Land-use profiles of agrarian income and land ownership inequality in the province of Barcelona in mid-nineteenth century: hypothesis and initial results

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Abstract

The use of two very exceptional historical sources has allowed us to gather a big dataset on the cadastral valuation of income obtained from real estate ownership for every taxpayer in nearly all the three hundred municipalities in the province of Barcelona, together with the prevailing land-uses in 1858, and population data in the 1857 census. These sources are the *Distribution of Personal Wealth in Real Estate Ownership* published in 1852 by the Official Gazette of the Barcelona province; and a *Land-Use Statistics of the Province of Barcelona* compiled by a Spanish topographer in 1858. Although the unique nature of these sources does not allow a diachronic use, they do permit of a cross-section analysis. This database has provided for the first time quantitative answers to a set of questions posed for a long time by Catalan rural historians: Was the number of landowners greater among residents in the winegrowing municipalities, rather than in cereal-oriented ones or in mainly forest localities? Was the value of their respective real estates very different? Was their personal income obtained from wealth in lands, houses and livestock more evenly or unequally distributed in municipalities specialized in vineyards, cereal cropping or woodland and pastureland? Was there a big difference between small rural villages and bigger cities and towns? In order to establish the main land-use patterns of inequality in personal agrarian income distribution in the province of Barcelona in mid-19th century, we have answered these questions applying to the abovementioned dataset the inequality possibility frontier and extraction ratio put forward by Branko Milanovic, Peter Lindert and Jeffrey G. Williamson. The results confirm that landownership inequality was lower in winegrowing municipalities than in cereal cropping or forest ones, in spite of the fact that developing a commercial vineyard specialization, and attaining higher population densities, could have also meant an an extended frontier of possible inequality through a greater potential extraction ratio by

This work springs from the research project HAR2009-13748-C03-01 on Environmental History of Mediterranean Agrarian Landscapes at the University of Barcelona, financed by the Spanish Ministry of Science and Innovation (On-line URL: http://www.ub.edu/histeco/p2/eng/index.php). We thank Yaiza Alemany, Marta Nieto, Julia Ossorio and Alba Pigrau for their care in transferring data from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852 to excel sheets.

the elites. This outcome can be interpreted as a historical process of empowerment, achieved through the long-lasting social fight waged by the Catalan rural class of wine-growing tenants.

Keywords: agrarian income distribution, inequality possibility frontier, land-use patterns, manorial system, population density, Catalonia

Introduction

The *Distribution of Personal Wealth in Real Estate Ownership* of 1852 published in the Official Gazette of the Barcelona province is a rather exceptional document. It lists for each of the municipalities the names of all owners of land, houses and livestock who were subject to payment of the cadastral tax, adding up the monetary evaluation of their taxable incomes and annual tax burden paid. Drawn from this source, we have been able to include in our database more than 86,000 taxpayers in 295 municipalities out of the 311 existing at present. These real estate owners represented 12% of the total population, 24% all males, and 41% of all male inhabitants older than 21 recorded in the provincial census of 1857. The second main source used in our database is a *Land-Use Statistics of the Province of Barcelona* compiled in 1858 by a Spanish topographer, Pedro Moreno Ramirez, which relates the total agrarian area and the extent occupied by each agricultural, forest or pasture land-use in each municipality. This information has been combined with the 1857 census data, so as to construct a dataset to find out the land-use profiles of agrarian income and land ownership inequality in the province of Barcelona in mid-19th century.

Our starting point is the hypothesis that the spread of vineyard specialization during the 17th and 18th centuries, and its consolidation during the first half of the 19th century, was accompanied by a reduction of inequality in access to land and agrarian incomes. This hypothesis is based on previous comparative local case studies published by other Catalan historians and our research team (Garrabou et al. 2004, 2008, 2009 and in press, Cussó et al. 2006, Tello et al. 2006, Badia-Miró et al. 2010). According to this research, there were two specific mechanisms through which winegrowing specialization could have led to a reduction of inequality in land ownership and agricultural income, one direct, the other indirect. The direct mechanism involved the leasing of small plots of land from wealthy landowners to landless winegrowers through a traditional sharecropping contract called *rabassa morta* in Catalan. The tenancy established by this peculiar contract lasted until the death of all vines planted by the tenant. Given that winegrowers used to bury strains of their old vines in order to keep them alive, the *rabassa* tenants tried to maintain almost permanent access to

land through the emphyteutic ownership over their vineyards, (Carmona and Simpson 1999).

However, the duration of the contract, together with the rent share taken by the landowner from the winegrower's harvest, gave rise to a long-lasting class conflict from the end of the 18th century until the Spanish Civil War in 1936-1939. The first lawsuits regarding the duration of the contract began in the 1780s, motivated by the landowners' demands that sought to prohibit the permanent renewal of vines. Their initial court victories led to a succession of petitions in favour of the *rabassa* sharecroppers sent to the absolutists or liberal governments in 1793, 1806 and 1837 (Tello 1997). Complaints from these sharecroppers also bore fruit. Every instance judgments favourable to the landowners were later annulled by the higher courts decisions or through political resolutions. Consequently, the thorny issue of ownership of Catalan vineyards remained unresolved for another century. While the former landowners reasserted their old emphyteutic entitlement to the land during the liberal revolution, which abolished the old manorial rights that existed up until 1836, and also abolished the tithe in 1840, the *rabassa* tenants maintained their ownership, also of a emphyteutic nature, of the vines they had planted. Very often the *rabassers* themselves had created the soils in which their vines grew, by means of terracing the sloping lands leased from the landowners (Olarieta et al. 2008). The *rabassa* sharecroppers paid the "colonic part" of the cadastral tax, and appeared as taxpayers on the cadastral lists. As in any other emphyteutic entitlement, the ownership of "their" vines could be sold or transferred through inheritance by the *rabassa* tenants—with the consent of the landowner. Why did these sharecroppers not aspire to become freeholders of the land they possessed only in emphyteutic terms? Hadn't the counterpart of their contract become landowners in a similar way, by abolishing the manorial entitlements of their former lords?

