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Explaining vineyard specialization in the province of Barcelona (Spain) in the mid-19th century[1]

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Abstract: We present a statistical model of agrarian vineyard specialization in the province of Barcelona towards 1860, that combines the “Boserupian” push of population increase, the demand pull of a “Smithian-type” of growth (measured by the time-distances to the nearest seaport), and the agrological land’s suitability for sowing grain or growing vines (as measured by water stress, slopes and frost risk). The overall outcome of the adjusted R2 levels, which range from 0.608 to 0.826, can be considered very successful. The inequality in land ownership is another factor that we believe to have played an important role, but has had to be omitted for the moment due to the lack of statistical data. Further research is also needed to deal with a possible endogeneity problem that working with socio-demographic variables entails.
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Keywords: regional land-use patterns; vineyard specialization; population pressure; wine international market integration; agrological suitability

Resum: Presentem un model estadístic de l’especialització vitícola a la província de Barcelona cap el 1860 que combina la pressió “boserupiana” de l’augment de població, l’atracció de la demanda induïda per un creixement de tipus “smithià” (mesurada per les distancies horàries al port més proper), i l’adequació dels sòls disponibles per sembrar gra o plantar ceps (mesurada per l’estès hídric, el pendent i el risc de glaçades). L’assoliment global d’uns nivells de R2 ajustats que oscil·len entre 0,608 i 0,826 poden considerar-se força bons. Creiem que la desigualtat en la propietat de la terra també va jugar un paper molt important, però l’hem hagut d’ometre de moment per manca de dades estadístiques. També cal aprofundir en el tractament del problema de possible endogeneïtat derivat de l’ús de variables socio-demogràfiques.

Introduction

There is a strong consensus among economic historians that vineyard specialization was a key factor in the relatively early beginning of industrialization and modern economic growth in Catalonia (Spain). Since the publication of Pierre Vilar's masterpiece *La Catalogne dans l'Espagne moderne* (Vilar, 1962), historians and economists have stressed the role played by the spread of vineyards during the 18th and 19th centuries. Brandy and wine exports linked the Catalan economy to a large, open market from which it could import cotton. The possibility of exports deepened regional specialization and offered an increasing number of working people a way to earn their living, thus avoiding the Malthusian fate typically associated with fast population growth. It also increased the rural population's purchasing power and their consumption of industrial textiles, and enabled landowners or their inheritors to accumulate rural savings which were increasingly invested in new trading or industrial enterprises.[2] This strong historical link in Catalonia between vines and the cotton industry stands in sharp contrast to the trend of «*vigne contre draperie*» which characterized other contemporary contexts such as Languedoc.[3]

Three main features distinguished the Catalan agrarian specialization in brandies, wines and sparkling *cava*. First of all, it started very early, in the 17th century, and advanced slowly but steadily during the 18th and 19th centuries, until the sudden phylloxera rush and crash (1867-1890) which was eventually overcome. Secondly, wine growing was always combined with cereals and other crops in Catalan agrarian landscapes, which were hardly ever devoted to

[2] Giralt (1952); Torras (1976 and 1995); Fradera (1987); Pascual (1990); Sudrià, Pascual and Castañeda (1992); Maluquer de Motes (1998); Sánchez and Nadal (1998); Sudrià and Pascual (1999); Colomé coord. (2003); Valls (2001 and 2004).
[3] Fohlen (1949); Dugrand (1963); Berger and Maurel (1980); Johnson (1995).

monoculture.[4] And third, the intensity of vineyard specialization remained locally diverse, and sometimes changed location over its long history. After the fine work done by any economic historians over the last fifty years, it is now time for a new, deeper exploration of the reasons behind this distinctive geographic and historical pattern of wine specialization.

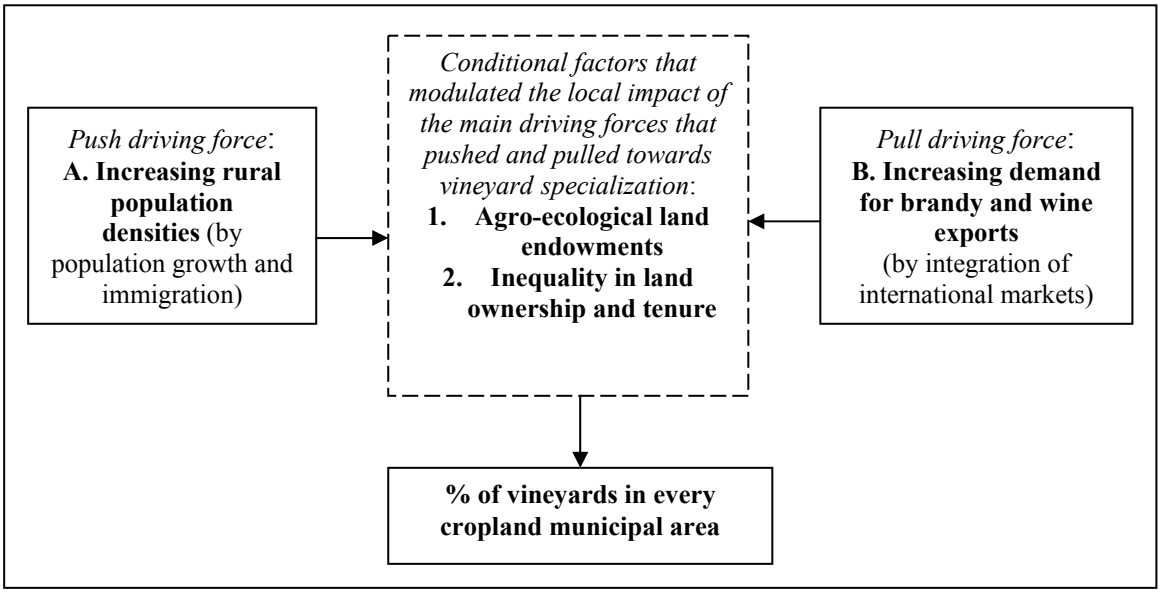
Following the qualitative explanations proposed by many Catalan historians, we have used a number of variables to build a model of agrarian vineyard specialization in the province of Barcelona (Spain) in the mid-19th century. We have assembled a 1858 survey on the main land-uses, and another one for the years 1859-67 to assess the coverage degree of cereal consumption by local wheat or rye production. We also incorporate other available statistics on population densities and increases, and data on agrological land endowments. With this panel set of historical and agrological data, the multidisciplinary team of the research project SEJ2006-15108-C02-01/GEOG has started to build and assess an econometric model to explain the local differences in vineyard or cereal specialization in the nearly three hundred municipalities of the province of Barcelona around 1860. This is a historical model that does not aim at explaining any type of vineyard specialization in every period of time or geographic location, but the role played by a specific set of factors throughout the long-lasting spreading of vines in the province of Barcelona that led to a particular organic-based agrarian economy during the second half of the 19th century.[5]

These set of factors has been pointed out by several economic and social historians, and we are now combining them in a model that can be quantitative assessed and statistically tested in a clearer way. In order to build this modelled

[4] Tello, Garrabou and Cussó (2006); Tello, Marull and Pino (forthcoming).
[5] For an epistemological and methodological approach to this kind of modelled historical explanation see Daniel Little's idea of «*meso-history*» (Little, 2008).

historical interpretation we distinguish two main driving forces, namely the «Boserupian» *push* of population increase and the demand *pull* of a «Smithian-type» of growth.[6] The combined outcome of these two main drivers of vineyard specialization in Catalonia became locally and temporarily diverse according to the role played by two other conditional factors that modulated their territorial impact, namely the agro-ecological and socio-economic land endowments. The overall explanation looks like this (Figure 1):

Figure 1. Set of factors used to explain the historical process of vineyard specialization in the province of Barcelona until mid-19th century



Source: our own

[6] Boserup (1981); Vries (2001).

The province of Barcelona in 1860: western Mediterranean organic agriculture

Many economic historians regard commercial specialization in woody crops such as vines, olive or almond trees as a key feature in the agrarian development of the western Mediterranean basin during the 18th and 19th centuries.[7] As land use became increasingly market-oriented and labour could be more efficiently used and allocated, the economy was able to respond to the challenge of population growth and thus avoid a Malthusian fate. Thus, agrarian specialization would have been a characteristic vehicle for Smithian-type growth in this region.[8] However, in recent times it has been stressed that the Dutch-English mode of «agrarian revolution» in the European Atlantic area was impracticable in the Mediterranean bioregion due mainly to its low rainfall.[9] Therefore, environmental constraints may have also played an important role in the spread of specialization in vine cultivation in southern Europe.

