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Location of agricultural output and economic geography. Uruguay in the long-run (1870-2008)

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Abstract

This article examines how geographical conditions influenced the territorial distribution of agrarian output in Uruguay over the long run. Covering 17 time-benchmarks (1870–2008), we contrast the impact of first-nature factors (land endowments, climate, location) with second nature factors (agglomeration economies, infrastructure, transport). Using panel data and R^2 decomposition, our findings show that second nature factors gained relevance in the 20th century, as technological change fostered intensive agriculture. Large markets, including Montevideo and border regions (Buenos Aires, Entre Ríos, and Río Grande do Sul), became key drivers of agricultural concentration, with market potential emerging as the predominant factor over time.

Keywords: agriculture, location, geographical factors, Uruguay.

JEL Classification: N5, N56, O33, Q16, R12.

Localización de la producción agraria y geografía económica. Uruguay en el largo plazo (1870–2008)

Resumen

Este artículo examina cómo las condiciones geográficas influyeron en la distribución territorial de la producción agraria en Uruguay a lo largo del tiempo. Abarcando 17 referencias temporales (1870–2008), contrastamos el impacto de los factores geográficos de primera naturaleza (dotación de tierras, clima, ubicación) con los de segunda naturaleza (economías de aglomeración, infraestructura y transporte). Utilizando datos de panel y una descomposición de R^2, los resultados muestran que los factores de segunda naturaleza ganaron relevancia en el siglo XX, a medida que el cambio tecnológico impulsó una agricultura más intensiva. Los grandes mercados, incluyendo Montevideo y las regiones fronterizas (Buenos Aires, Entre Ríos y Río Grande do Sul), se convirtieron en impulsores clave de la concentración agraria, emergiendo, con el paso del tiempo, el potencial de mercado como el factor predominante.

Palabras clave: agricultura, localización, factores geográficos, Uruguay.

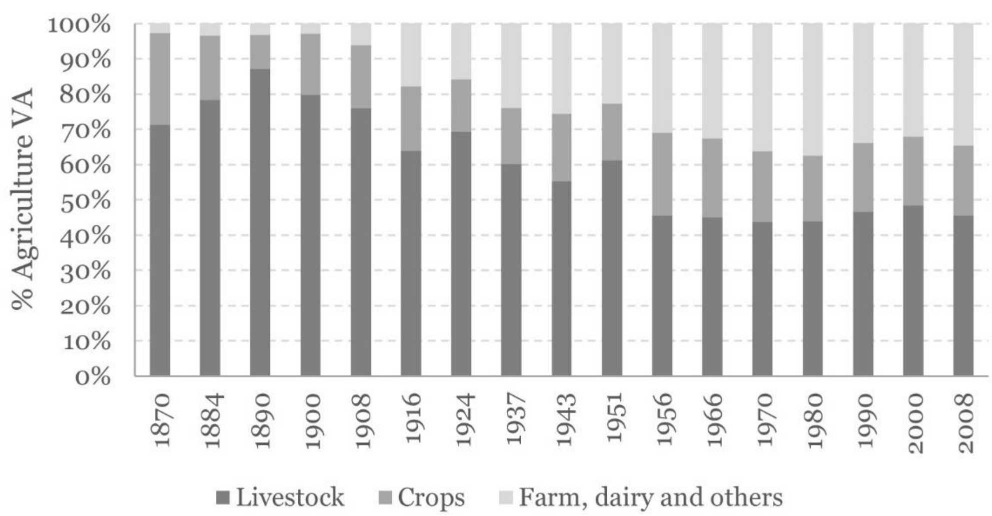
Códigos JEL: N5, N56, O33, Q16, R12.

Motivation

Agriculture in Uruguay–as well as in other Latin American countries–has been one of the main activities of the productive structure since the constitution of the country as an independent nation in the first half of the 19th century (and even before). Agriculture represented a third of GDP (Bértola et al., 2024) and almost 50 per cent of employment (Álvarez Scanniello *et al.*, 2024) at the beginning of the 20th century, although these percentages at the beginning of the 21st century had fallen to 9 percent and 11 per cent, respectively. In spite of the decline in the relative economic significance of this sector in the national economic structure, agriculture maintained two relevant features. First, it sustained dynamic backward and forward linkages; on the one hand, demanding agricultural inputs (many times from abroad) and, on the other hand, providing inputs to the agro-industry sectors such as processing and preserving of meat, fruit and vegetables, manufacture of dairy products, grain mill products, beverages, textiles, leather and related products. Second, agriculture provided the majority of exports during the last century, representing 85 per cent of the total exports at the beginning of the 20th century and around 75 per cent one hundred years later.

The long-run agricultural evolution included important transformations (a true structural change within the sector). This evolution involved significant changes in the type of agrarian activities –especially the increasing share of non-perennial (cereals, rice, vegetables) and perennial crops (citrus and other tree fruits) to the detriment of animal production (rearing of cattle and sheep) (see Figure 1) and with increasing labour and land productivities –both indicators multiplied by more than 3 during the century– (Castro Scavone, 2017). These transformations were related to significant changes in the territorial location of agriculture in the long run. According to Araujo et al. (2015), the geographical location of agricultural production can be described through six stylized facts.

Figure 1. Value-Added of Agriculture by classes of agricultural activity



Source: Our own data.

First, production is relatively decentralised in the territory. Second, this low territorial concentration is explained, fundamentally, by animal production (cattle and sheep) while the other types of production show higher concentration (especially farming production). Third, the provinces with the most differentiated productive structures are Montevideo, Canelones, San José and Colonia, i.e. the southwest region of the country with diversified production and a significant presence of farming and dairy production. Fourth, the agricultural specialization allows us to identify provinces typically dedicated to livestock (the majority of the territory with the exception of the southwest region); the growing of cereals (the south and the Littoral regions); vegetables and fruits (provinces around Montevideo and Salto); the rearing of swine and poultry, the dairy industry (in the south) and sugar cane and sugar beets (in the north Littoral and Canelones) and, at the end of the 20th century, forestry and logging (in the centre and east of the country). Fifth, the highest labour productivity corresponded to the provinces more dedicated to cattle production. Sixth, the highest land productivity corresponded to those provinces more dedicated to growing cereals and rearing swine and poultry, and the dairy industry, which coincides with having the land with the best agronomical quality.