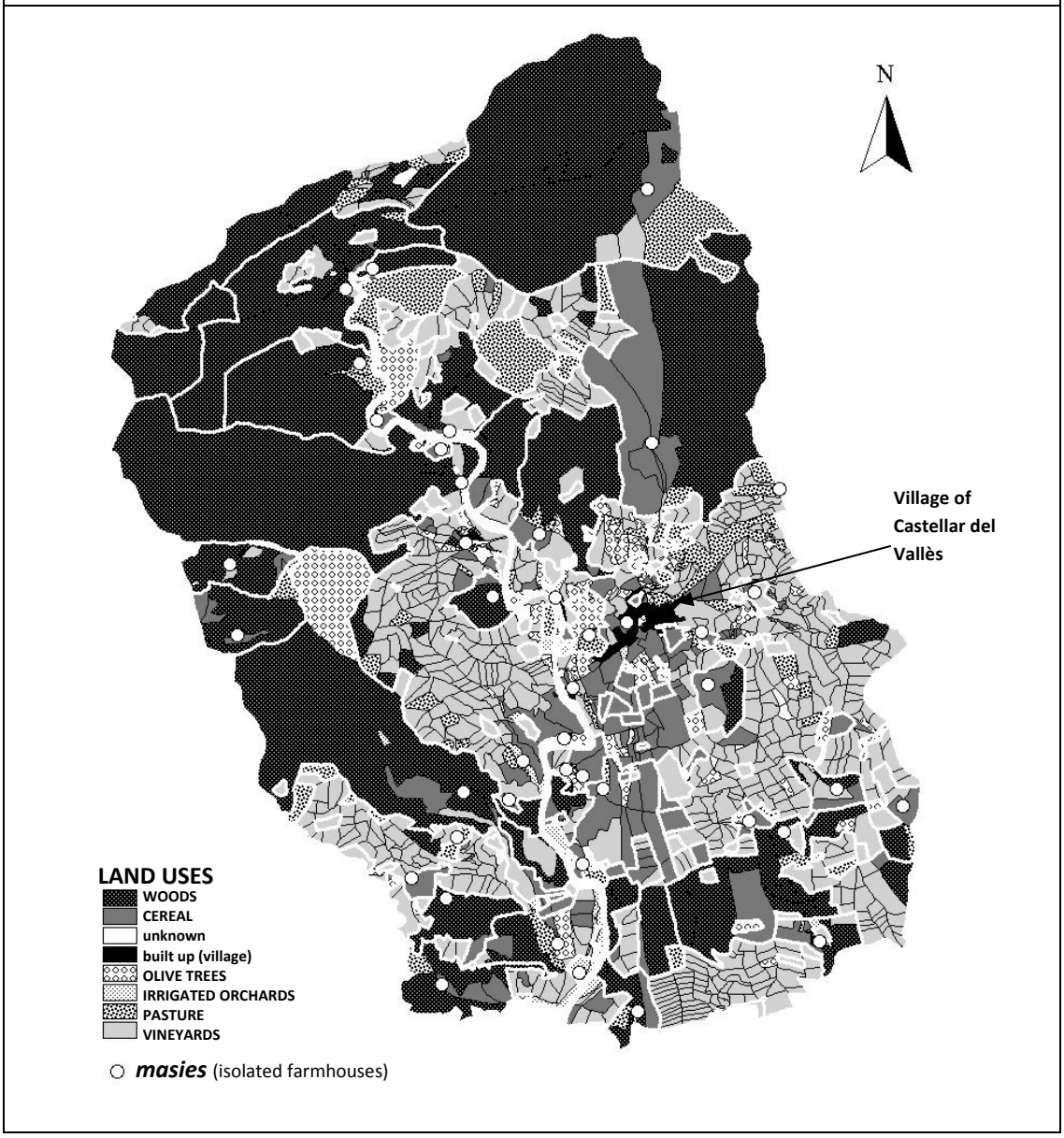
We do not believe that the contractual relationship between landowners and their winegrowing tenants was founded on mutual trust, entering into crisis with the arrival of the Phylloxera plague (Carmona and Simpson 1999). Rather, we consider that the *rabassa* partnership constituted only a second best choice for both sides. We have found very expressive texts written in the late 18th century that show the distrust felt by Catalan rural landowners towards the growing number of immigrants and other landless peasants living in neighbouring villages, typically accusing them of stealing their fruits, chickens or firewood, (Garrabou and Tello 2004). Despite this distrust, landowners offered sharecropping contracts to these peasants, most probably to exert a better control over them, while profiting from their presence in the territory. The *rabassa* tenants accepted the leases as this opened a way for them to earn a living. Their acceptance, however, did not mean that they were content with all the contractual terms, as demonstrated by the eruption of conflicts that led to collective

action. As we have seen, all these conflicts had began a century before the Phylloxera plague which brought about the biggest turning point of the contractual relationship between landowners and *rabassa* sharecroppers in the 1890s onwards, together with the rise in wages and other costs experienced at the time (Carmona and Simpson 1999, Badia-Miró et al. 2010). Therefore, the fact that the *rabassa* tenancy system became so widespread during the 18th and 19th centuries, in spite of the long-lasting conflicts between landowners and tenants, could also be acknowledged as an achievement of the poorest sections of Catalan rural society resulting from their collective action.

The second indirect mechanism through which vineyard specialization could have led to a reduction in landownership and agrarian income inequalities was the ability of many *rabassa* tenants to subsist from their vines, endure the pressure of the rent taken by the owner over their crops, and prosper enough to buy a small house, an adjoining garden and even a plot of their own. It is important to note that many of these landless tenants were immigrants coming from the South of France and the mountain villages of the Pyrenees. Some others, however, came from the non-inheriting progeny of the same class of wealthier peasants who offered them a *rabassa* tenancy. Furthermore, as non-heirs they received a legitimate compensation from the first-born brother heir, which was paid either in cash or with a small plot of land. This second mechanism restrained landownership inequality, while the first direct spread of *rabassa* tenancies only reduced the inequality of access to land, and consequently of income distribution. Taken together, both entailed an improvement of access to land that the *rabassa* tenants managed to open in wine-growing municipalities. These options were not available to the poorest sectors of Catalan rural society in cereal-growing or forest and pasture areas. In this sense, we may say that Catalan winegrowing tenants managed to harness the ongoing process of population growth, commercial specialization and agricultural intensification to carry out a genuine process of empowerment.

The complex fabric of this mid-19th century Catalan rural society can be summarized looking at Fig 1, made out of a cadastral map of the small village of Castellar del Vallès drawn by Pedro Ramirez Moreno in 1854—the same topographer who compiled the abovementioned *Land-Use Statistics of the Province of Barcelona*. The most apparent feature of agrarian settlement in most of the province was a network of scattered poly-cultural farms called *masies* in Catalan, structured into compact units around an isolated rural dwelling (see the white dots in Fig 1). In contrast, the poorest share of population used to live in the streets of small towns or villages like Castellar del Vallés.