The idea of an «organic economy», put forward by Anthony Wrigley and Rolf Peter Sieferle among other scholars[10], may help to highlight this relationship between the environmental constraints and the economic forces behind the viticultural focus of agrarian development in the western Mediterranean basin. From a historical standpoint we consider «organic» any agrarian system in which nearly all of the energy and material flows come, directly or indirectly, from the photosynthetic capture of solar radiation. In this «areal-based» energy

[7] Vilar (1954:121-135; 1962).
[8] See the distinction between "Malthusian", "Smithian" and "Schumpeterian" economic growth in Vries (2001:177-194).
[9] Pujol, González de Molina, Fernández Prieto, Gallego and Garrabou (2001); González de Molina (2002:257-270); González de Molina and Guzmán (2006).
[10] Wrigley (1988; 2004); Sieferle (2001); McNeill (2000); Malamina (2001:51-68; 2003); Krausmann and Haberl (2002:177-201); Krausmann (2006:501-530).

system the entire economy became highly dependent on the biological net primary production that could be attained from the land. A key feature of this organic agriculture was the bioregional diversity of limiting factors that became bottlenecks for economic development. Consequently, technological and socioeconomic responses to these environmental constraints had necessarily to be different. This bioregional diversity of past organic agrarian developments stands in very sharp contrast to the uniform global tendencies that characterize the great transformation undertaken after the «green revolution».[11] One of the main goals of our research project is to conduct a historical analysis of the link between energy efficiency, territorial efficiency and a healthy landscape ecology and account for this relationship from the perspective of ecological economics.[12]

Specifically, we intend to assess and explain the role played by market specialization in driving the specific agrarian system in the Catalan western Mediterranean basin towards a more advanced organic economy, prior to the industrial revolution and the coming of the fossil fuel era. From the point of view of ecological economics, trade is usually seen as a two-edged sword: while it has often been a powerful factor in environmental degradation, it can also foster a better allocation of resources, which might also be useful for reducing human impact on natural systems. The first outcome may arise from the ecological-scale effect over a set of biophysical flows that become increasingly unlocked, together with the socio-environmental consequences of a possible unfairness of trade when it entails an unequal ecological exchange.[13] The second outcome may actually arise through a backward shift of the limiting factors

[11] Van Zanden (1991).
[12] Cussó, Garrabou and Tello (2006:49-65); Cussó, Garrabou, Olarieta and Tello (2006:471-500); Tello, Garrabou and Cussó (2006:42-56); Marull, Pino, Tello and Mallarach (2006:59-72); Tello, Marull and Pino (submitted). From an international overview of this Long-Term Socio-Ecological Research (LTSER) programme undertaken by the emerging transdisciplinary Sustainable Science, see Haberl and others (2006).
[13] See the volume edited by Hornborg, McNeill and Martínez Alier (2007) and its references.

known in ecology or agronomy as «Liebig's Law of the minimum», either indirectly, with a product specialization for which each bioregion has a relative «ecological optimum», or directly, by transferring limit goods from one bioregion to another.[14] Economic and environmental historians can contribute to a clearer assessment of this complex and often ambiguous relationship between trade, economy and ecology, through the comparative assessment of different historical paths of commercial specialization and globalization.

We intend to contribute to this area of research by analysing the scope of trade in the province of Barcelona in the production and consumption of staple agrarian products during the second half of the 19th century. Having reconstructed the energy balances of the agrarian system prior to 1860 in a series of local case studies and compared them with current values, and having assessed the changes in land use, its impact on landscape ecology, and examined the distribution of land ownership, we now aim to identify the turning points that transformed a specialized Catalan agriculture into a globalized one, both before and after the agrarian crisis at the turn of the 20th century.[15]

Vines had been grown in the western Mediterranean basin for many centuries before they became the main commercially specialized woody crop in the area. In Catalonia they were planted as a temporary crop in some small plots of woodland which were previously slashed and burnt, until the vines became too old and the vineyard was left to be reforested. Another very common crop pattern in some less wooded inland areas consisted in planting sparse rows of vines with furrows in between that were alternatively sown with grain or left

[14] Grigg (1982:47-67). Ecologists have dismissed the simple theory that every ecosystem tends towards a single 'climax' and that every external disturbance would only move it back from its own 'equilibrium' end. For each territory there is not a single natural 'vocation' but rather a set of possible outcomes. Therefore, any 'ecological optimum' must be understood only as a relative bias within an open range of possibilities.
[15] Koning (1994); Persson (1999); Pomeranz (2000); Williamson (2006).

fallow. Whether temporary or permanent and sparsely or densely planted, these vineyards existed for centuries as a complementary side of the traditional Mediterranean three-crop system, together with wheat and olive trees, in a multi-crop cultivation pattern usually oriented toward relatively local markets.

The challenge of population growth as a push driving force towards a more intensive land use system, that combined with trade links as a pulling force that opened a wider range of commercial opportunities

Things started to change from the 17th century onwards, as population growth made it necessary to adopt more intensive land use, while the Dutch trade connection between the Western Mediterranean coast and the emerging Atlantic economy pulled the European or American demand for wines and spirits.[16] Moving beyond the city of Barcelona and its outskirts, population densities in the overall province increased from nearly 20 inhabitants/km^2 in 1718 to more than 36 in 1787 and almost doubled again to 64 in 1858-1860. In the space of 140 years, land availability had been reduced from more than five hectares per inhabitant to only 1.5 (Table 2).

[16] Vilar (1962); Fradera (1987); Valls (2003); Garrabou, Manera and Valls (2006:249-304).

Table 2. Population increase and population densities in the province of Barcelona (1718-1860)

Districts	1718			1787			1858			1718-1858 (1718 =100)
	Inhabi-tants	Inhab./ km^2	Has/ Inhab.	Inhabi-tants	Inhab./ km^2	Has/ Inhab.	Inhabi-tants	Inhab./ km^2	Has/ Inhab.	
Barcelona	36,781	234.4	0.43	125,745	801.4	0.12	247,942	1,580.3	0.06	574.1
Arenys	14,599	36.6	2.73	30,070	75.3	1.33	37,063	92.9	1.08	153.9
Berga	12,121	10.0	10.03	19,299	15.9	6.30	39,632	32.6	3.07	227.0
Granollers	16,819	27.7	3.61	22,819	37.5	2.66	38,521	63.4	1.58	129.0
Igualada	12,354	12.5	8.02	25,714	26.0	3.85	54,934	55.5	1.80	344.7
Manresa	16,586	14.7	6.80	25,692	22.8	4.39	53,057	47.0	2.13	219.9
Mataró	16,639	92.2	1.08	29,986	166.2	0.60	43,164	239.3	0.42	159.4
Sant Feliu	8,110	17.1	5.84	24,207	51.1	1.96	39,588	83.5	1.20	388.1
Terrassa	9,937	17.3	5.79	20,552	35.7	2.80	52,737	91.7	1.09	430.7
Vic	21,740	20.1	4.98	40,954	37.8	2.64	59,618	55.1	1.82	174.2
Vilafranca	11,721	17.6	5.67	28,837	43.4	2.31	48,079	72.3	1.38	310.2
TOTALS	**177,407**	**23.7**	**4.23**	**393,875**	**52.5**	**1.90**	**714,335**	**95.3**	**1.05**	**302.7**
Outside Barcelona District	***140,626***	***19.2***	***5.20***	***268,130***	***36.6***	***2.73***	***466,393***	***63.7***	***1.57***	***231.7***

Sources: our own, based on the Territorial Statistics compiled by Pedro Moreno for 1858 and taken from the Gran Enciclopedia Catalana *for 1718 and 1787.*

Population growth, increasing landownership inequality and market incentives had combined to drive the extension of cultivated land mainly through the planting of dense vineyards in former woodland or mixed grain-vine cropping areas. It is interesting to note that 65 inhabitants/km^2, or one and a half hectares per person, is exactly the density that, according to Ester Boserup, could be taken as the threshold between a highly intensive agrarian system and an urban-industrial one.[17] Let us imagine for a moment what it would have meant to rely on only 1.5 hectares per person to feed the local population and provide them with fuelwood and pasture with an organically based intensive agricultural system in a Mediterranean bioregion subject to low rainfall and where keeping livestock and obtaining fertilizers became severely limiting factors.

As in any type of organic agriculture, an innovative response had to deal with two difficult side-effects: the scarcity of fertilizers and firewood. The

[17] Boserup (1981).