The aim of this article is to explain the geographical distribution of agricultural output in Uruguay –referring to the first four previous stylized facts– and, for this, we proposed to examine the role of the geographical conditions in this process in the long-run (from the last decades of the 19^{h} century to the first decade of the 21st century).We conducted an exploratory analysis of the determinants of the location of the regional agriculture value-added in seventeen time-benchmarks (1870, 1884, 1890, 1900, 1908, 1916, 1924, 1937, 1943, 1951, 1956, 1966, 1970, 1980, 1990, 2000 and 2008)[1], by considering the explicative power of the factors closely related to "pure" geographical features (land endowments, climate and places where provinces are situated) in contrast to the second nature causes (those related to agglomeration economies, infrastructure and transport). Additionally, we considered the effect of other factors (control variables): technological change, institutional arrangements and some relevant prices in agrarian production as those corresponding to land and commodities. For this purpose, we took advantage of a previously constructed database that includes value-added provincial agriculture (Araujo et al., 2015; Castro Scavone & Willebald, 2022; Castro Scavone, 2017[2]) and developed a set of explicative variables to test our hypotheses. One of the main challenges was to apply the New Economic Geography –a theoretical framework worked out for explaining industrial location– to understand the location of agriculture in the long-run.

The article is ordered as follows. Initially, we provide a brief literature review, focusing on recent studies of agrarian development in Latin America that emphasize geographic and environmental factors, while also considering the location of production within national economies (Section 2). Then, we characterized the agricultural concentration in Uruguay by territory during the period (1870-2008), presenting maps and considering a long run evolution of agrarian production (Section 3). Third, we present our conceptual framework considering the

[1] The selection of years is dependent on the availability of information (agricultural census).
[2] These studies offer information for particular years (each 10 years around) and this determined part of our possibilities to make statistical exercises.

influence of "first-nature geography" factors (the physical geography of climate, topology and resource endowments) and the "second-nature geography" factors (the location of economic agents relative to one another in space). In accordance with the previous discussion about the stylized facts of the agricultural location and the conceptual arguments, we proposed our working hypotheses (Section 4). Then, we presented our empirical strategy based on two types of exercises: panel data analysis and R^2 decomposition using the relative importance of variables (Section 5). Our results (Section 6) show that first-nature and second-nature factors compete in explaining the unequal territorial distribution of agriculture in the long term, and the intensity of their influence changed over time.

During the 20th century, second-nature factors gained explanatory power as technological change fostered the rise of intensive agricultural activities. In addition, we found evidence of the increasing role of large markets (cities in the Uruguayan littoral, the south of the country, Montevideo, and key border region in neighbouring countries such as Buenos Aires, Entre Ríos, and Río Grande do Sul) in concentrating these agrarian productions. While first-nature factors were relevant throughout the period, second-nature factors have historically been the principal explanatory variables, with market potential emerging as the predominant factor over time. Finally, we present some final remarks (Section 7).

Literature review

The relationship between geographic factors and agricultural performance lies at the intersection of agrarian economics, economic history, and economic geography. Yet, despite its relevance, historical economic geography has traditionally paid limited attention to agriculture, focusing instead on industrial location, urbanization, and transport networks. The spatial dynamics of the rural economy were often treated as background conditions rather than as central objects of inquiry. This imbalance is important to address, since the organization of agricultural space –its adaptation to natural endowments and its transformation through markets, infrastructure, and institutions– has been a fundamental component of long-run economic change.

In the field of agrarian development, the classic theory of induced innovation by Hayami & Ruttan (1971) provides a useful starting point. They argued that technological change in agriculture responds to incentives shaped by factor endowments (land, labor, capital) and relative prices. Geography influences both: soil quality, climate, and access to markets determine production costs and profitability, shaping the direction of technological adoption. This framework highlights the adaptive character of agricultural innovation but often treats space implicitly, assuming that natural and institutional settings are exogenous. Integrating spatial heterogeneity into this theoretical view allows a more complete understanding of how economic geography interacts with agricultural productivity.

From comparative economic history, the literature on factor endowments and institutions (Engerman & Sokoloff, 1997, 2002) introduced an institutional dimension to geographic explanations. Their argument is that initial conditions –particularly land abundance, climate suitability for export crops, and the resulting landownership structures– shaped the formation of economic and political institutions. These institutions, in turn, influenced investment, technology adoption, and long-term productivity. Although their perspective is not explicitly spatial in the modern sense, it established the idea that geography and the distribution of resources affect not only output levels but also the institutional capacity for agrarian development.

A major conceptual contribution emerged from environmental and historical geography. Cronon (1991) discusses how the expansion of railroads, the rise of urban markets, and technological advances in transportation and communication redefined the geography of the American Midwest. Rural production, marketing, and even the perception of "nature" itself were reorganized through the spatial and economic integration of city and countryside. His key insight is that economic geography is historically constructed: spatial patterns of specialization reflect evolving market relations rather than static physical conditions. This perspective highlights agriculture as an integral component of regional transformation, deeply embedded in the urban–industrial nexus rather than standing apart from it. A similar methodological orientation can be found in Martinelli (2014), who examines interwar Italy. The author shows that northern regions –better connected to urban and industrial centers– developed a more dynamic and diversified agriculture than the southern regions. The study demonstrates how market access and infrastructure mediated the spatial differentiation of agricultural performance, but it also reveals the persistence of a disciplinary bias: industrial growth is often portrayed as the driver of agricultural transformation, while the reverse relationship receives less attention. By recovering agricultural space as a key analytical dimension, it is possible to bridge agrarian history and economic geography and thus it offers a template for rethinking similar processes in other contexts, such as Latin America.

Recent advances in spatial and quantitative economic history have revitalized interest in geography's role in agricultural productivity. Adamopoulos (2025) provides new empirical evidence for Latin America and the Caribbean, showing that variations in soil quality, rainfall, and temperature explain a substantial part of subnational productivity differences. These effects, however, are strongly mediated by infrastructure, market accessibility, and agricultural policy. Similarly, studies of Total Factor Productivity (TFP) in Latin American agriculture –such as Lachaud et al. (2021)– emphasize technological diffusion and regional heterogeneity as key sources of divergent agricultural growth paths. In a broader regional synthesis, Berdegué et al. (2015) examine the spatial diversity of rural development across Latin America, showing how differences in productive structures, local institutions, and social coalitions account for divergent territorial trajectories. The study emphasizes that rural development depends not only on natural endowments but on the interaction among actors, policies, and institutions. Yet, most of these analyses are limited to the late 20th and early 21st centuries and lack a long-run, historical perspective that connects geography to changing economic structures.