Fig. 1. *Old poly-cultural* masies, *new vineyard plots and main land-uses in the cadastral map of* Castellar del Vallès *in 1854*



Source: made with GIS by Marc Badia for the research project HAR2009-13748-C03-01, out of the cadastral map 1:5000 drawn by Pedro Moreno Ramírez in 1854 and kept in the historical archive of the Catalan Cartographic Institute. It has been reproduced in Garrabou et al. (in press).

Thanks to the late medieval peasant struggles held in Catalonia, the peasant landowners who lived in these *masies* gradually gained control of the rights of access to cropped and uncultivated land over a complex and conflictive transition from feudalism to agrarian capitalism (Garrabou et al. 2008). Then, from the 17th century onwards population growth was fostered by increasing French immigrants coming from the Pyrenees. The owners of the scattered farms saw these immigrants, and the disinherited descendants of the old local families, as a new and frightening landless

class that established itself in the villages or towns between their networks of *masies*. However, landowners soon discovered new favourable opportunities to take advantage of their lack of land, their labour availability, and the high relative prices of wine at the time, by leasing to them some marginal lands to plant vineyards. Many landless men became winegrowers through the emphyteutic *rabassa* contract, and a new social and environmental geography appeared when a patchwork of small vineyard plots arose among the interstices of the old poly-cultural *masies* (Tello et al. 2006, Olarieta et al. 2008, Marull et al. 2008 and 2010). While the shape of the diverse compact fields of every *masia* tended to be higher and be located around a scattered farmhouse, the small plots of vineyards planted by the *rabassers* used to be orientated towards the village, were they lived, following the existing ways and roads (see Fig 1).

The abovementioned local case studies have shown a decrease in the Gini coefficients of landownership distribution from the beginning of the 18th century up to the Phylloxera Plague (Garrabou et al. 2009 and in press). Later, when every old vine had been ravaged during the 1880s, all the *rabassa* contracts came to an end and many tenants were evicted or gave up winegrowing (Badia-Miró et al. 2010). Many old *masia* owners recovered the land, and there was a new increase in landownership inequality. Nevertheless, could this path be generalized assuming that the reduction in inequality of the rural Catalan society was a general trend triggered by the spread of vineyard specialization? We might cast some doubts on that hypothesis, considering three important points. First of all, specialization could attract more immigrants to the municipalities where vineyards were spreading, and also foster population growth in them by increasing birth rates, thus growing the number of people who owned only very small plots or had no land of their own. Secondly, vineyard specialization also increased the total income and wealth of the whole rural community. As Lindert, Milanovic and Williamson have pointed out (2007), a higher income in a wealthier economy could also mean the possibility to increase the maximum extraction ratio taken by a small elite, thus raising the frontier of maximum inequality. Thirdly, there are many historical examples showing that an increase in market integration and globalization lead to a greater inequality, not the opposite. Even adopting a standard Heckscher-Ohlin economic approach, this could be the expected outcome when land was still the most abundant factor endowment of a region joining a global market (Acemoglu and Robinson, 2002 and 2006).

Having these historical and theoretical considerations in mind, we cannot take for granted that the reduction of inequality in landownership or agrarian incomes was a general trend, without carrying out a cross-section analysis encompassing a great deal of municipalities of the Barcelona province. This is exactly what can be done with the dataset we have been able to assemble from the abovementioned historical sources.

Inequality of what, and from whom?

The *Distribution of Personal Wealth in Real Estate Ownership* of 1852 is an exceptional source, but also a rather obscure one. We do not know exactly why it was published in the provincial Official Gazette, and for what purpose. It was not accompanied by any preamble, order or instruction. The only thing sure is that this publication must have been related with the efforts to build a land tax system developed by the Spanish liberal governments after the new Tax Act passed in 1845. The document offers a list of the names of each local taxpayer, the cadastral estimated value of his or her property, and the amount of taxes yearly paid. Then, at the end of the list, the total cadastral value of all lands, houses and livestock was added up, together with the total amount of the cadastral taxes yearly paid in the municipality. Finally, the two sums were used to assess the tax burden, calculated as the percentage share taken by the cadastral tax out of the total income estimated in the cadastre.

This leads us to guess that the most likely aim of this document could have been to try to make apparent one of the worst features of the anomalous cadastral system established in the country at the time. In nineteenth-century Spain liberal governments never ended the cadastral enquiries and maps needed to assess an income value for each land unit devoted to a specific crop in a given type of soil, so as to apply a uniform tax burden to calculate the amount of annual taxes to be paid by each taxpayer. Without all this complex process of cadastral inquiry no one could guarantee that properties of equal value always paid the same tax burden in all the municipalities. Due to this long-lasting failure of completing a true cadastral survey, a temporary tax system called *amillaramientos* was established. Instead of following a bottom up process to comply with the most basic principle of tax equity, the *amillaramientos* run top to bottom. Each year the provincial quotas were politically distributed in Parliament at first, and then each provincial quota was politically shared out between municipalities by provincial governors. It was only at municipal level were the already given amount of taxes to be paid for was distributed among the taxpayers according to the estimated cadastral value of their property and income—although provincial governors could take into account the local cadastral information also to allocate the provincial tax quota in each municipality. The *Distribution of Personal Wealth in Real Estate Ownership* published in 1852 clearly demonstrated that the tax burden applied to different municipalities varied a lot, from twelve per cent of the local aggregated income up to more than twenty. It seems rather understandable that this bold initiative taken by the provincial Administration of Finance in Barcelona was carried out only once, and only in that province—as far as we know.

All these details are relevant for our purpose, because they entail a very important ambiguity in the economic data provided by this historical source. The primary information contained in the local *amillaramientos* referred to the surfaces of land owned by each taxpayer, together with their houses and livestock. Clearly, this was information on the distribution of agrarian wealth. Owing to another contemporary source (Peña 1852) we know the specific methods used by the Finance officials to estimate in monetary terms an average yearly income from the cadastral information on personal properties recorded in physical units. However, only these final cadastral estimates of average annual incomes were published in the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. This is understandable, taking into account the likely aim to assess the tax burden variation among different municipalities of the Barcelona province. But it requires us to deal with the resulting ambiguity: are we calculating inequalities of wealth or income? It is well known that inequality of wealth is always greater than income inequality (Zanden 1995). While all people should at least be able to survive with the latter, properties were usually the results of a long-lasting accumulation that could only be carried out by those having higher incomes, and often over generations.