Mediterranean solution of planting vineyards helped to prevent firewood and manure becoming bottlenecks that might have halted the progression towards a more intensive land use pattern. Vines were planted mainly by poorer peasants in poor, sloping land, and no manure was put on them after planting. The specialization in vine cultivation was only partially maintained, which enabled the poly-cultural landowners of the typical scattered Catalan farms to use most of what little manure was available on the better soils used primarily for cereals and legumes, together with some fruit trees, vegetables and hemp. After vintage time, even the green shoots of the vines were used to fertilize other crops grown as fodder for sheep which, in turn, produced the much-needed manure. Vines were also pruned to provide a valuable substitute for increasingly scarce firewood.[18]

Assessing the degree of coverage of cereal consumption by local production, and wine growing as the main driving force behind agrarian specialization

We will try to assess the degree of specialization and trade in cereals of the province of Barcelona in the mid-19th century, combining two main historical sources. A first land use data set is taken from the *Territorial Statistics* for the province of Barcelona compiled in 1858 by the Spanish topographer Pedro Moreno, which has been benchmarked with other contemporary estimates.[19] In order to gain a more detailed understanding of the socioeconomic, institutional and demographic fabric of this process of specialization in vine cultivation, several of the local case studies use other private records, together with some data from land registry records, censi and notarial sources. This comparative

[18] Tello, Garrabou and Cussó (2006:42-56).
[19] Moreno (1858).

approach enabled us to highlight the key role in the spread of vineyards played by the large number of existing farm plots held by poor peasants or labourers who had to give up on the idea of achieving self-sufficiency through multi-crop cultivation due to difficulties of attaining land ownership or tenancy.[20]

The second principal source is an extensive survey on exports, imports, local production and apparent consumption of staple agrarian products in each municipality of every district in the province of Barcelona, undertaken in the period 1859-1867 by the Spanish Agricultural Provincial Commission (Junta Provincial de Agricultura).[21] If this statistical source had been sufficiently accurate, it would have directly provided us with the information needed to assess the degree of specialization and trade of the regional agrarian system in the mid-19th century. Unfortunately, several contemporary authors and some present historians have deemed the data to be comparatively unreliable. To substantiate this claim and correct the accounts made in the original survey, we carefully checked the figures with alternative data on population, land use and common staple consumption from other sources.[22] When the apparent consumption recorded in the survey was too high or fell below an intake of 2.4 hectolitres per inhabitant per year, we decreased or increased the original values by adjusting them to the level considered normal by other contemporary sources.[23] We are convinced that the final data following the adjustment are

[20] Garrabou, Planas and Saguer (2000:89-108; 2001); Garrabou and Tello (2004:83-104); Garrabou, Tello and Cussó (in print).

[21] The original manuscripts of the Junta Provincial de Agricultura are stored in the National Library of Catalonia (Fons de la Junta de Comerç, *Estadístiques de la producció i consum de cereals als partits judicials de la província de Barcelona*, lot CXXVI, boxes 163 and 164).

[22] Moreau de Jonnés (1835); Isabel (1994:107-154); Garrabou and Planas edits. (1998); Cussó and Garrabou (2007:60-100).

[23] Box 164 contains manuscripts showing the estimates of land sown with cereals and the respective yields in almost every municipality of the province of Barcelona. These were included in the data collected and sent to the Statistical Commission of the Treasury Department (*Delegación de Hacienda*). Although it is not stated explicitly, from our previous research on some of these municipalities using the original land registers and census, we can

reliable enough to be used in an historical analysis of the degree of coverage of cereal consumption by local production in the province of Barcelona during the mid-19th century.

How great an area in the province of Barcelona was allocated to cereal cultivation in the mid-19th century? The approximate value of 96,200 Has obtained from the survey conducted by the Junta Provincial de Agricultura for the period 1859-1867 fits almost exactly between the values recorded in two other available sources.[24] We also compared the data for cereal yield per district gathered by the Junta Provincial de Agricultura survey for 1859-1867 with the figures given in a *Statistical Advance* for the period 1885-90. Using these sources we were able to establish a more reasonable estimate of mean yields to verify and adjust data on the production, local consumption and trade of cereals that from the original survey, which we corrected upwards when appropriate. This data adjustment, considered alongside all the other available information on cultivated land and crops, enabled us to produce reasonable estimations for cereal production in every municipality and district. Using the 1860 population census, and considering a normal per capita intake of 2.4 Hl a year, we estimated from the survey data that local cereal consumption in the province of Barcelona was slightly higher than 1,750000 Hl per year. Considering a regional

be fairly confident that the origins of this information were the land registry records (*amillaramientos*). The local figures do not always coincide with those given by Pedro Moreno in his 1858 *Territorial Statistics*.

[24] The *Territorial Statistics* made by Moreno (1858) and the ones assembled by Llovet (1948), taking into account that Llovet pointed out that his estimates of irrigated cereal lands only included 75% of the municipalities and 93% of dry-farming cereal areas, leading to an underestimation of 7,000 or 8,000 Has. However, the survey made by Junta Provincial de Agricultura (1859-67) and the statistics assembled by Llovet (1948) only give disaggregated data for each district, not for every municipality. In order to explain the local differences in the degree of coverage of cereal consumption by local production, and the main driving forces of specialization in commercial winegrowing, our following regressions are based on the municipal data taken from the *Territorial Statistics* compiled by Moreno (1858).

production of wheat and rye of something less than 750,000 Hl[25], net imports of cereal and flour may have amounted to something more than 1,000.000 Hl per year during the period 1860-70, with approximately a 80% coming from coastal trade and another 20% transported by carts or railway.

We drew two important conclusions from this assessment of the degree of cereal consumption coverage by local production: first, that the area of land sown with cereals was clearly not sufficient to cultivate the amount of wheat, rye or corn required to feed the province of Barcelona in 1859-67, due mainly to the large proportion of the available land taken up by vineyards; second, that a large number of small peasant units had switched partially or totally from cereal production to viticulture, thus abandoning multi-crop cultivation as a means of self-supply. By reducing cereal production for their own subsistence the peasants were forced them to seek their staple food in local markets. At the same time, many wealthy landowners continued to sow cereals on their best lands as they remained more profitable than planting vines. Thus, cereal sowing and wine growing were two different but complementary forms of agrarian specialization. Grain was grown and sold in the province, while wine was exported to international markets and paid for cereal imports from inland Spain. The fact that local human-edible cereal production in the province of Barcelona could only meet 39% of the population's needs accounts for the high dependence on distant markets for staple foods in the mid-19th century. Table 3 shows that this coverage rate of 39% is in good agreement with the overall assessment made by Moreno in his 1858 *Territorial Statistics*, which recorded that 44% of cropland in the province of Barcelona was allocated to cereal cultivation (39% as dry-farming, and the rest on irrigated land):

[25] According to the *Estados* and other complementary information extracted from the survey of the Junta Provincial de Agricultura (1859-1867), the *Territorial Statistics* (1858) compiled by Moreno, and our own upward-adjusted data based on this and other contemporary sources.

Table 3. Land allocated to vines and cereals by the district councils in the province of Barcelona between the 1850s and 1880s

Districts	*In 1858, according to the* Territorial Statistics *compiled by Moreno**					*C Hectares planted with vines in the 1880s, according to Roig*	*C-B New hectares planted with vines between 1858 and the 1880s*
	A Hectares sown with cereals	*% of crop land*	*B Hectares planted with vines*	*% of crop land*	*A/B*		
Outskirts of Barcelona	4,344.1	48.9	4,081.3	45.9	1.1	2,928	-1,153
Arenys de Mar	5,836.9	44.4	6,865.2	52.2	0.9	4,183	-2,682
Berga	9,232.9	89.0	864.8	8.3	10.7	1,252	387
Granollers	12,936.8	58.7	7,921.9	35.9	1.6	7,404	-518
Igualada	11,322.4	33.9	19,336.2	57.8	0.6	20,450	1,114
Manresa	10,145.0	34.7	17,655.5	60.4	0.6	27,714	10,059
Mataró	1,867.3	21.0	6,450.5	72.7	0.3	7,319	869
Sant Feliu Llobregat	7,568.8	32.0	14,750.4	62.4	0.5	14,306	-444
Terrassa	6,396.9	25.5	16,806.9	67.0	0.4	20,258	3,451
Vic	18,965.0	97.3	303.5	1.6	67.0	329	26
Vilafranca	9,982.5	31.7	20,417.9	64.8	0.5	25,474	5,056
TOTAL	**98,598.5**	**43.7**	**115,454.0**	**51.2**	**0.9**	**131,617**	**16,163**

Sources: Moreno (1858), Roig (1890) and our own estimates. In this case we include all of the land sown with any type of cereal, either for human consumption or not.

The figures provided by Moreno show that in the period 1858-60 the cropland planted with vines exceeded the land sown with cereals. Specialization in vine cultivation clearly seems to have been the main factor behind the low degree of coverage of cereal consumption by local production and the corresponding high dependence upon foreign markets to guarantee sufficient quantities of food. This specialization in the vine cultivation began in coastal areas of Catalonia during the 17th century and spread inland during the 18th century.[26] It continued to spread in the mid-19th century, driven by the high relative prices of wine during the oidium plague in 1840-50, and reached a peak after 1867 when French vineyards were infested by the phylloxera insect –this situation would last until the 1880s, when Catalan vines also became affected. In summary, from the mid-19th century to the phylloxera crisis of the late 1880s, some 16,000 additional hectares of vines were planted in the province of Barcelona.