Within Latin American economic history, Martín-Retortillo et al. (2022) argues that there is no single pattern of agricultural growth in the region, given its diverse natural environments, land tenure systems, and policy regimes. This heterogeneity reinforces the need for country-specific, long-term studies that integrate geography, technology, and institutions. Likewise, Helfand et al. (2018) show that farm size and production organization mediate the relationship between geography and productivity, indicating that the spatial logic of agriculture cannot be explained by natural endowments alone.

Considering national cases, Mores et al. (2022) document the reconfiguration of the Brazilian agricultural geography between 1990 and 2015, showing how technological diffusion, infrastructural improvements, and regional specialization reshaped production centres. Choumert & Phélinas (2015) examine the determinants of agricultural land values in Argentina, applying a hedonic-price model to assess how soil quality, distance to markets and urban centres, and land-tenure arrangements influence land values. OCDE (2014) underscores the deep territorial heterogeneity of the Chilean countryside, where differences in geography, infrastructure, and market access shape agricultural specialization and productivity. It advocates a "place-based" approach to rural development, recognizing that regional disparities in connectivity and institutional capacity remain key determinants of performance.

Together, these studies reinforce the view that geography continues to exert a fundamental influence on agricultural development in Latin America. They also underscore the need for long-run, subnational studies that integrate natural and infrastructural dimensions –an approach still rare in the region. Against this backdrop, the Uruguayan case adds a valuable comparative benchmark by extending the analysis back to the late 19th century and explicitly connecting spatial dynamics to structural change.

Some stylized facts about agriculture location

Agriculture is not a homogeneous sector. It includes several types of activities with different conditions, requirements and results. In Uruguay, livestock (based on the use of the natural prairies) has historically been the country's main activity. Crop agriculture has occupied a secondary place, and more intensive activities, such as dairy and farm, have had a minor importance in the productive structure. However, activities that make intensive use of the land factor become increasingly important during the period and have been located in certain areas of the country. In accordance with DIEA-MGAP (2015) we selected three groups based on the intensive use they make of the land.

- Livestock: cattle (for beef), sheep (for lamb, mutton and wool).
- Crop: cereals, fodder, leguminous crops and oil seeds
- Dairy and farm: production of milk, rearing of swine/pigs and poultry, growing of vegetables and melons, roots and tubers, grapes, citrus fruits and other fruits.

One of the more classical characterizations of Uruguay corresponds to Reyes Abadie et al. (1966) who describes it as the combination of "prairies, border and harbour". In other words, Uruguay –usually referred to as Banda Oriental in colonial times– was a region with abundant natural resources suitable for cattle production, with one of the better ports of South America (which was the main "exit door" for commodities from the River Plate to the international markets until the end of the 19th century) and was the frontier between the two empires that conquered Latin America: Spain and Portugal. This feature continued even after the independence from other protagonists –Argentina and Brazil– but with similar consequences: Uruguay constituted a buffer state between two immense countries that productively, institutionally and culturally moulded the society, leading to differences within the country that have persisted until today (see Martínez-Galarraga et al., 2020).

The current provincial division of Uruguay has been in force since 1884-1885 including 19 "*departamentos*" (provinces) that, as shown in Figure 2, have very diverse dimensions.

Figure 2. Provinces of Uruguay

Source: our data based on Instituto Nacional de Estadística (INE)

The largest province (Tacuarembó) is 30 times the size of the smallest (Montevideo), and the most populated in the mid-20th century (Montevideo) was 28 times more populous than the least populated (Flores). We consider this administrative division as a reference due to the availability of the information.

The sector concentration between regions can be addressed by estimating the density of the agriculture value-added (VA). If the regions concerned were the same size, regional VA could be used as a simple indicator of the spatial distribution of the total economic activity of the country. However, as provinces have different surface areas, the density of the value-added (VA per km^2) controls the differences between administrative divisions (equation 1). Such indicators are commonly used as a measure of economic concentration, and they are useful to rely on the New Economic Geography (NEG) theoretical framework for studying industrial concentration (Novel & Tirado, 2008). The use of this indicator to study the concentration of agricultural VA is justified in the growing importance that intensive agricultural activities in land use and labor acquired in the 20th century in the provinces with the highest access to regional markets.

$$density_{i,t} = \frac{VA_{i,t}}{area_i} \quad (1)$$

We analyze the evolution of VA–average values–between 1870-2008 but considering three sub-periods that guided the trajectories of the Uruguayan economy in the long term (Román & Willebald, 2021).

The first period covers the last three decades of the 19th century and the first two of the 20th century and contains seven benchmarks: 1870, 1884, 1890, 1900, 1908, 1916 and 1924. The results of this period reflect the reality of an agro-export economy inserted in the dynamics of the First Globalization. The last benchmark could capture the effects of the transition period in the 1920s and is included in the following period as well. So, the second period contains the years 1924, 1937, 1943, 1951, 1956 and 1966. These benchmarks cover the period of import-substitution industrialization (ISI) (or state-led industrialization), from the transition in the 1920s to its decline in the 1950s. The third period –including the benchmark of the transition in 1966– covers the last three decades of the 20th century (1966, 1970, 1980, 1990, 2000) and ends in 2008. It is a period characterized by growing financial liberalization and promotion of non-traditional exports in the 1970s, and once the "lost decade" of the 1980s was over, the liberalizing that had begun in the 1970s resumed, until the economic and social debacle that culminated in the crisis of 2002 occurred. The last year of the period coincides with the first official regional VA estimates (OPP-INE, 2012) and represents the first years of the new agro-export cycle and transformations in agriculture, which are still underway (Bértola et al., 2014).

As our interest is focusing the analysis on the 19th and 20th centuries, we decided not to advance beyond 2008. With the information referring to 2008, we "closed" the 20th century. Additionally, it is true that agriculture, from the second decade of the 21st century, experienced a new context that led to deep and significant changes. The region combined a favorable macroeconomic context, high international prices, and auspicious public policies, which encouraged important transformations in Uruguay's agriculture, and which were expressed in a growing intensification of agricultural production with a marked expansion of crop agriculture and forestry. This process cannot be analyzed without addressing a set of factors, within which the presence of new business actors (with a strong presence of transnational capital) and very profound changes in the models of management, production, financing, and use of modern technology stand out (Arbeletche, 2020). In future stages of our research, we will go into these topics in depth (for this, it would be essential to have the census information from 2024, which is currently being processed).