The answer is far from simple. We cannot take this income information as if it had recorded all sorts of agrarian earnings, since only the estimated revenues from land, houses and livestock were included. All the data provided is about the aggregate value of these properties locally owned by each taxpayer. However, this information on personal wealth is only given by means of an estimated average income that any owner or tenant could obtain yearly from their properties, according to the standardized procedures applied by the cadastral officials. Surprisingly enough, the Gini coefficients obtained from this indirect data on personal agrarian wealth, by means of an estimated value of a yearly income taken from them, are very similar to the ones directly calculated from the distribution of landownership measured in surface units from the local *amillaramientos*. This intriguing coincidence deserves to be studied in the future, and might have something to do with the existence of proportionality between the distributions of wealth and rents paid for housing (Peña 1852). Some economists had alleged the existence of this kind of correspondence at the time, and suggested to use the data on rental housing as an easy proxy for personal income (San Julián 2010).

In any case, the way of accounting the value of agrarian wealth of every taxpayer through an estimated income introduces and important bias in our dataset: a relevant share of all taxpayers included in the lists had only a very poor house of their own. Their recorded income was the implicit rent that could have been obtained by leasing these poor houses in the market, after having deduced a quarter of the rent as repair

costs. Some others could also be sharecroppers, either as *rabassa* winegrowing tenants living in a village or as sharecropping families who, according to another typical Catalan contract called *masoveria*, had to live in the farmhouse where they worked—usually when landowners were wealthy enough not to work the *masia* by themselves. In this case, the cadastral valuation had to include the sharecropper with their nett income, obtained by deducting from their annual earnings the rent paid to the landowner (Peña 1852).

However, in most cases there were in the *Distribution of Personal Wealth in Real Estate Ownership* of 1852 a great deal of very poor taxpayers with only rather fictitious incomes, because they were below the lowest male agricultural wage at the time, and no one could have survived with such a yearly earning. According to the available series of Catalan agricultural wages for unskilled tasks, like digging, during the five years between 1850 and 1854 an agricultural labourer who worked 260 days a year would earn an income of some 1,720 Spanish *reales* in the province of Barcelona (Garrabou and Tello 2002). The urban planner Ildefons Cerdà calculated the prevailing family budgets at the time in Barcelona, and according to his detailed data the subsistence minimum expenditure on food, clothing and housing would have required some 6,622 *reales* for a full working-class family (Cerdà 1968-1971[1867]). This means that at least three or four adult unskilled wages like the ones considered would have had to be added up in order to achieve the minimum standard of living calculated by Cerdà. The cost of living was probably cheaper outside Barcelona, but this data reveal that some 1,500 to 2,000 *reales* could be considered a minimum income to survive at the time. However, the list of taxpayers in the *Distribution of Personal Wealth in Real Estate Ownership* of 1852 included a lot of people below that level (Table 1):

Table 1. *Number of taxpayers in the* Distribution of Personal Wealth in Real Estate Ownership *of 1852 in the Barcelona province*

Districts of the Barcelona province	taxpayers				
	all	with less than 2,000 *reales*	%	with less than 1,500 *reales*	%
Barcelona	11,940	7,642	64,0	7,004	58,7
Arenys	6,774	6,161	91,0	5,980	88,3
Berga	3,657	2,970	81,2	2,820	77,1
Granollers	8,384	7,608	90,7	7,447	88,8
Igualada	9,852	9,055	91,9	8,785	89,2
Manresa	9,561	8,796	92,0	8,601	90,0
Mataró	5,326	4,748	89,1	4,576	85,9
Sant Feliu de Llobregat	8,673	8,021	92,5	7,834	90,3
Terrassa	8,276	7,659	92,5	7,491	90,5
Vic	7,356	6,430	87,4	6,242	84,9
Vilafranca del Penedès	6,500	5,676	87,3	5473	84,2
Province of Barcelona	**86,299**	**74,766**	**86,6**	**72,253**	**83,7**

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852 in the Barcelona province (Library of the University of Barcelona, reference 146-1-II/13).

An astonishing 84-87% appeared in the document with a cadastral attributed income under the abovementioned poverty line of 1,500-2,000 annual *reales*. Although all these people who had such a small property worth less than 2,000 *reales* a year only owned 27% of all income recorded, they paid a respectable 30% of all cadastral taxes raised in the whole province. And if we set aside the very special case of Barcelona city, in the rest of rural districts the proportion of taxes paid by taxpayers with an attributed income lower than 2,000 *reales* ranged from 32 to 50%. Assuming that such poor taxpayers had endured exactly the same tax rate as the very rich, the prevailing tax system would already have been very regressive. Our data show that they always bore an even higher tax burden (Table 2).

Table 2. *Taxes paid and tax burden of tax payers above and below an attributed cadastral income of 2,000 reales a year in the Barcelona province, according to the* Distribution of Personal Wealth in Real Estate Ownership *of 1852 (in* reales *a year or %)*

Districts of the Barcelona province	estimated cadastral income of all taxpayers	taxpayers with more than 2,000 *reales*				
		estimated cadastral income	% of all income attributed	taxes paid	% of all taxes paid	% of tax burden
Barcelona	40.745.709	36.242.839	88,9	4.447.032	87,4	12,3
Arenys	5.918.547	3.362.731	56,8	513.458	55,6	15,3
Berga	5.061.354	3.708.250	73,3	541.062	68,5	14,6
Granollers	7.774.228	5.178.452	66,6	812.785	66,3	15,7
Igualada	6.778.104	3.579.993	52,8	629.203	50,2	17,6
Manresa	6.933.038	4.343.674	62,7	755.428	60,5	17,4
Mataró	5.076.673	2.980.214	58,7	472.361	57,0	15,8
Sant Feliu de Llobregat	6.555.209	3.710.259	56,6	606.685	55,1	16,4
Terrassa	6.571.379	3.781.913	57,6	580.909	57,3	15,4
Vic	6.994.514	5.110.590	73,1	1.039.174	72,2	20,3
Vilafranca del Penedès	7.038.780	4.895.405	69,5	890.345	68,2	18,2
Province of Barcelona	**105.447.534**	**76.894.320**	**72,9**	**11.288.442**	**69,6**	**14,7**
Districts of the Barcelona province	taxes paid by all taxpayers	taxpayers with less than 2,000 *reales*				
		estimated cadastral income	% of all income attributed	taxes paid	% of all taxes paid	% of tax burden
Barcelona	5.087.106	4.502.870	11,1	640.074	12,6	14,2
Arenys	923.500	2.555.816	43,2	410.042	44,4	16,0
Berga	790.410	1.353.104	26,7	249.348	31,5	18,4
Granollers	1.225.356	2.595.776	33,4	412.571	33,7	15,9
Igualada	1.252.699	3.198.111	47,2	623.496	49,8	19,5
Manresa	1.249.441	2.589.364	37,3	494.013	39,5	19,1
Mataró	829.013	2.096.459	41,3	356.653	43,0	17,0
Sant Feliu de Llobregat	1.100.946	2.844.950	43,4	494.261	44,9	17,4
Terrassa	1.013.776	2.789.466	42,4	432.866	42,7	15,5

Vic	1.439.601	1.883.924	26,9	400.427	27,8	21,3
Vilafranca del Penedès	1.304.541	2.143.375	30,5	414.196	31,8	19,3
Province of Barcelona	**16.216.389**	**28.553.214**	**27,1**	**4.927.947**	**30,4**	**17,3**

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852 in the Barcelona province (Library of the University of Barcelona, reference 146-1-II/13).