[26] Colomé and Valls (1994:47-68); Valls (2003).

The major increases measured in absolute values corresponded to pre-littoral districts like Manresa, Terrassa, Vilafranca and Igualada which already had a clear wine growing specialization and were prepared to sacrifice additional woodland to create new land for vineyards, except when sparsely planted vines in mixed cropping with cereals could be replaced by dense, specialized vineyards. The comparatively low increases recorded in other coastal districts like Vilanova, Mataró, Arenys, Sant Feliu or the outskirts of Barcelona even though these were the first areas to switch to a specialization in vine cultivation, may suggest that no extra land was available for vineyards on them. In addition, commercial opportunities and the aim of retaining a minimum amount of cropland for cereals and legumes may have raised the opportunity cost of maintaining or even increasing the area of land allocated to vine cultivation in these coastal districts. The land allocated to vineyards in some inner districts specialized in cereal growing like Berga or Vic remained marginal.

At first sight, Table 3 suggests that those districts with the highest degree of specialization in vine cultivation fit with the ones that might register the lowest degree of coverage of cereal consumption by locally-grown grain production. This general impression can be more precisely stated by disaggregating and mapping the data at the municipal level. Map 4 shows the local variations in the degree of shortage of cereal production to meet local consumption needs, and Map 5 shows the proportion of cropland devoted to vine cultivation. By comparing the two maps we confirm that wine growing was a key feature of the agrarian specialization pattern in this Western Mediterranean region during the second half of the 19th century. Maps 6 and 7 also suggest that the increase in population density, the degree of urbanization and industrial development, and the travel time-distances to coastal ports played a role that may explain the municipal differences in the degree of coverage of cereal consumption by local

production.[27] At the same time, some ecological features such as the amount of annual or spring rainfall, the slope of the land, and the climatic suitability of the crops may have been taken into account when people decided to allocate their lands to either wheat or vine cultivation (Maps 8).[28]

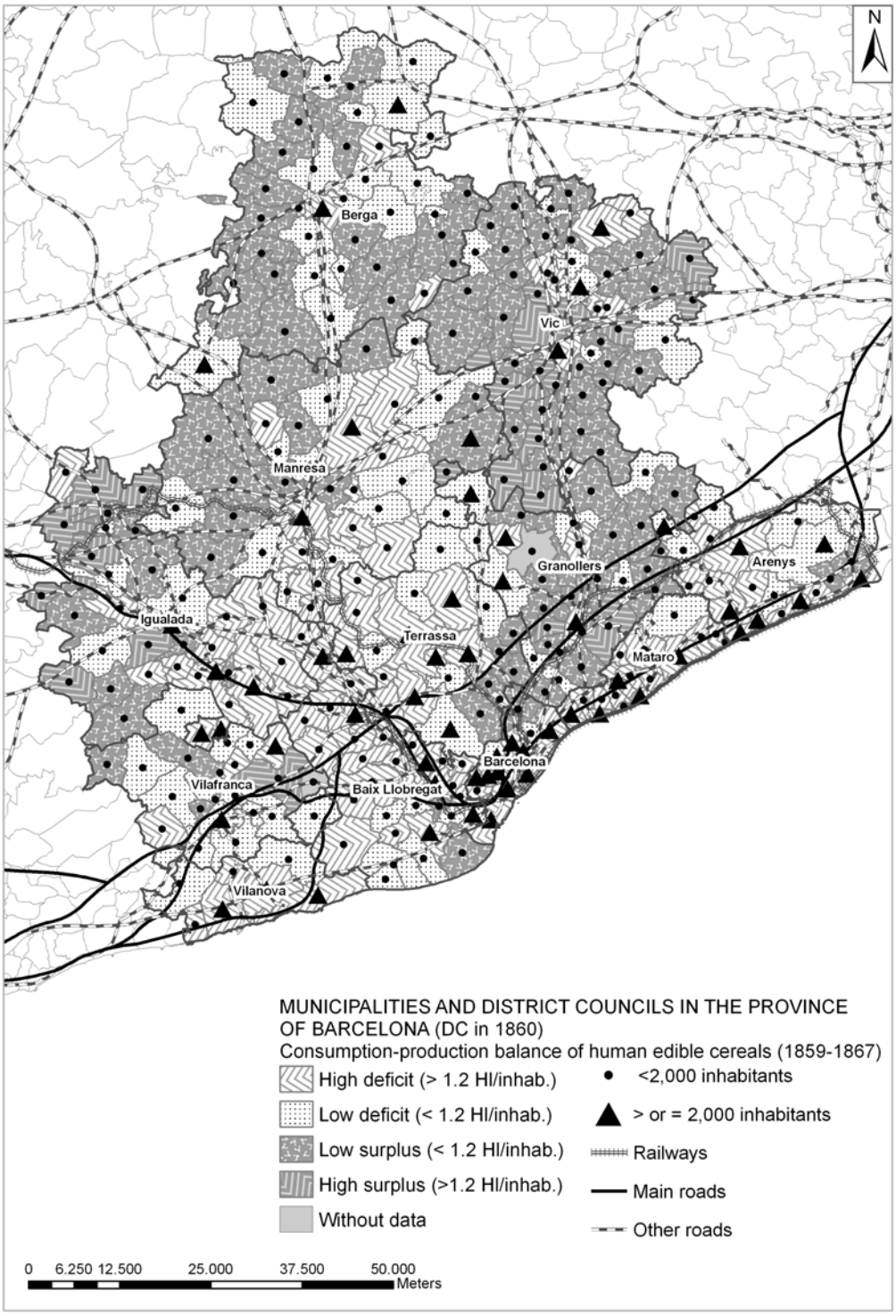
As the maps show, the municipalities that were capable of producing surpluses of wheat or rye once their consumption needs had been met were located in the mountainous regions in the coastal hinterland (Granollers DC), in some isolated coastal hillsides (Vilafranca, Mataró and Arenys DCs) or around the deep valleys in the districts of Igualada, Manresa, Berga and Vic in particular. The only exception to this rule was the fertile irrigated plain in the Sant Feliu district. With all its specific local characteristics, we can see that the geographical distribution in the region matched the distribution of specialization in vine cultivation in the mid-19th century. Undoubtedly, vineyard specialization was the overriding factor that caused the degree of trade of staple agrarian products to fluctuate from a cereal shortage of 20-50% to a slight surplus.

It is only when we combine these environmental and socio-economic factors – rainfall and water stress, land slope, agrological suitability of crops, population density, inequality in landownership, the degree of specialization of vine cultivation and the weight of urban population and non-agrarian activities– that local differences in grain or wine production, consumption and trade become apparent. To attain a better understanding of the prevailing pattern of agrarian production and marketing in the province of Barcelona in the period leading up to 1860 it is useful to conduct a statistical analysis of the interaction between them.

[27] We studied the weight of industrial activities, agricultural work and domestic tasks by applying the methodology of a Time-Land Budget Analysis in a local case study (Garrabou, Tello and Cussó, in print).