Historically, the south and littoral[3] of the country (see Figure 3) was the leading location of agricultural production. The provinces that occupied the first places in the ranking were Montevideo, Canelones, San José, Colonia and Soriano, with the provinces of Río Negro, Flores, Florida, and Maldonado a few steps below. In addition, in a previous study, we found evidence that these provinces are characterized by a high specialization in intensive activities (such as

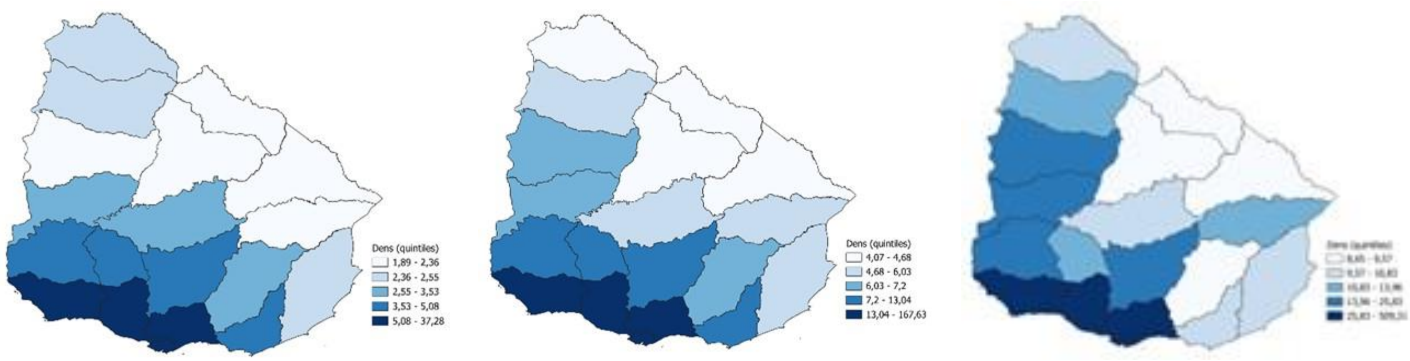
[3] In Uruguay, the zone in the border with Argentina corresponding to the Uruguay river is identify as the littoral.

farming involving dairy, poultry, pigs, fruit, vegetables and industrial crops) and show a higher degree of productive diversification (Castro Scavone, 2017).

Those regions would have taken advantage of their natural benefits in terms of land quality but also would have benefited from their better access to the Montevideo market, and, consequently, to the port to participate in international trade. It is possible that these factors, together with the incorporation of technology, contributed to a higher diversification of their productive structures and allowed them to incorporate increasingly intensive activities, such as dairy and farming (Castro Scavone, 2017).

Figure 3. Density of value-added in provinces of Uruguay

1870-1924[4] 1924-1966 1966-2008



Source: our own data.

Conceptual framework and hypotheses

Over the last 25 years, the uneven distribution of economic activity across the territory has received renewed attention with the emergence of the NEG (Krugman, 1991a; Fujita et al., 2001). Whereas traditional neoclassical explanations of the distribution of economic activity across the territory emphasize "first-nature geography" –the physical geography of climate, topology and resource endowments– (Gallup et al., 1998; Sachs, 2000), this new body of research stresses the role of "second nature geography" (the location of economic agents relative to one another). NEG models introduce product differentiation, increasing returns to scale and transport costs as essential components of the analysis, which together create pecuniary externalities that explain the agents' location choices (Redding, 2010). Combined with either factor mobility or intermediate inputs, these three components have given rise to forces of cumulative causation and agglomeration.

As workers tend to concentrate their location in specific areas, the resulting shift in expenditure encourages the firms to locate production in those areas (the so-called "home market effect"). Likewise, as firms concentrate production in a location, the resulting reduction in the

[4] The current administrative division of Uruguay composed of 19 provinces corresponds from 1885 onwards; the consideration of the map for the period 1870-1924 has an instrumental purpose. See an explanation in Castro Scavone & Willebald (2022).

consumer price index –as a consequence of a higher supply– increases workers' incentives to concentrate in that location (the so-called "price index effect").

In NEG models, the tension between these agglomeration and dispersion forces in the form of immobile factors of production (Krugman, 1991a, b) and non-traded amenities (Helpman, 1998) determines the spatial distribution of economic activity. A central implication of these models is that for a range of parameters this distribution is not uniquely determined by locational fundamentals, but exhibits multiple equilibria (Redding, 2009).

Some authors have argued that embedding endowment-based comparative advantages within a standard NEG framework helps solve the indeterminacy due to multiple equilibria and the ambiguity concerning the relation between integration and specialisation (Epifani, 2005). In other words, the interplay between factor abundance and agglomeration forces can offer a better explanation about the location of economic activity than considering both arguments as alternative hypotheses.

The use of these economic geography models in addressing historical questions is relatively recent. Nonetheless, the increasing interest of economic historians in economic geography has been mainly focused on the manufacturing sector (Kim, 1995; Wolf, 2007; Martínez-Galarraga, 2012, Klein & Crafts, 2012). Agriculture is rarely considered and is involved as an exogenous determinant of income (Rosés et al., 2010; Combes, 2011).

This lack of interest in economic geography models in the agricultural sector seems, at the very least, contradictory when we take into account that the first model of spatial distribution of economic activity specifically focused on agriculture (Martinelli, 2014). In effect, von Thünen (1826) was interested in the pattern of agricultural production around a central town in an isolated state, in a homogeneous featureless plain of equal fertility. He developed a system of concentric circles, in which bulky or perishable goods are produced closer to the city and valuable or durable goods are imported from a greater distance. In this central town the price of a product like grain is determined by the production and transportation costs from the most distant farms whose production is required to satisfy the town's demand. Since grain must sell at the same price irrespective of its location of production, land rent is highest in the first concentric ring and decreases with distance (Blaug, 1997). However, the von Thünen model was rather neglected for decades, at least outside the specific field of urban economics (Krugman, 1991a). In the second half of the 20th century, the model was refined with mathematically rigorous formulation within the neoclassical framework (Beckman, 1972; Samuelson, 1983), but its empirical applications have still been scarce or marginal.[5] The recent contribution of Kopsidis & Wolf (2012) (for Prussia) and Martinelli (2014) (for Italy) represent important contributions in the line of research inspired in a Thünen framework, in a historical economic analysis, referring to agriculture in a main role.