This clearly explains why the wealthy rural classes were so interested in including such a great amount of poor people in the list of taxpayers. They had already discovered, together with the provincial officials, that the Spanish Treasure could raise a lot by extracting a bit from many taxpayers who only had very little. Insofar as the tax shares of each province and municipality came as given by previous policy decisions taken top-to-bottom from the parliament and provincial governors, it was literally true that everything paid by the poorest contributors became tax cuts for the wealthy taxpayers.

In per capita terms, while the vast majority of poorer taxpayers were only attributed with cadastral earnings ranging from several tens to some hundreds of *reales*, and paid taxes for a few tens to less than a *real* per year, the small group of the richest taxpayers owned rural properties worth tens of thousands *reales*, and paid taxes for several thousand *reales* a year. It was as if they were in different orders of magnitude, and somehow they were. In an electoral system based on the census of taxes paid, this clear differentiation between levels of wealth and taxation meant that only major taxpayers were entitled to vote. We wonder, though, if the Spanish tax system described above might have something to do with the granting of voting rights to the entire adult male population as early as 1890; and also, consequently, with the immediate corruption of this general suffrage by the so called Spanish *caciquismo* (Moreno-Luzón 2007). The anomalous tax system based on the political up-to-bottom allocation of cadastral fees established, in effect, a perverse rule of the game encouraging the creation of vertical lobbies to get the minimum tax share to be paid to the Treasure, and receive the maximum public expenditure in each province and municipality (Curto-Grau, Herranz-Loncán and Solé-Ollé 2010). A comparative historical study of the relationship between the fiscal and electoral systems might shed new light on that matter.

In any case, the inclusion of so many people owning only a house, and perhaps a small orchard, together with landless tenants with very low yearly earnings, clearly biases our database on landownership and agrarian incomes derived from it. However, their presence also provides valuable information. Furthermore, it is not easy to establish a non-arbitrary threshold value to clearly separate the 'real' agricultural landowners to the ones who mainly earned most of their living working with their hands, in spite of having a house and a small plot of their own, or perhaps a sharecropping contract. We

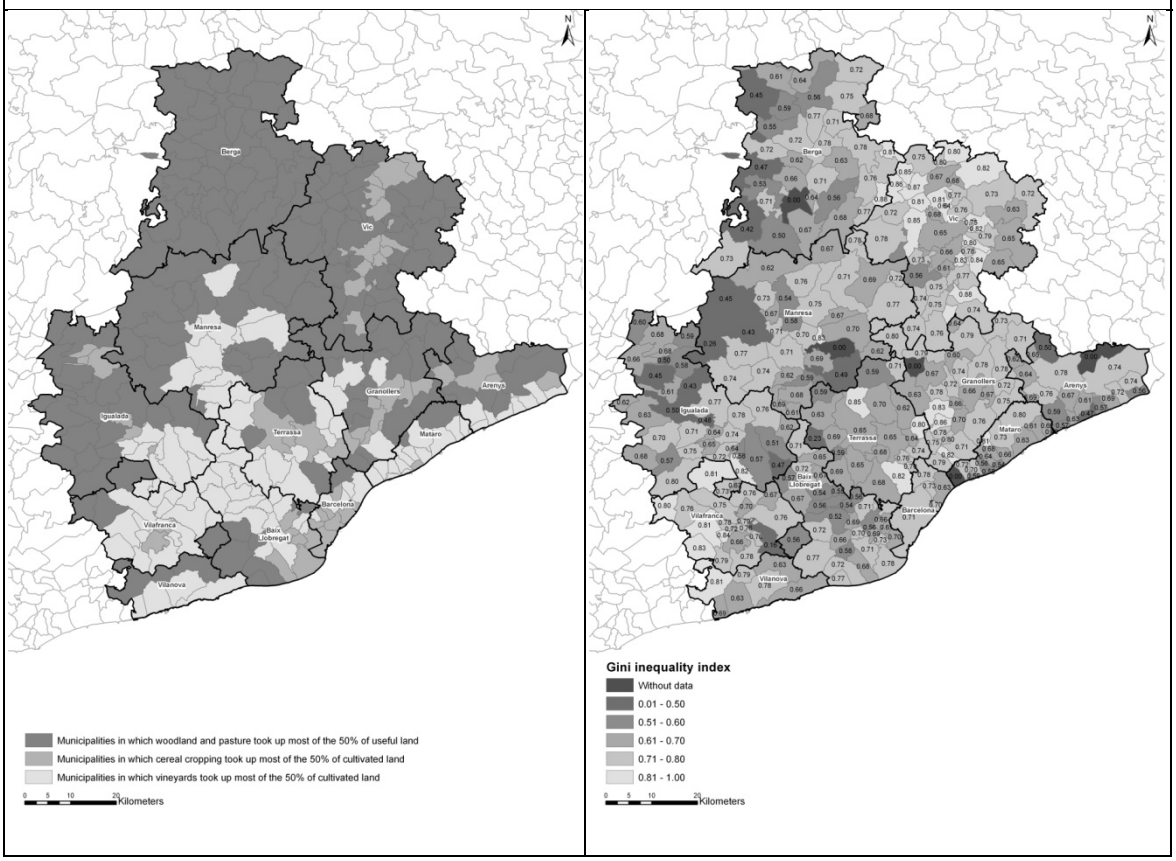
will later explain the solutions we have found to deal with this database in order to try to obtain significant results on wealth and income distribution.

Before resuming with our analysis, we must refer to other concerns raised by this historical source. What credibility can we give to the information it contains, given the tax purpose of the document? Our research team has worked for many years using the private accounting records of the patrimony of the Marquis of Sentmenat, one of the richest Catalan landowners at the time. From his private records, we know that during the five years from 1850 to 1854 the Marquis earned in the two municipalities of Sentmenat, and Palau-solità i Plegamans, an actual average income of 12,047 and 15,983 *reales* a year respectively (Garrabou et al. 2000). The *Distribution of Personal Wealth in Real Estate Ownership* of 1852 attributed to the Marquis of Sentmenat a yearly cadastral income of 11,607 and 15,323 *reales* in the same municipalities. Although it is only a single case, this comparison increases significantly our trust in the accuracy of the information provided by this source.