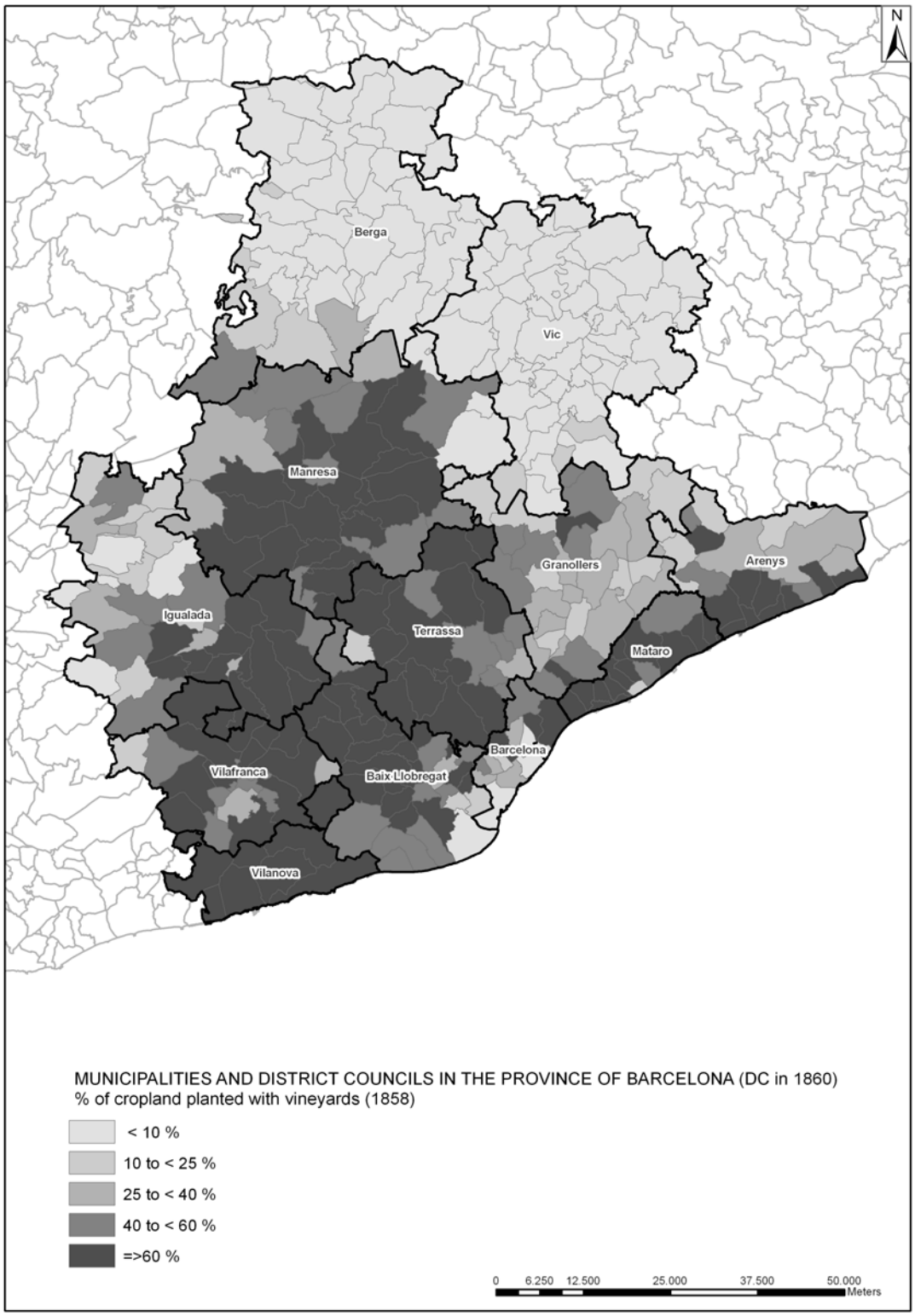
[28] On the role of soil management in a local case study, see Olarieta, Rodríguez-Valle and Tello (2008:474–484); for a general overview, see McNeill and Winiwarter edits. (2006).

Map 4. Degree of shortage in cereal production to meet local consumption needs in the municipalities and districts of the province of Barcelona according to the survey of the Junta Provincial de Agricultura, following upward adjustment (1859-67)



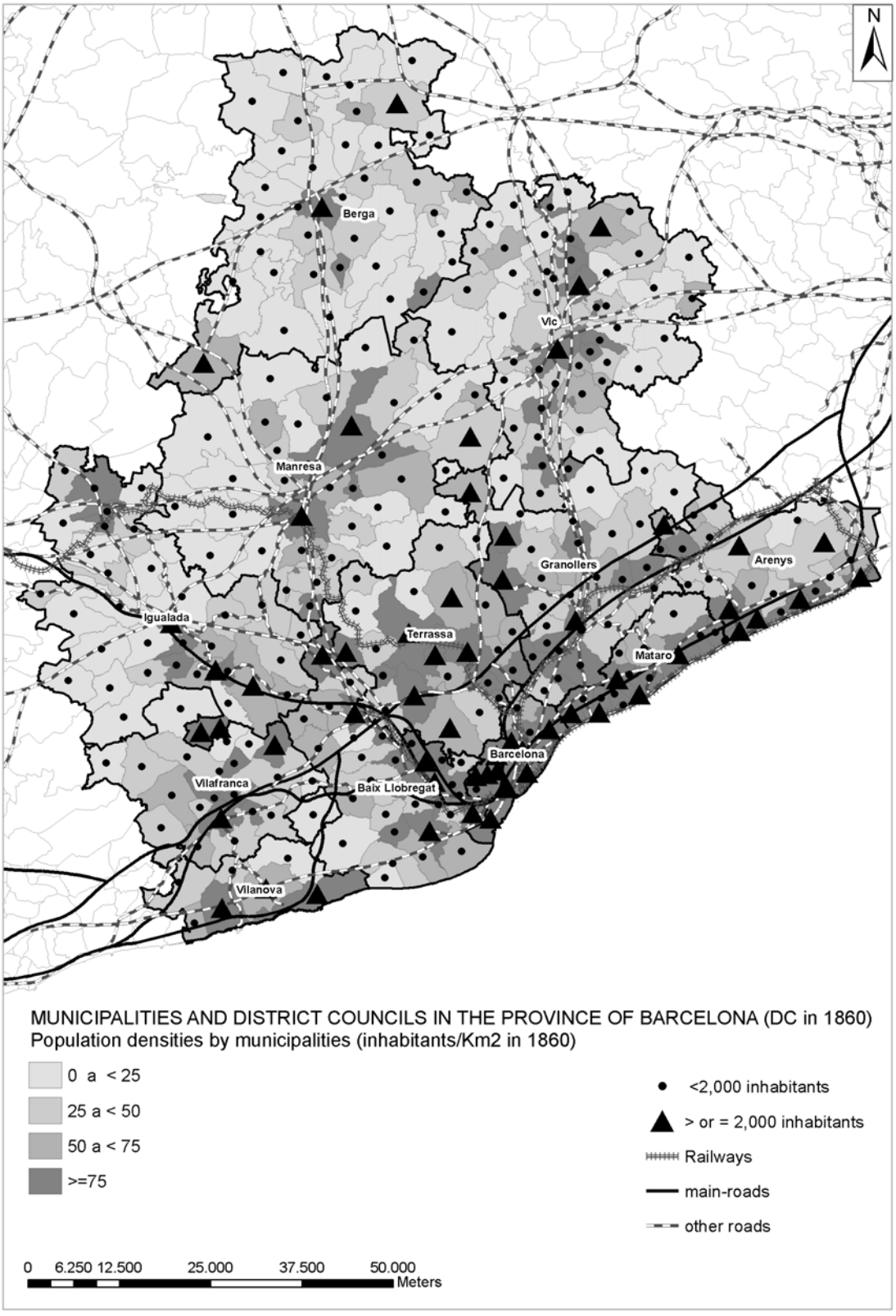
Source: made with GIS by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG, with the municipal data from the survey of Junta Provincial de Agricultura *(1859-67), following upward adjustment as explained in the text.*

Map 5. Proportion of cropland devoted to vineyards in every municipality, according to the Territorial Statistics compiled by Pedro Moreno for the province of Barcelona (1858)



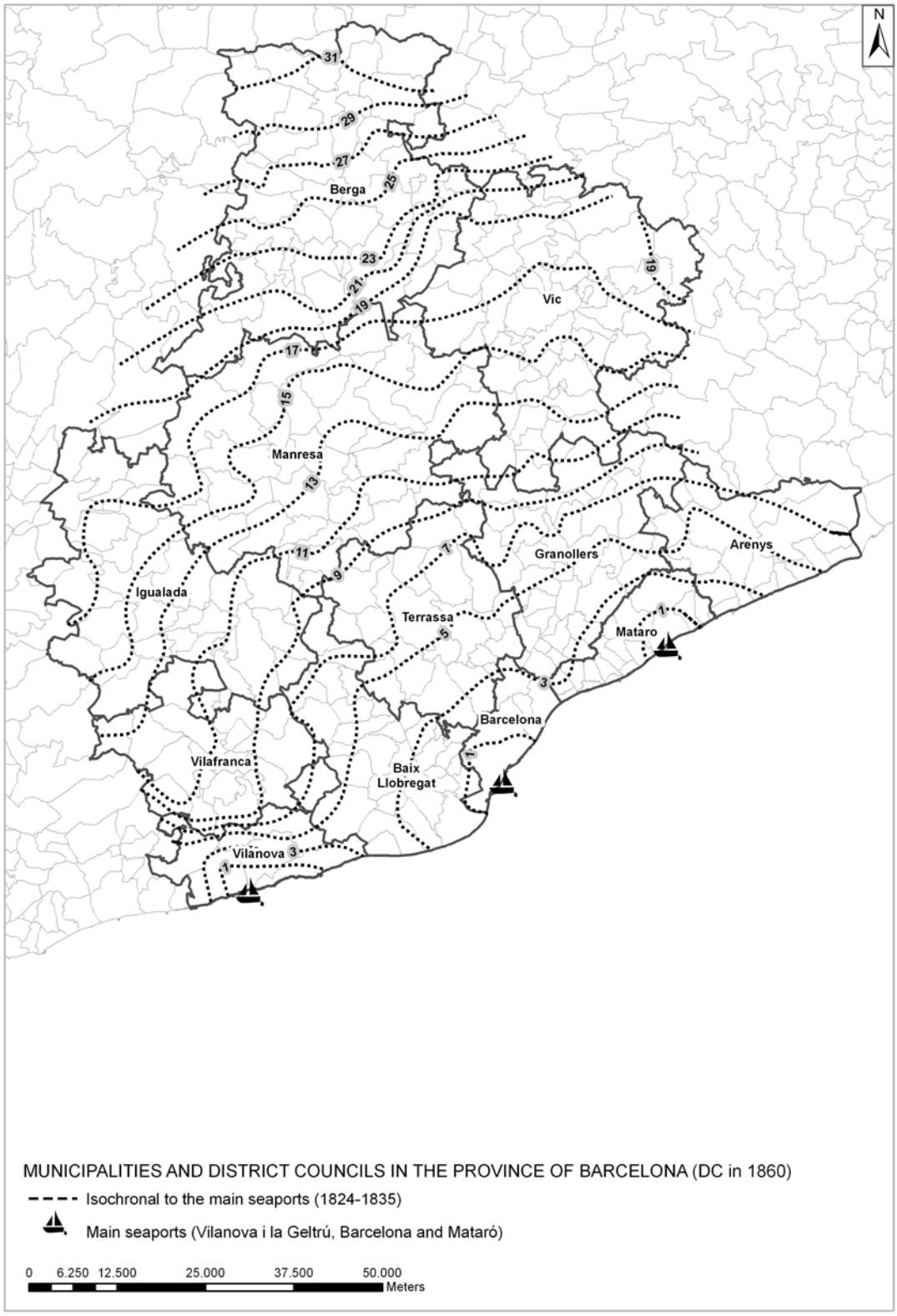
Source: made with GIS by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG, with the municipal data from the Territorial Statistics of Moreno (1858).