Our research shares the same intellectual inquisitiveness as the previous papers, i.e. the explanatory factors of the geographical location of agriculture in the long run. We take into account the conceptual proposal of Epifani (2005) and consider the simultaneous influence of the

[5] Curiously enough, one of these scarce empirical exercises was applied to Uruguay in the beginning of the 1970s (Griffin, 1973)

first and second nature factors and the combined incidence of both aspects on location. Our working hypotheses are the following: agricultural production in Uruguay is highly decentralized with a strong persistence along the 20th century. Natural resources in Uruguay are suitable for agrarian production. More than 95 percent of total territory corresponds to grassland, steppe, and open shrub land (Willebald & Juambeltz, 2018) and, in fact, (almost) all the territory is apt for rearing livestock and crops. Only in the second half of the century was it feasible to expect some regions with an increasing specialization in the dairy industry (Bertino & Tajam, 2000) and cereal growing regions (Bertino & Bucheli, 2000). Our argument posits that the spatial distribution of economic activity is determined by a combination of competing factors. The existence of comparative advantages related to factor endowments (first-nature factors) is only part of the explanation. As more intensive agricultural activities increased their share of total value-added and concentrated on the best lands, second-nature factors, such as market access, would have solidified their importance, ultimately becoming, from a long-term perspective, the main factor explaining regional differences in Uruguay's agriculture.

Empirical strategy

The first and second nature factors "compete" in the explanation of the location of agriculture across the area and, presumably, it is possible to find interactions that also influence the process (Beltrán 1999; Rosés, 2003; Tirado et al., 2008; Ayuda et al., 2010). With the aim of obtaining a measure of the importance of these factors to explain the location of agricultural production we propose two complementary exercises. First, we built and analyzed a panel data set to take advantage of the spatial and temporal variability of the variables. This allowed us to obtain information about the signs and significance levels of these variables as explanatory factors of agricultural location. Second, we performed a decomposition of the R^2 to measure the relative contribution of both types of factors –first-nature geographical factors, such as soil quality, and second-nature geographical factors, such as proximity to markets– to explain the location of agricultural output.

Panel data analysis

We faced the double challenge of analysing the agricultural location for different areas and for long periods. Therefore, we considered benchmarks during the last three decades of the 19th century, the entire 20th century and first decade of the 21st century (1870, 1884, 1890, 1900, 1908, 1916, 1924, 1937, 1943, 1951, 1956, 1966, 1970, 1980, 1990, 2000 and 2008) and distinguished several regions of Uruguay that we identified with local administrations (*departamentos* or provinces). Our benchmark-based cross-sectional design limits the ability to capture intermediate dynamics and structural adjustments occurring between observation points. In addition, the models assume institutional and territorial stability of provinces and consistency of sources which, while appropriate for long-run comparison, reduces sensitivity to short-term or conjunctural situations. Finally, the 1870–2008 window does not encompass recent transformations in the agricultural sector (the rise of agribusiness, the expansion of rainfed cropping, and post-2010 forestry). These dynamics –linked to technological, organizational, and capital changes– will be addressed in future research once the 2024 census data are fully available.

We consider panel data (or cross-sectional time series data) to be a good technique to approach our problem because it allows us to work with two dimensions. In effect, there are two kinds of information in cross-sectional time-series data: the cross-sectional information reflected in the differences between subjects (18 *departamentos*), and the time-series or within-subject information reflected in the changes within subjects over time (139 years covered with 17 benchmarks). Panel data regression techniques allow us to take advantage of these different types of information.

We used a model to represent the influence of each factor on the density ($dens_{i,t}$) of the agricultural VA assuming additive and linear relationships (data in Appendix A). We considered the impact of different first and second nature factors on agricultural location (see equation 2), and we detailed the explanatory variables in Table 1. Full information on the variables is presented in the end of the document; we made a complete description of the variables and their operationalization in Appendix B and we detailed the sources of information in Appendix C, Table C.1.

We used a random effects model for the exploratory analysis based, first, on its ability to test the importance of first-nature factors, which are assumed to be fixed (endowments and location), and second, on the fact that the variable $dens_{i,t}$ is relatively stable within the provinces during the analyzed period, but changes significantly between provinces (see descriptive statistics in Appendix D). The consideration of a fixed effects model is not appropriate, since it has the limitation of not taking into account the variation between agents (provinces in our case) and imposes too many restrictions (Baltagi, 2013).

The structure of the model in matrix notation is as follows:

$$Y = F\beta + S\gamma + X\delta + \varepsilon \tag{2}$$

Where: The dependent variable Y corresponds to the natural logarithm of agricultural value-added density, denoted as $\ln(dens_{i,t})$; F is the matrix of natural-first variables; S is the matrix of second-nature variables; X is the matrix of control variables (see Table 1); β, γ and δ are the parameters to be estimated; ε is the error term.

t: represents each year 1870, 1884, 1890, 1900, 1908, 1916, 1924, 1937, 1943, 1951, 1956, 1966, 1970, 1980, 1990, 2000 and 2008.

i: represents each province, with i= Artigas, Canelones, Cerro Largo, Colonia, Durazno, Flores, Florida, Lavalleja, Maldonado, Paysandú, Río Negro, Rivera, Rocha, Salto, San José, Soriano, Tacuarembó, and Treinta y Tres.[6]

[6] We excluded Montevideo for two reasons: (i) it represents only 1 per cent of the total territory; (ii) Montevideo has presented, historically, a marked urban profile inducing other conditions to the location of economic activities (see Martinez-Galarraga et al., 2020). Given that the field of study of this research is the agricultural sector and proposes a methodology based on econometric exercises, including Montevideo would lead to problems, often attributed to atypical data.