No apparent inequality pattern?

The first results we got with this dataset have been quite puzzling. The picture obtained from our main source showed a more complex outlook than expected, and no simple correlation between inequality indices and many other variables tested in the same municipalities appeared to be significant. Often, the differences between neighbouring municipalities located in the same zone of land-use specialization were as pronounced as the ones observed among the major boundaries between land-use areas of winegrowing, cereal cropping, and woodland. Comparing the maps in Fig 2, no apparent pattern seems to arise in the spatial distribution of main land-uses and prevailing inequality of agrarian incomes earned from real estate ownership.

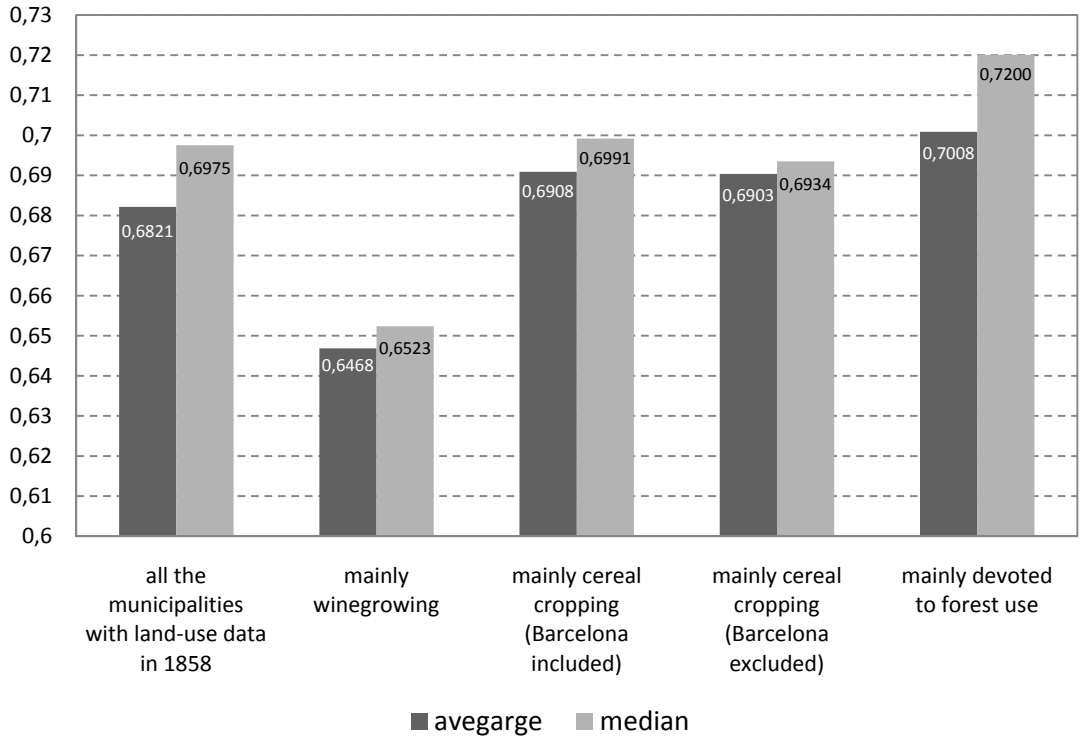
Fig 2. *Comparison between the main land-uses and the Gini indices of inequality in the municipalities and districts of the province of Barcelona in 1852-1858*



Source: our own, from the *Land-Use Statistics of the Province of Barcelona* compiled in 1858 by the topographer Pedro Moreno Ramírez, and from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852.

However, if we split off the dataset according to the main land-use in each municipality, we can see in Fig 3 that the mean and median Gini indices of inequality were actually lower in the winegrowing ones than in cereal cropping zones, while the highest values were recorded in mainly forest areas:

Fig 3. *Gini indices in the distribution of incomes earned from rural properties, according to the prevailing land-use in the municipalities of the Barcelona province in 1852-1858*



Source: our own, from the same historical sources referred in Fig 2.

Nevertheless, the differences between averages appear to be less marked than expected while the value distances among mean and median warns us about the likely existence of non-normal distributions in the dataset. This outcome leads us to ask about the underlying reasons for this lack of an apparent pattern of inequalities in the incomes earned from rural properties in the province of Barcelona in mid-19th century, and the best statistical way to deal with them. Taking into account the characteristics of the available information, and the abovementioned biases present in the dataset, we can outline a list of five likely factors that may have obscured these first results:

1. There were no large areas of monoculture in the province of Barcelona; all municipalities combined different proportions of any sort of land usages. The very different size of the municipalities, and the absence of large flat areas, involved the existence of many contrasting realities in the land-uses prevailing within each municipality. In particular, the larger municipalities always combined cereal crops in the flattest lands with forest uses in the more slopping ones, and vineyards planted in intermediate slopes. Thus, we have never a 'pure' winegrowing municipality clearly detached from other totally devoted to cereal or forest uses.

2. As explained above, the database includes only taxpayers who had some real estate of their own. That means excluding some people deprived of property which, nevertheless, earned most or all of their income by working in agriculture. At the same time, however, the database includes a large proportion of taxpayers only owing a poor house and a small vegetable garden, or having a sharecropping contract. Whether they owned a house or hired one in the market, the differences between them could be minimal. If there existed a significant number of adults deprived of property, and they were unevenly distributed between municipalities with different land usages, this may introduce another bias in our database.
3. The simultaneous presence of wealthy landowners along with a high proportion of residents who only held a poor house with garden, or could rely on a sharecropping contract, involves mixing very different realities in the same database. The resulting distribution seems to move in different orders of magnitude. As already explained, this is largely the outcome of ambiguous data which is halfway between a distribution of land ownership and a distribution of agrarian incomes. To make it more coherent and handier, either all types of income are included in the database or all attributed cadastral incomes should be converted into the original valuation of real estate property.
4. The municipalities were not only very different in size, but also in population and wealth. As population density increased, so did the number of residents who made their living with activities that had little or nothing to do with land and livestock ownership. In this point, the contrast between rural towns, villages and the city matters. Barcelona becomes a special case, and often we need to set it aside as an outlier.
5. The inequality degree in the distribution of agrarian income within each municipality also depended on its level of wealth. As mentioned earlier, poorer areas could have lower indexes because people had to achieve at least a subsistence minimum. However, the frontier of maximum inequality rose along with the wealth of a community. Consequently, the comparisons of inequality between municipalities should take into account their respective levels of wealth. For example, if inequality indices were lower in winegrowing municipalities than in the ones where cereal crops or forest uses predominated, and these areas specialized in vineyards were also wealthier, average values do not reflect the greater distance from the maximum possible inequality associated with this.