Map 6. Population densities according to the 1860 census, and main roads and railways in the municipalities of the province of Barcelona at that time



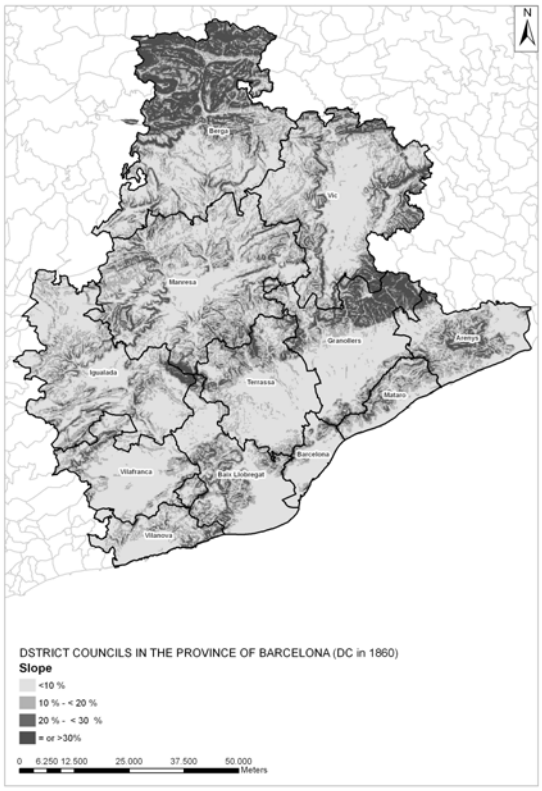
Source: made with GIS by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG, with information from the 1860 population census. We thank Barcelona Regional for facilitating digital information on the road and rail networks in 1860.

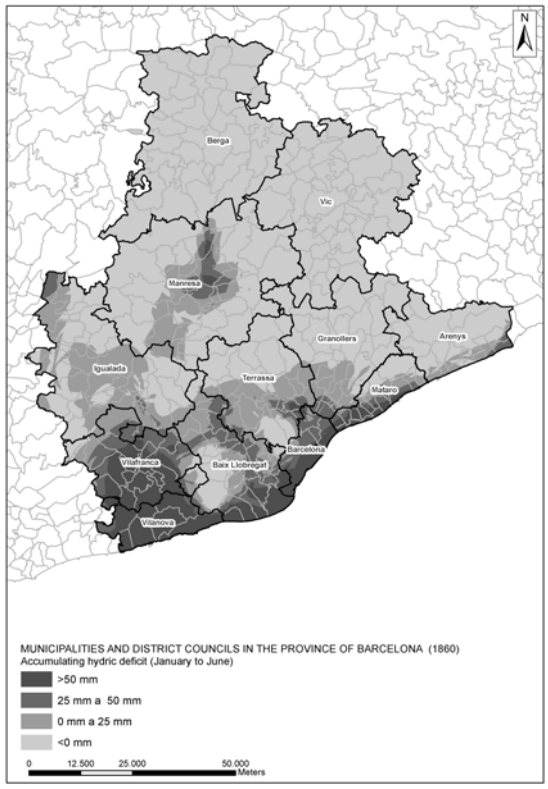
Map 7. Time distances to the nearest seaport through the existing roads and ways in the province of Barcelona in 1824-1838

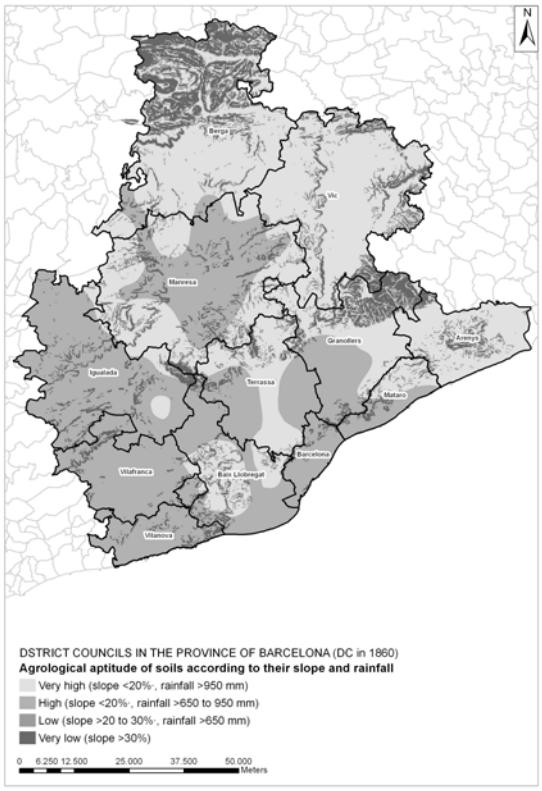


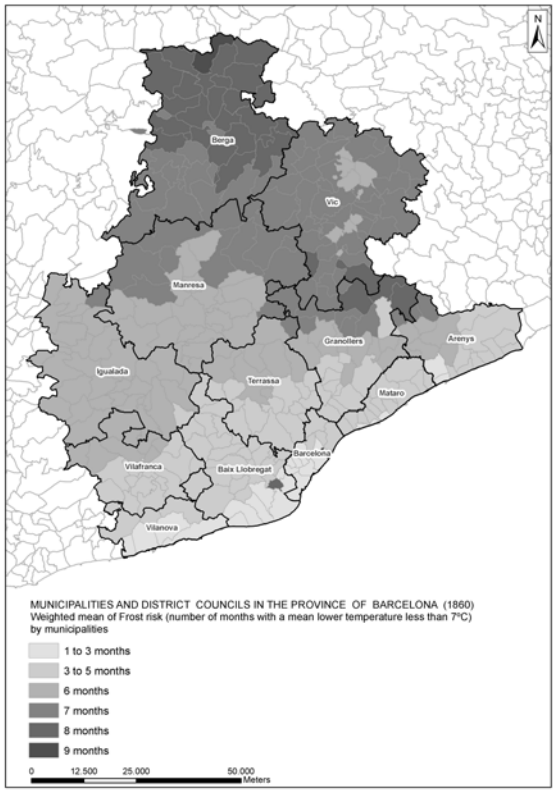
Source: made with GIS by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG, with information from two itineraries made before the first railway set up in 1848 (Frígola, 1824 and Anonymous, 1838).

Maps 8. Mean slopes, water stress, index of agrological suitability of soils, and number of months with frost risk in the province of Barcelona









Source: made with GIS by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG.