Table 1. Explicative variables

Related to:		Variable:	Concept:
First nature geography	Endowments	landq	Land quality: indicator of aptitude of soils for agriculture.
		distcap	Distance (linear) of each province to national capital (Montevideo).
		rain	Rainfall: average annual rainfall (litres/ha).
Second nature geography	Market forces	markpot	Market potential: measure of economic activity that each province has access after having deducted cost transportation.
	Infrastructure and transport	connect	Connectivity: global measure that considers the national transport network.
Control variables	Agrarian prices	commp	Commodities prices: commodities price index that considers the main products (meat, wool., and wheat).
		landp	Land price: real land price index.
	Technological change	tech	Technological change: global indicator of technological change that considers the main technical transformations of the period.
	Institutional arrangements	size	Farm size: average size of the agricultural plots.
		hold	Tenure: ratio between numbers of tenant farmers and landowners.
		inia	Governmental support for researching in agriculture: indicator that measures the impact of being close to an experimental station.

Source: developed by the authors.

Decomposition of R^2

We employed the R^2 decomposition method to evaluate the relative importance of the explanatory variables in explaining the variance of the dependent variable. This approach quantifies the contribution of each variable to the overall explanatory power of the model, identifying first and second nature factors. We measure the marginal contribution of each variable to the explained variance using the Lindeman, Merenda, and Gold (LMG) method, which accounts for the order in which variables enter into the model. This method provides an additive measure of each variable's contribution to the total R^2, offering clear interpretability and enabling comparisons across variables and time periods.

The R^2 decomposition is implemented in two steps:

i. A random-effects panel model is estimated to capture spatial and temporal variability.
ii. The panel structure is then re-estimated as a linear model to calculate the R^2 decomposition using the LMG method.

By applying this decomposition across moving time windows, we analyse how the relative importance of first and second nature factors evolves over time. We present the results graphically, which illustrate the dynamics of variable importance across periods. Detailed calculations are presented in Appendix E.

Results

Panel data analysis

The general approach was to estimate a base model and so add explanatory variables in two additional specifications. Firstly, we estimated a model only with geographical factors of the first nature: $landq_i$, $distcap_i$ and $rain_{i,t}$ (model 1). Land quality ($landq_i$) −defined as the combination of physical, chemical, and biological attributes of the soil that determine its capacity to sustain plant production in a continuous and sustainable manner− is a variable commonly incorporated into analyses of agricultural production. The inclusion of $distcap_i$ among first-nature variables rests on its exogenous, time-invariant character as a locational attribute. $distcap_i$ captures each province's geographic position relative to Montevideo −historically the administrative, commercial, and port hub− independent of market interactions. Thus, it functions as a structural geographic determinant rather than an outcome of economic dynamics. Finally, Uruguay's subtropical–temperate climate exhibits marked long-run stability and only moderate spatial variation (Castaño et al., 2011). The historical record does not indicate structural breaks in the climatic regime, but rather episodic droughts and surges in precipitation without persistent effects on the territorial organization of production. Moreover, there is evidence of an upward trend in precipitation and in the intensity of rainfall events over time (Taks, 2024). Accordingly, annual precipitation ($rain_{i,t}$)is an appropriate climatic control to capture regional differences without resorting to complex reconstructions (see Figure B.1 in Appendix B). This methodological choice −consistent with prior environmental and economic history studies− keeps the focus on long-term spatial determinants, for which transitory climatic variability is not decisive.

Second, we included those factors that the NEG considers key in the explanation of the unequal distribution of economic activity in the territory −internal market forces ($markpot_{i,t,}$) and transport network ($connetc_{i,t}$)− and variables associated with factors which were particularly relevant from a historical perspective but are not usually considered in the NEG framework. For thi, we included technical change ($tech_{i,t}$), institutional variables related to some relevant aspects of the agrarian structure −average size of establishments ($size_{i,t}$), land tenure ($hold_{i,t}$)−, sectoral policies for the promotion of research and development ($inia_{i,t}$) and, finally, variables associated with the relevant prices in agriculture –land prices ($landp_{i,t}$) and commodity prices ($commp_{i,t}$)– (model 2). The results are presented in Table 2. [7]

The first noteworthy result is the high relevance of first-nature geographical factors in explaining the territorial distribution of agricultural output. In particular, the allocation of resources, measured through the CONEAT index ($landq_{i,t}$), is significant and positive throughout the analyzed period. On the other hand, location ($distcap_i$) is negative and significant in the initial specifications, suggesting that regions close to Montevideo enjoyed a privileged position that allowed them to benefit from their proximity to the country's capital and main national port. Finally, model 1 includes a variable that measures rainfall volume ($rain_{i,t}$) as a proxy for climatic conditions. Similar to resource endowments and location, the estimates provide evidence of its importance in explaining the long-term spatial distribution of agricultural production in Uruguay.

From the estimation of model 2, in addition to the importance of the resource endowments, geographical location, and climate, we found evidence about the importance of second nature geographical factors; i.e. variables associated with market forces and transport infrastructure. The significance and the positive sign obtained in the estimation of transport infrastructure indicator ($connect_{i,t}$) suggests that connectivity and the development of the transport network, together with the importance of regional markets ($markpot_{i,t}$), in particular those close to the country's port cities –Paysandú and especially Montevideo– had an influence on the regional location of agricultural output. The inclusion in model 2 of an infrastructure indicator that incorporates information on the distance to the capital is the reason why the variable $distcap_i$ is excluded from this analysis.

[7] We acknowledge that some control variables, including the INIA variable as a proxy for sectoral R&D policies, may be potentially endogenous. Determining whether the establishment of INIA centres was random or responsive to existing local production would require a detailed historical study beyond the scope of this paper. Notably, while the first centre in Colonia (1914) appears unrelated to regional specialization, the Eastern Experimental Station (Treinta y Tres, ca. 1970) aligns more closely with the local rice sector.

Table 2. Econometric results.
Dependent variable: natural logarithm of agricultural VA density (ln(dens))

Variables	Model 1	Model 2
distcap	-0.0015*** (0.0005)	
landq	0.0142*** (0.0025)	0.0044*** (0.0039)
rain	0.0005*** (0.0005)	0.0003*** (0.0001)
markpot		0.0044*** (0.0008)
connect		0.0753*** (0.0167)
size		-0.0005*** (0.0001)
hold		-0.1085* (0.0626)
inia		0.3892*** (0.0933)
tech		0.1041*** (0.0193)
commp		-0.0003 (0.0006)
landp		0.0048*** (0.0007)
overall	0.2680	0.8494
observation	306	306

Coefficients estimated with robust standard error (p-value in brackets)
Significance levels: *** (1%); ** (5%); * (10%)
All the models were estimated including constant (not shown).