In order to solve these difficulties, and improve the quantitative analysis of our enquiry, we will undertake a deeper analysis of rural income inequality taking the following three decisions: a) we are going to add to the original database the adult male population without any land, house or cattle of their own, taken as a zero group

in the valuation of property in each municipality, by subtracting from the population census figures of 1857 the number of landowners included in the lists of taxpayers of 1852; b) we are going to add a minimum vital income of 1,500 *reales* a year to the earning valuation of property held by all inhabitants included in the new dataset, in order to overcome the valuation ambiguity of the data on personal wealth by turning it into a distribution of agrarian incomes; and c) we are going to set aside the Gini index and use Theil indices to carry out further analysis, as these makes it easier to calculate the frontier of maximum inequality linked to the wealth of each community, and compare it with the actual inequality registered.

A deeper analysis of rural income inequality

The following calculus of the Theil inequality indices have been obtained from the dataset of income cadastral values recorded for every taxpayer included in each municipality in the *Distribution of Personal Wealth in Real Estate Ownership* of 1852:

$$Theil_i = \frac{1}{N}\sum_j \frac{x_j}{\bar{x}} \ln(\frac{x_j}{\bar{x}}) \quad (1)$$

$$Theil_{Max} = Ln(N) \quad (2)$$

$$Theil_{Normalized} = \frac{Theil_i}{Theil_{Max}} \quad (3)$$

where N is the number of observations, *i* is the municipality, $x_{i,j}$ each one of the individual observations of the annual incomes for every municipality *i* and $\bar{x}$ is the mean value of the distribution. The Theil index shows more equality as values tend to zero and more inequality as values tend to one. In a first approach, we have considered N as the number of all taxpayers in each municipality. This distribution shows the main statistics calculated in Table 3:

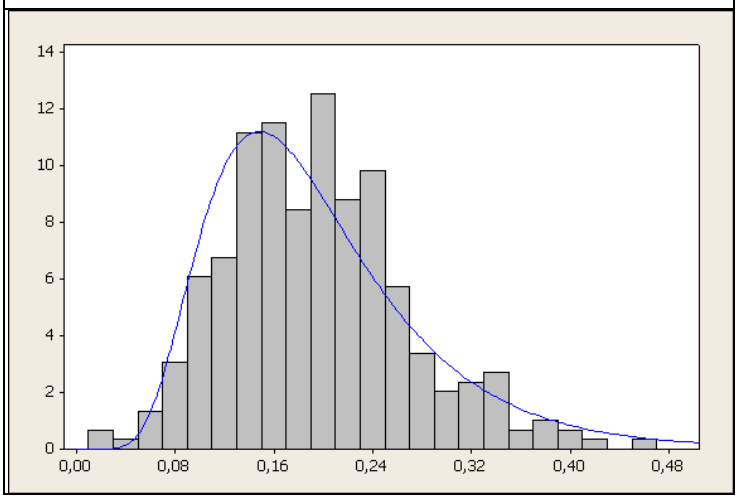
Table 3. *Main statistics of the database on 1852 taxpayers in all the municipalities of the Barcelona province*

Number	295
Mean	0,195
Standard deviation	0,074
Median	0,192

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852

To grasp the outline of this dataset, and obtain a more complete picture of the distribution of wealth in the municipalities of the province of Barcelona, we have constructed the histogram which appears in Fig 4. Instead of a normal distribution around the mean, it shows higher concentrations of municipalities near two intervals which are relatively far from the average. The first peak assembles a group of municipalities with lower levels of inequality, around 0.15, while the second one displays another group with higher levels of inequality around 0.20—the mean of the sample is at 0.19:

Fig 4. *Theil Index histogram for all the taxpayers in all the municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

The high dispersion of these Theil indices, added to the two peak concentrations around inequality values far from the mean, leads us to seek a few complementary explanations. As we have already discussed, our dataset is highly heterogeneous. We find a maximum population of 235,643 inhabitants in the city of Barcelona, together with many municipalities having a minimum below 300 inhabitants. At the same time the mean and median values of either the inhabitants or taxpayers differ significantly, thus indicating the need for a deeper statistical analysis.

Table 4. Comparison between the *main statistics of the database on the number of taxpayers in 1852 and of inhabitants **in** 1857 in all the municipalities of the Barcelona province*		
	Taxpayers in 1852	Inhabitants in 1857
Maximum	9,616	235,643
Minimum	17	211
Mean	297	2,396
Median	205	979
Standard deviation	9,616	235,643

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852 and population census of 1857.

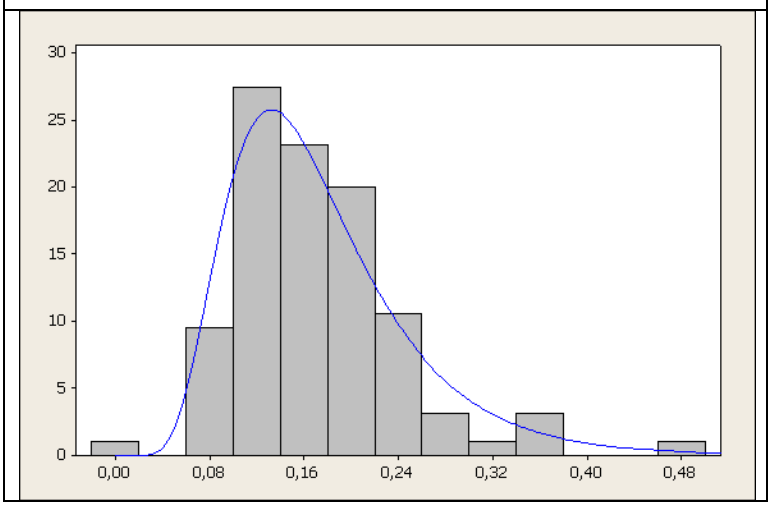
Therefore, in order to correct the potential bias attributable to the wide range of variation in the number of taxpayers and inhabitants in different municipalities, the inequality indexes have been recalculated using the Theil index of order 1. These values are homogenous among the observations of the sample, regardless of its size. Then, in order to check the relationship between this inequality index and the main factor used to explain it, we have repeated the analysis of the basic statistics splitting the municipalities according to the prevailing land-use (table 5).