Explaining the regional pattern of vineyard specialization, and the corresponding degree of coverage of cereal consumption by locally grown production

As a first step, we are going to test statistically the extent to which we can explain the municipal differences in the degree of coverage of human-edible cereal consumption by local production, expressed as a percentage (*PERCOV*), by taking into account two sets of factors which are considered to be the principal agrological features[29] in determining land suitability for cereal cropping: the number of hectares per capita sown in each municipality, distinguishing whether they were irrigated (*IRHAPC*) or dry-farming (*DFHAPC*); and the mean water stress (*WTSTR*) during the growth period of wheat from January to June –that has been calculated subtracting from the mean monthly rainfall in mm the Thornwaite Potential Evapotranspiration (PET)—, together with the mean slope of lands (*SLOP*) in percentage shown in Map 8. After omitting the municipalities for which there was no reliable information on the degree of coverage or which posed too many problems due to the evolution of the municipal boundaries over time, we assembled a set of 285 observations which we will try to explain following this model:

$$PERCOV_i = \alpha_1 + \alpha_2 \cdot IRHAPC_i + \alpha_3 \cdot DFHAPC_i + \alpha_4 \cdot WTSTR_i + \alpha_5 \cdot SLOP_i + \varepsilon_i \quad (1)$$

The panel set comes from a network of small municipalities in the province of Barcelona with area of between one and one hundred km^2 each and a mean area

[29] According to its agro-climatic features, wheat can be sown in almost any land in the province of Barcelona. However, wheat yields mainly depend on the moisture during the growth period of the plant (Leon, 1989:131). As such, the success of the harvest is mainly dependent on the spring rainfall, although higher annual rainfall in dense, plain soils with better water retention can produce a reserve of water that may allow the wheat to mature even without a sufficient spring rainfall. In order to test the land suitability to grow cereals we have used the water stress accumulated from January to June, measured subtracting from the monthly mean rainfall the Thornwaite Potential Evapotranspiration (PET).

of 25 km^2. This observation network is suitable for revealing local variations in natural features such as slopes, rainfall, water stress or frost risk, while the scale may be too small to assess the impact of other socioeconomic factors such as population densities or concentration of manufactures, which would probably exceed the municipal boundaries. The smallest municipalities may also lead to biased or anomalous observations. In any case, we have kept as many observations as possible so that the test takes into account the actual variability in natural and socioeconomic endowments between municipalities. The results are shown in Table 9:

Table 9. Land allocation and land suitability for grain cultivation as the main determinants of the degree of coverage of cereal consumption by local production in the municipalities of the province of Barcelona towards 1860

	(a)	(b)
Constant	30.21***	30.25***
	(4.17)	*(4.21)*
Total hectares per capita sown with cereals (*CHAPC*)	276.72***	
	(12.08)	
Squared total hectares per capita sown with cereals (*CHAPC*^{2})	-48.30**	
	(-2.59)	
Neighbour hectares per capita sown with cereals (*NGCHAPC*)	-31.23*	-36.87**
	(-1.88)	*(-2.19)*
Dry-farming hectares per capita (*DFHAPC*)		282.77***
		(12.35)
Irrigated hectares per capita (*IRHAPC*)		292.35***
		(5.01)
Squared dry-farming hectares per capita (*DFHAPC*^{2})		-51.45***
		(-2.77)
Squared irrigated hectares per capita (*IRHAPC*^{2})		-147.24*
		(-1.73)
Mean water stress from January to June in mm (*WTSTR*)	0.24***	0.24***
	(6.31)	*(6.30)*
Mean slope of lands in % (*SLOP*)	-1.82***	-1.84***
	(-3.98)	*(-4.02)*
Adj R^2	0.77	0.77
Number of observations	285	285

*Note: t-ratios are in brackets; ***1%, **5% or *10% statistical confidence interval. Source: our own estimates using the data from the survey referenced in Table 2, following upward adjustment, for the percentages of coverage of cereal consumption by local production (PERCOV); the data compiled in the 1858 Territorial Statistics by Moreno, and the 1860 population census for the acreage per capita sown with grain (IRHAPC, DFHAPC or CHAPC); and the GIS assessment carried out by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG to evaluate both the mean slopes of land (SLOPE), and the water stress*

(WTSTR) by means of subtracting from the monthly rainfall accumulated during the wheat period of growth from January to June the Thornwaite potential evapotranspiration.

Column (a) corresponds to a model that does not divide the total acreage per capita sown with cereals between irrigated plots or dry-farming, while Column (b) corresponds to Model 1. The explanatory capacity attained is the same for both Tests (a) and (b) and the Akaike discrimination criterion between estimates is similar. We therefore chose to use Test (b), as the specification between irrigated or dry cropland adds more information to our analysis. The estimated coefficients give the expected signs, and with an adjusted R^2 of 0.77 the overall result is significant enough. Thus, the outcome corroborates that the need to import different volumes of wheat in each municipality was inversely related to the quantity and quality of cropland devoted to cereal cultivation by the local population. We can conclude that when the acreage per capita sown with grain was higher, the degree of coverage of cereal consumption by local production was also higher, thus reducing the need for imports. The small differences in annual rainfall and soil water stress between localities also had a positive effect, i.e. when the acreage per capita sown with cereals was equal, the degree of coverage grew slightly if greater rainfall allowed for less water stress and produced higher yields. The opposite was true when lands were more sloped and hence less fertile, because a lower yield from an equal acreage per capita sown with cereals reduced the degree of coverage.

This statistical outcome is less obvious than it might seem at first sight, when compared with a very common situation in contemporary agriculture in which local consumption is almost entirely unrelated to what is local production. In this type of globalized model, any municipality might even import products similar to the ones that it simultaneously produces and exports. This situation was not very common before the economic watershed brought about by the introduction of railways and steam ships, although this only became significant

after 1860 as the high transport costs precluded complete reliance on imports to provide staple foods.[30] Again, this can be regarded as a feature of the «organic» nature of this economic system.[31] When we consider these features together in their historical context, the fact that local grain production only covered 39% of the wheat consumption, despite the then unavoidable environmental and socioeconomic constraints, acquires greater significance. This outcome of our test, which corroborates the close relationship between this degree of coverage and the 44% of cropland allocated to cereal cultivation, also confirms the reliability of the two main historical sources used in the study: the 1859-67 survey and the 1858 *Territorial Statistics.*

This immediately raises a second and more important question: which was the main determining factor of the different quantities of cropland allocated to the cultivation of wheat or rye in each municipality? The answer seems clear: a simple linear correlation between the proportions of cultivated land devoted to vines or cereals in our sample of 285 municipal observations gives an R^2 value of 0.9181. This indicates that grains and vines were almost perfect substitutes given the same cropland allocation. The slight deviation derives from the small proportions of land used for olive, almond, hazel, apple, orange or lemon trees, together with the small acreage taken up by vegetables grown in irrigated land. This leads to final query: how can the different municipal intensities of specialization in vine cultivation be explained?

As a second statistical test we check the explanatory capacity of commercial specialization in vine cultivation by considering three main sets of variables: population densities or increases, terrestrial time-distances from seaports, and

[30] Railway construction in the province of Barcelona began in 1848 and is explained in Pascual (1999). For an overview of the spatial distribution of the Spanish transport network after 1860, see Herranz-Loncán (2007:189-208).
[31] Fischer-Kowalski, Krausmann and Smetschka (2004:307-342).

agro-climatic endowment for wine growing. The model is designed to explain the percent proportion of cropland devoted to vineyards (*PRVI*) in each municipality, taking into account: the population density (*POPDENS*); the time-distances to the nearest harbour in hours (*HARBTAIMDIS*) following the existing roads and ways before the railways shown in Map 7; the mean water stress (*WTSTR*) during the growth period of wheat from January to June; the mean land slope as a percentage (*SLOP*), and the average number of months with a mean minimum temperature below 7°C, which entails a frost risk (*FRSTRIS*) that could affect the blooming of the vines.[32] The general equation is the following:

$$PRVI_i = \alpha_1+\alpha_2 \cdot POPDENS_i+\alpha_3\, HARBTAIMDIS_i-\alpha_4 \cdot WTSTR_i+\alpha_5 \cdot SLOP_i+\alpha_6 \cdot FRSTRIS_i+\varepsilon_i \quad (2)$$

In order to correct for spatial autocorrelation, in the first column (a) we introduce neighbour density population (*WCMPDENS*). It is also necessary to ensure that the rebound effect of specialization in vine cultivation on a further increase in population is not confused with the opposite effect, i.e. the pushing force generated by the population increase to plant more vines. Therefore, in column (b) the population growth rate prior to 1718-1860 (*PPOPGR*) substitutes for the population density (*POPDENS*). The historical lag of this variable seeks to guarantee that the test detects the desired causal relationship, which is the «Boserupian» push toward a more intensive land use pattern.[33] In column (c) we discard those municipalities with a population density greater than 70 inhabitants/km^2, taking into account the threshold proposed by Boserup that divided a high-intensity agrarian economy from an industrialized one. This