Source: developed by the authors.

The third key finding is that we found evidence of the impact of certain control variables. First, technology, measured through the adoption and diffusion of innovation curves –crossbreeding, mechanization, improved pastures, and fertilization– was significant and positive in explaining the concentration of production in the provinces of Uruguay. Additionally, we found evidence about that in those provinces near to state research centers ($inia_{i,t}$), producers may have leveraged the advantages of knowledge transfer and rural extension programs to improve their production practices and achieve higher productivity levels. Second, the estimation of institutional factors reflecting the agrarian structure, such as the scale of production, was significant and negative, which could indicate that Uruguay's historical latifundia problem posed a long-term limitation for agricultural development. Similarly, the negative sign of the variable capturing the dynamics of land tenure in the country's provinces suggests that land leasing, historically high in Uruguay, was associated with lower levels of output per hectare.

Finally, as expected, we found that higher land prices in certain areas could be associated with higher levels of output per hectare. Conversely, no evidence was found that international commodity prices influenced the unequal distribution of production across Uruguayan provinces.

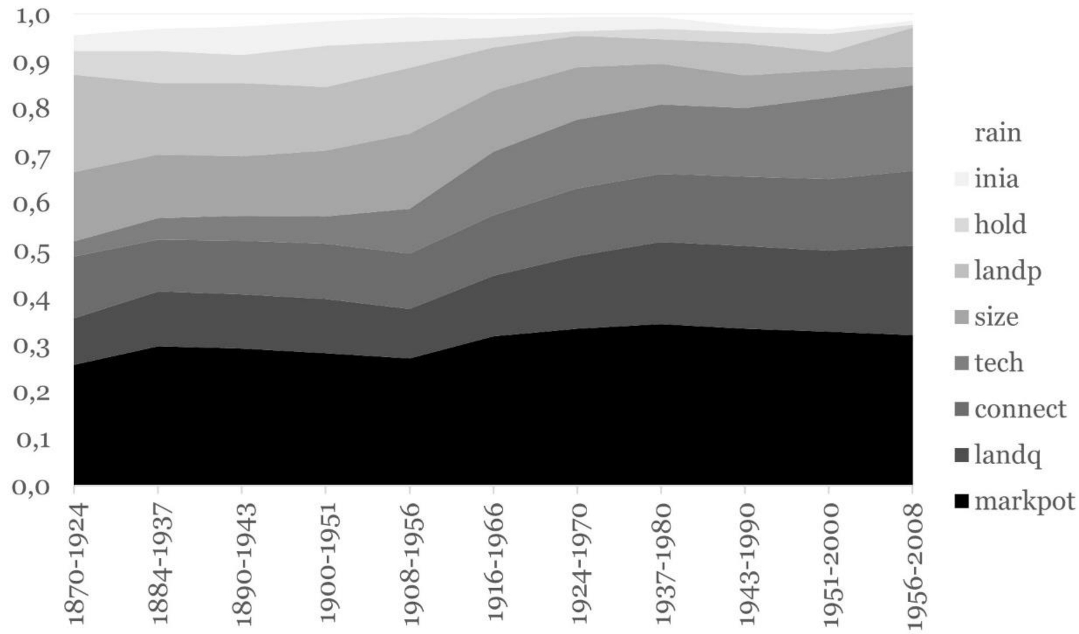
Decomposition of R^2

The aim of this exercise is to assess the relative importance of the variables competing to explain the distribution of regional agricultural VA over the long run (1870−2008). Conducting an intertemporal comparison requires a model that can be evaluated at different points in time. To achieve this, we adopted the following procedure. First, we used the specifications of Model 2 (the complete model) presented in the previous section. Then, we applied a moving-window approach to different time periods: 1870−1924, 1884−1937, 1890−1943, 1900−1951, 1908−1956, 1916−1966, 1924−1970, 1937−1980, 1943−1990, 1951−2000, and 1956−2008. The selection of these moving windows follows an instrumental criterion, ensuring that a sufficient amount of data is available for reliable model estimation.

From the comparative analysis, several noteworthy results can be identified (Figure 4). A first result is the significant prominence of market potential. Market potential is the factor that provides the greatest explanatory power in the model. The evidence shows growing dynamism during the period identified in Uruguayan literature as the era of import substitution industrialization. The strengthening of the domestic market in the context of state-led industrialization could have generated spillover effects into the agricultural sector, explaining its distribution across the territory. While a reduction in the importance of the domestic market is observed after the industrialization period, its values remain relatively high. Secondly, first-nature geography plays an important role as a determinant of the distribution of agricultural production in Uruguay from a long-term perspective. A third significant result is the decreasing influence of factors associated with institutional arrangements, reflected in changes in the agrarian structure. In particular, the extensive nature of production and, to a lesser extent, land leasing as a tenure system were more relevant during the 19th century, but throughout the 20th century, both factors lost importance, ending the period with low values.

While market potential is the factor that provides the greatest explanatory power throughout the entire period, it becomes particularly relevant as the 20th century progresses, coinciding with the development of the road transport network. The combined transport indicator considers the three main transport networks of the period (railways, roads, and inland navigation), but the limited explanatory capacity of the transport indicator ($connect_{i,t}$) contradicts our initial expectations regarding the importance of the railroad, which has been documented in previous studies (Barrán & Nahum, 1978; Díaz, 2017; Herranz-Loncán, 2011).

Figure 4. Evolution of the explanatory power of geographic factors (1870-2008 moving windows)



Source: our own data.

