult to identify the precise location of publications. Nevertheless, considering that this university has courses of Agrarian Sciences in Jaboticabal and Botucatu, both in region 1, it also shows a concentration process. Regarding region 2, we did not find any representative institution publishing papers about sugarcane. The exception is the campus of Universidade Estadual Paulista Julio de Mesquita Filho in Dracena, that has a course of Agrarian Science. Our hypothesis is that that region 2 benefits from the knowledge infrastructure of region 1. In region 3, there are three representative institutions: Universidade Federal de Uberlândia (16° in the ranking), Universidade Estadual de Maringá (18°) and Universidade Estadual de Londrina (20°).

Conclusions

The paper analyzed the regional inequalities in the sugar-energy sector, considering the growth of bioethanol production after the 2000s and the territorial dispersion of mills and sugarcane production. The theoretical approach is associated with the idea that modern capitalism is based on a learning and knowledge economy. For capturing this, we divided the Centre-South region into three regions. We also divided the knowledge effects into three dimensions: the know-how, the know-why related to labor qualification and the know-why related to research activities.

The know-how shows evidence of regional structural changes in the sugar-cane industry, reflected in the occupational structure. At this point, the most important gain resulted from worker experience is in region 2. Regarding the know-why related to labor qualification, region 2 also appears with the higher percentages of formal workers that completed high school or have at least college. In this part, both region 2 and 3 have more percentage of workers with a superior education than region 1. The know-why related to publications show an inverse situation. Region 1 has by large the most representative knowledge infrastructure, which reflects in its dominance of publications.



Based on these results, the paper reinforces the importance of considering the regional differences of sugar-energy sector to analyze its socio-economic effects in a learning economy. The traditional regions increased its share in the creation of knowledge. The new regions increase the number of qualified jobs that allow absorbing external knowledge, and the accumulation experience allows learning by doing process with tests and recognizes the specific demands of the regions.

References

- ASHEIM, B.; GERTLER, M. The geography of innovation: regional innovation systems. In: FAGERBERG, J.; MOWREY, D. (Eds.). **The oxford handbook of innovation**. Oxford: OUP Oxford, 2006. p. 291–317.
- ASHEIM, B. T.; SMITH, H. L.; OUGHTON, C. Regional Innovation Systems: Theory, empirics and policy. **Regional Studies**, v. 45, n. 7, p. 875–891, 2011.
- BACCARIN, J. G.; ALVES, F. J. D. C.; GOMES, L. F. C. **Emprego e Condições de Trabalho dos Canavieiros no Centro-Sul do Brasil, entre 1995 e 2007**. XLVI Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural. **Anais...**Rio Branco: 2008
- BALLAND, P.-A.; RIGBY, D. The Geography of Complex Knowledge. **Economic Geography**, v. 93, n. 1, p. 1–23, 2017.
- BELIK, W. et al. Milling capacity and supply competition in sugar- ethanol industry in São Paulo, Brazil. **Geografia-Rio Claro**, p. 1–19, 2017.
- BÖGEL, G. Competing in a smart world: The need for digital agriculture. **Management and Organization: Concepts, Tools and Applications**, p. 11–28, 2017.
- BOSCHMA, R. Proximity and Innovation: A Critical Assessment. **Regional Studies**, v. 39, n. 1, p. 61–74, 2005.
- BRINKMAN, M. L. J. et al. Interregional assessment of socio-economic effects of sugarcane ethanol production in Brazil. **Renewable and Sustainable Energy Reviews**, v. 88, n. September 2017, p. 347–362, 2018.
- BUENO, C. D. S.; SILVEIRA, J. M. F. J. DA; BUAINAIN, A. M. Innovation, networks and the paradigm of biofuels. **International Journal of Entrepreneurship and Small Business**, v. 35, n. 3, p. 452, 2018.
- CASTILLO, R. **Sistemas orbitais e uso do território: integração eletrônica e conhecimento digital do território brasileiro**. 343 f. Departamento de Geografia Humana, USP, São Paulo. 1999.
- CASTILLO, R. Dinâmicas recentes do setor sucroenergético no Brasil: Competitividade regional e expansão para o bioma Cerrado. **GEographia**, v. 17, n. 35, p. 95–119, 2015.
- CERQUEIRA LEITE, R. et al. Can Brazil replace 5 % of the 2025 gasoline world demand with ethanol? **Energy**, p. 1–7, 2008.
- CHAGAS, A. L. S.; TONETO JUNIOR, R.; AZZONI, C. R. Sugarcane, land use and regional development. **TD**, n. 9, p. 21, 2011.
- COOKE, P.; URANGA, M. G.; ETXEBARRIA, G. Regional innovation systems: institutional and organizational dimensions. **Research Policy**, v. 26, p. 475–491, 1997.
- FORAY, D. **Economics of knowledge**. Cambridge, London. MIT Press, 2004.
- FRANK, A. G. **Capitalism and underdevelopment in Latin America**: historical studies of Chile and Brazil. New York, London. Monthly Review Press, 1969.
- FURTADO, A. T.; SCANDIFFIO, M. I. G.; CORTEZ, L. A. B. The Brazilian sugarcane innovation system. **Energy Policy**, v. 39, n. 1, p. 156–166, 2011.