[32] Due to their agro-climatic features, vines can be planted in almost any land in the province of Barcelona. However, the success of a vintage depends on late frosts, which can damage the vines and prevent grapes from maturing (León, 1989:152). Water stress is a less limiting factor for growing grapes than it is for cereals, so in this case we have used the simple rainfall values to test the land suitability for vines, together with mean slope and frost risk.
[33] Boserup (1981).

reduces the sample to 186 observations. Finally, in order to compensate for a network of municipalities that may become too thin for the analysis, if their activities were highly influenced by the impact of neighbouring towns or higher populated villages, in the last column (d) we account the average population density of every municipality together with their contiguous municipalities, and discard those greater than 70 inhabitants/km^2. This reduces the sample again to 164 observations. The results are summarized in Table10:

Table 10. Explaining specialization in vine cultivation in the province of Barcelona in the period leading up to 1860 through population increase or population density, time-distances to coastal harbours, and the agro-climatic suitability of vines

	(a)	(b)	(c)	(d)
Constant	62,64**	43,35**	53,19**	63,40**
	(8,26)	(6,38)	(6,13)	(12,65)
Population density, inhab./Km^2 (*POPDENS*)	-0,02**			
	(-2,73)			
Average population density weighted by contiguous municipalities (*WCMPDENS*)	-0,02**			
	(-3,48)			
Population growth rate (*PPOPGR*) from 1718 to 1860		0,04**	0,04**	0,01**
		(4,45)	(4,02)	(2,68)
time-distances to the nearest harbour in hours (*HARBTAIMDIS*)	-0,98**	-1,02**		
	(-3,70)	(-3,83)		
time-distances to the Barcelona harbour in hours (*BCNHARBTAIMDIS*)			-1,36**	-0,93**
			(-4,24)	(3,49)
Mean water stress from January to June in mm (*WTSTR*)	-0,27**	-0,27**	-0,24**	-0,20**
	(-9,57)	(-9.50)	(-7,26)	(7,35)
Mean slope of land in % (*SLOP*)	2,02**	2,13**	1,79**	1,55**
	(7,93)	(8,43)	(5,82)	(7,67)
Number of months with frost risk (*FRTRIS*)		-2,17*	-2,54**	-5,20**
		(-1,66)	(1,68)	(-8,88)
Adj R^2	0,608	0,612	0,634	0,826
Number of observations	285	285	186	164

*Note: t-ratios are in brackets; t-ratios are in brackets; **5% or *10% statistical confidence interval. Estimated by OLS corrected for Heteroscedasticity effects. Source: our own estimates, using the data from the 1858 Territorial Statistics for the percentage of cropland allocated to vineyards (PRVI); the 1860 census for population density (POPDENS or WCMPDENS); Vilar (1962) for the 1716-1860 population increase ratios (PPOPGR); and the GIS assessment carried out by Rodríguez-Valle for the research project SEJ2006-15108-C02-01/GEOG to evaluate: the mean slopes of land (SLOPE); the water stress (WTSTR) by means of subtracting from the monthly rainfall accumulated during the wheat period of growth from January to June the Thornwaite Potential Evapotranspiration; and number of months with frost risk (FRTRIS).*

Almost all results are significant and signs are as expected, except in column (a) where population density appears to be negatively linked with vineyard specialization (and the check for spatial autocorrelation reinforces that). This means that not discarding those municipalities with populations densities higher to some threshold, that led to a local economy dominated by industrious or industrial activities, may render negative the correlation between population density and vineyard specialization. There are two ways to overcome this accountancy problem with the «*Boserupian push driving force*» of our model. Following the first one, when we use the population growth rate for the previous period 1718-1860, like in the other three columns (b), (c) and (d), the sign turns out to be positive and the significance of the test becomes higher. Moreover, the lag of this substitution helps to deal with the feedback problem in the relationship between population growth and vineyard specialization. The second way round is leaking the sample. When population densities greater than 70 inhab./km^2 are omitted, as in tests (c) and (d), all the signs remain as expected and the significance increases again, albeit within smaller samples.

The agro-ecological variables also give the expected signs. Not surprisingly, slope has a positive effect on vineyard specialization. This confirms the economic suitability of the wine-growing habitually carried out by poor peasants on poor, sloping lands, while grain used to be sown mainly on better lands belonging to wealthy landowners. The same is true for mean water stress (*WTSTR*) during the growth period of wheat. Having been calculated subtracting from the mean monthly rainfall in mm the PET, the values may be either positive (expressing a surplus) or negative (deficit). Therefore, the negative statistical outcome means that vines use to be planted in drier areas. Frost risk may have also limited the spread of vines throughout the northern part of the

province, according to the negative impact that becomes significant in tests (b), (c) and (d), because winegrowers avoided colder areas.

Finally, the «*commercial pull driving force*» exerted by more intense trading opportunities are measured through the hourly-distances either to Barcelona or the nearest harbour, according to some travel time-tables published in 1824-1838 before the functioning of the railway. With distances ranging up to 33 hours, the mean time-distance was 10.9 to the nearest harbour and 11.7 to Barcelona port. This variable shows the expected negative impact of specialization in vine cultivation, thus confirming the high relative cost of transporting bulky and low value-to-weight commodities over terrestrial short distances in an already mainly organic economy.

Conclusions and prospects for future research

The overall outcome of these tests suggests that the direct *pulling* force from market incentives had to combine with agro-ecological land endowment in vineyard or grain specialization, together with the *pushing* effect exerted by previous population growth, in order to jointly move the entire agrarian system towards the specialization degrees in vines or grain attained in 1860 in the province of Barcelona. If we look at the adjusted R^2 levels, which range from 0.608 to 0.826, the results can be considered very successful bearing in mind that the intention was merely to establish the weight of three main *driving forces* (population increase and density, time-distances to the coast and agrological suitability of vines compared with wheat or rye) that jointly set up the context in which economic agents took the decision of planting or not more and more vines. Other factors that we believe to have played a very important role, such as

rates of inequality in land ownership and tenancy contracts, have had to be omitted for the moment due to the lack of statistical data. Considering the evidence at hand, we believe we account successfully for a great deal of the variability in the specialization in vine cultivation between most municipalities in the province of Barcelona in the period leading up to 1860 by examining the role of environmental endowments in an organic-based agrarian economy, the «Boserupian» push of population increase, and the demand pull of «Smithian-type» growth.

However, the explanatory power of this set of environmental, commercial and demographic variables can still be enhanced when applied to a local pattern of specialization in vine cultivation. This is mainly because the model omits, as has already been explained, one other important socio-institutional factor: the inequality of land ownership. On the basis of a more in-depth analysis of local case studies using a wider range of data from land registry records, censi and notarial sources, we have suggested in previous papers that the process of specialization in vineyard cultivation –through the peculiar, quasi-emphyteutic Catalan tenancy contracts called *rabassa morta* which lasted until the death of the vines planted by the tenant— can be seen as a social agreement between wealthy landowners and a new class of landless peasants. The social conflict over land entitlement between *rabassa* tenants and landowners lasted from the 18th century until the Spanish Civil War in 1936-39. Nevertheless, the contractual agreements reached between tenants and owners helped to reduce the prevailing agrarian inequality and channelled the social unrest triggered by this conflict towards creating a more productive rural society. After the initial success of this statistical test, we will intend to improve in future research our socio-economic and agro-ecological approach by including the previously

omitted variable of the inequality in land ownership using a 1852 nominal list of taxpayers and their annual payment of the cadastral duties.[34]

This significant statistical results can also be seen as an indirect confirmation of the Heckscher-Ohlin theoretical explanation of commercial specialization, by means of the relative factor endowments of land and labour. However, *our main aim is to understand how these different land-labour ratios historically arose* at a municipal level in the Western Mediterranean bioregion over a long historical period. The agro-ecological endowments can be seen as almost immobile, given the few technological innovations in vine-growing prior to 1860. The available labour offer was created instead by the relative local presence or absence of landless peasants, who sought to earn their living working as tenants of a *rabassa morta* lease on the small, poor, dry and sloping plots offered them by landowners. The push of population growth, combined with the growing inequality in land ownership, seems to have played a very important role, and so we intend to include it in our model. A further discussion is needed on how to deal with the endogeneity problem that working with these socio-demographic variables may entail (though, to some extent, this problem is inevitable in the study of any historical process).

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[34] A provincial list of taxpayers in every municipality, with the amount of cadastral taxes they paid, was published in 1852. Unfortunately, after the catalogue was computerized this reference seemed to have disappeared in the library of the University of Barcelona where other researchers had used it some years ago (Segura, 1993:289). We have been able to eventfully find this source thanks to the help of Ricard García, but this problem has delayed the schedule time planned by our research team in order to get a full statistical assessment of the historical model proposed to explain vineyard specialization in the province of Barcelona towards 1860.

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