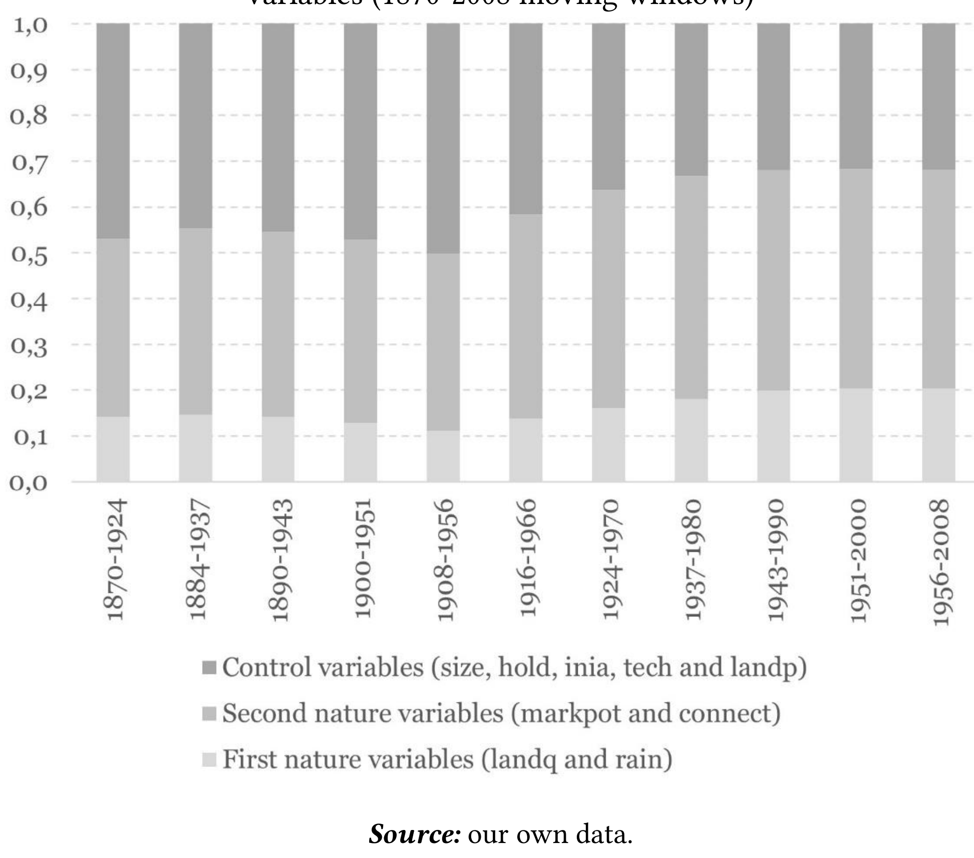
Although the railway network was essential for the formation of a national urban network, it did not achieve the same success in developing integrated internal markets. On the contrary, it was only recently, with the influence of automotive transport, that the process of urbanization was strengthened, and the integration of distant economic spaces was promoted (Klaczco & Rial, 1981). The expansion of automotive transport reinforced Montevideo's urban primacy and the consolidation of the country's main road and logistics corridors –particularly in the southern and littoral regions– thereby broadening the reach of domestic markets and improving accessibility between urban centers and their hinterlands. This process enhanced the market potential of better-connected provinces, strengthened rural–urban linkages and the integration of agri-food value chains, lowered transaction costs, and fostered the diffusion of agro-industrial activities in the metropolitan periphery and along the western littoral (Klaczco & Rial, 1981; Baracchini, 1981).

A fourth important result relates to the pattern of technological change as a determinant of the regional distribution of production. The combination of different technological paths used to construct the indicator highlights the importance of crossbreeding during the 19th century and the introduction and diffusion of the tractor, which reached its greatest dynamism in the mid-20th century. The increased explanatory power of this variable from the second half of the 20th century likely stems from the introduction of a technological package that combines a set of technologies already proven in other countries, with the mechanical technology of the tractor and the chemical technology of fertilization as key components (Moraes, 2001; Álvarez Scaniello, 2018; Álvarez Scaniello and Bortagaray, 2007).

Another result concerns the importance of land prices (*landp*$_{i,t}$). This indicator was significant from the late 19th century to the mid-20th century and is associated with the development of the land market. This variable has reflected, at a regional level, the movement of productive activities whose profitability was affected by the increase in land value close to the major markets.

Finally, we observe that both types of determinants –first-nature and second-nature geography– compete in explaining the distribution of agricultural production in the long run. On the one hand, the evidence shows the historical relevance of first-nature geography (represented by the endowment factor), explaining one-fifth of the variance in the dependent variable (Figure 5). On the other hand, the importance of second-nature geographical determinants has been the most prominent throughout the entire period. The relevance of these factors increases, primarily due to the evolution of factors highlighted by the NEG: market potential and transportation costs, but since the second half of the 20th century, this evolution is further complemented by the growing importance of technological change. This demonstrates how complementary factors can enhance the explanatory power of the standard factors derived from the NEG framework.

Figure 5. Evolution of the explanatory power of first and second nature geogaphy and control variables (1870-2008 moving windows)



Source: our own data.

Conclusion

We examined the influence of geographical conditions on the location of agriculture in Uruguay from the last decades of the 19th century to the first decade of the 21st century (1870-2008). We conducted an exploratory analysis of the determinants of this process at seventeen temporal benchmarks (1870, 1884, 1890, 1900, 1908, 1916, 1924, 1937, 1943, 1951, 1956, 1966, 1970, 1980, 1990, 2000, and 2008), considering the explanatory power of first- and second-nature factors. For this purpose, we built a database that includes the provincial-level agricultural VA and a set of explanatory variables, testing our hypotheses through two complementary exercises: panel data analysis and R^2 decomposition techniques.

We proposed empirical tests of some central postulates of the NEG for the case of agriculture in Uruguay in the long term, obtaining two main results. First, the evidence found allows us to assert that first- and second-nature geographic factors compete to explain the unequal regional distribution of agriculture in Uruguay over the long term (1870-2008). Second, it is possible to affirm that the influence of both sets of factors has changed over time. Second-nature geography gained explanatory power throughout the period. Indeed, the evidence indicates that the increasing importance of market integration, market access (mainly to Montevideo), the advantages associated with infrastructure, and the use of transportation means complemented the historical influence of resource endowments. At the same time, we found evidence of a growing role for agricultural technology and, in contrast, a declining relevance of the agrarian institutional structure, as reflected by the average size of farm plots. Lastly, land prices showed a decreasing influence over the period.

In summary, the combined effect of the internal market potential, the transportation network, and technology appears to have played a substantial role in regional location of agriculture. These findings show that the discussion on location of production go beyond the industrial activities and can be applied to other sectors where scale economies, diversification, specialization and cost of transport are relevant factors. In other words, our results confirm that, even in the long run, agricultural location continues to align with Von Thünen's original framework from nearly two centuries ago, where market access and transportation costs remain key factors in explaining the spatial distribution of agricultural production.

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