- FURTADO, C. **Análise do modelo brasileiro**. Rio de Janeiro: Civilização Brasileira, 1972.
- GARCIA, R.; VENEZIANO, A.; MASCARINI, S.; SANTOS, E. G.; COSTA, A. R. Interações Universidade-Empresa e a Influência das características dos grupos de pesquisa acadêmicos. **Rev. econ. contemp.**, v. 18, n. 1, p. 125–146, abr. 2014.
- GOLDEMBERG, J.; COELHO, S. T.; GUARDABASSI, P. The sustainability of ethanol production from sugarcane. **Energy Policy**, v. 36, n. 6, p. 2086–2097, 2008.
- LEE, K. How Can Korea be a Role Model for Catch-up Development? A “capability-based View”. **WIDER Research Paper**, v. 34, p. 22, 2009.
- LESTER, R. K. Universities, innovation and the competitiveness of local economies. **Local Innovation Systems Project**. v. 010, n. December 2005, p. 33, 2005.
- LOURENZANI, W. L.; CALDAS, M. M. Mudanças no uso da terra decorrentes da expansão da cultura da cana-de-açúcar na região oeste do estado de São Paulo. **Ciência Rural**, v. 44, n. 11, p. 1980–1987, 2014.
- LUNDVALL, B.-Å. Innovation as an interactive process: from user-producer interaction to the national system of innovation. In: DOSI, G.; FREEMAN, C.; NELSON, R.; SILVERBERG, G.; SOETE, L. (Eds.). **Technical change and economic theory**. London and New York: Pinter Publishers, 1988.
- LUNDVALL, B.-Å. **The Learning Economy and the Economics of Hope**. London: Anthem Press, 2016.
- LUNDVALL, B.-Å.; JOHNSON, B. The learning economy. In: LUNDVALL, B.-Å. (Ed.). **The learning economy and the economics of hope**. London and New York: Anthem Press, 2016. p. 107–133.
- MESQUITA, F. C. Evolução do aprendizado na expansão da cana-de-açúcar para Goiás: o papel dos centros de pesquisa. **Campo e Território: Revista de Geografia Agrária**, v. 22, 2016.
- MORAES, M. A.; COSTA, C. C.; GUILHOTO, J. J. M.; SOUZA, L. G. A.; OLIVEIRA, F. C. R. Social Externalities of Fuels. In: SOUSA, L. L. DE; MACEDO, I. D. C. (Eds.). **Ethanol and bioelectricity: sugarcane in the future of the energy matrix**. São Paulo: UNICA, 2011. p. 44–75.
- MORAES, M. A. F. D.; ZILBERMAN, D. **Production of ethanol from sugarcane in Brazil: from State intervention to a Free Market**. New York, Dordrecht, London: Springer, 2014.
- MYRDAL, G. **Rich Land and Poor**. New York: Harper & Brothers Publishers, 1957.
- NORTH, D. C. Agriculture in Regional Economic Growth. **Journal of Farm Economics**, v. 41, n. 5, p. 943–951, 1959.
- OLIVEIRA, A. L. R. Logística do etanol no Brasil. In: SALLES-FILHO, S. (Ed.). **Futuros do bioetanol: o Brasil na liderança?** Rio de Janeiro: Elsevier, 2015. p. 55–70.
- PAGE, B.; WALKER, R. From Settlement to fordism: The Agro-industrial revolution in the American Midwest. **Economic Geography**, v. 67, n. 4, p. 281–315, 1991.
- PEREZ, C. Technological revolutions and techno-economic paradigms. **Cambridge Journal of Economics**, v. 34, n. 1, p. 185–202, 2009.
- PIETRAFESA, J. P.; PIETRAFESA, P. A. International Capital and New Frontiers of Biofuel Production in Brazilian Midwest. **Ateliê Geográfico**, v. 10, n. 1, p. 7–27, 2016.
- POLANYI, M. **The tacit dimension**. Garden City, NY: Doubleday & Company, , 1966.
- SALLES-FILHO, S. L. M. et al. Perspectives for the Brazilian bioethanol sector: The innovation driver. **Energy Policy**, v. 108, n. June 2016, p. 70–77, 2017.
- SCHULTZ, T. **Transformação da agricultura tradicional**. Rio de Janeiro: Zahar, 1965.
- STORPER, M. **The Regional World: Territorial Development in a Global Economy**. Nova Iorque e Londres: Guilford Press, 1997.
- STORPER, M. **Keys to the City: How Economics, Institutions, Social Interaction, and Politics Shape Development**. Princeton, Oxford: Princeton University Press, 2013.



STORPER, M.; VENABLES, A. J. Buzz: Face-to-face contact and the urban economy. **Journal of Economic Geography**, v. 4, n. 4, p. 351–370, 2004.

WALKER, R. **The conquest of bread: 150 years of agribusiness in California**. New York, London: New Press, 2004.