Table 5. *Main statistics of the database on the number of taxpayers in 1852 according to the prevailing land-use in each municipality **of the Barcelona province***				
	All municipalities	Mainly winegrowing	Mainly cereal cropping	Mainly forest
Number	295	95	39	161
Mean	0,195	0,172	0,188	0,210
Median	0,192	0,161	0,182	0,207
Standard deviation	0,074	0,070	0,063	0,076

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852.

Observing the histogram of these Theil indices in winegrowing municipalities we confirm that an important number of municipalities had significant lower levels of inequality, and the lowest median (figure 5):

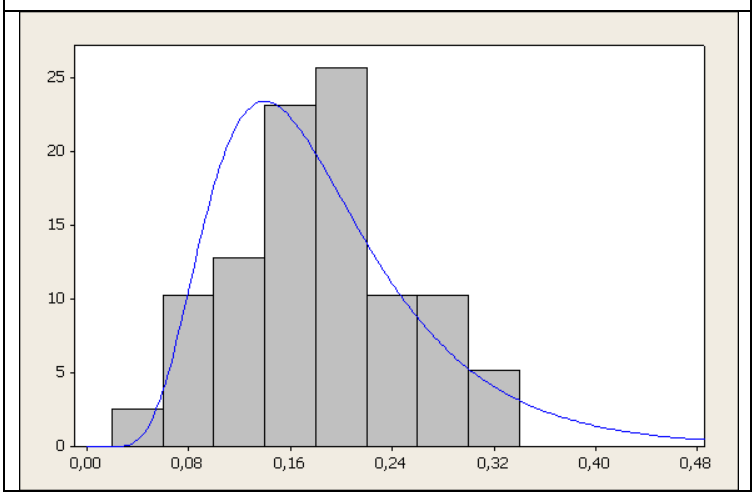
Fig 5. *Theil index histogram for all the taxpayers only in winegrowing municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

Figure 6 shows for cereal cropping municipalities a similar histogram to the one observed in vineyard zones: the existence of a big number of observations below the mean, although with a smaller dispersion than the existing one in the dataset of winegrowing municipalities (the difference between the mean and the median is smaller).

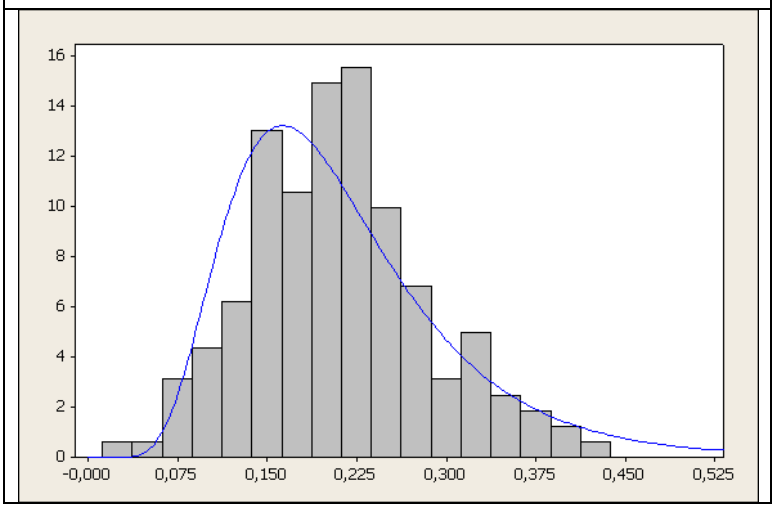
Fig 6. *Theil index histogram for all the taxpayers only in cereal cropping municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

Lastly, the histogram of mainly forest and pasture municipalities shows in Fig 7 a strong concentration around a Theil index of 0.20, a greater inequality than the observed in the other samples. This result helps us to understand the anomalous distribution in the whole dataset of inequality Theil indices, where two separated peaks of high concentration of municipalities appear. While the range of greater equality reflects the peak found in wine-growing and cereal-cropping municipalities, the other interval with higher inequality corresponds to the peak found in municipalities mainly devoted to forest and pasture.

Fig 7. *Theil index histogram for all the taxpayers only in forest and pasture municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

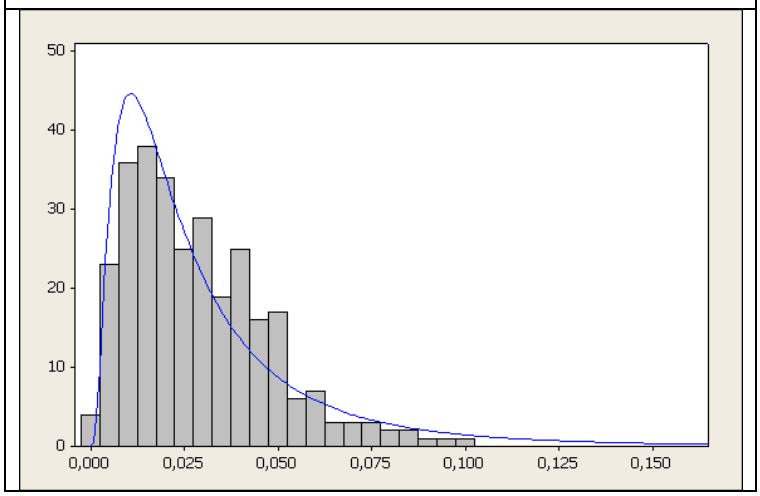
Estimating inequality in agrarian incomes of the entire population

Now we will try to deal with the double bias encountered, due to the fact that the original dataset includes taxpayers only, not the entire rural population who earned incomes from agrarian activities; and also that many of these taxpayers appear in it with implausible incomes below the minimum subsistence level. The first bias reduces and the second one increases the actual inequality level, but without knowing their relative weight we can not guess how they have skewed our database. To correct the first bias, we have subtracted from the population figures in the census of 1857 the number of real estate owners included in the lists of taxpayers of 1852, in order to

then add to the original database the adult male population without any land, house or cattle of their own, taken as a zero group in the valuation of property in each municipality. Afterwards, so as to turn the ambiguous dataset on personal wealth into a clearer distribution of agrarian incomes, we have added a minimum vital income of 1,500 *reales* a year to the earning valuation of property held by all inhabitants included in the new dataset. As already explained, this vital income is obtained considering the unskilled daily wage of a Catalan labourer at the time multiplied by 260 working days a year.

Unfortunately these two changes will entail some disadvantages as well. The major drawback is that all inequality levels resulting from the new dataset are, as we can expect, lowers than the original ones. If we obtain the histogram for the whole distribution of the new dataset, we can observe in Fig 8 a strong shift towards more equal values, with a huge grouping of observations around 0.01 while the mean is 0.03.

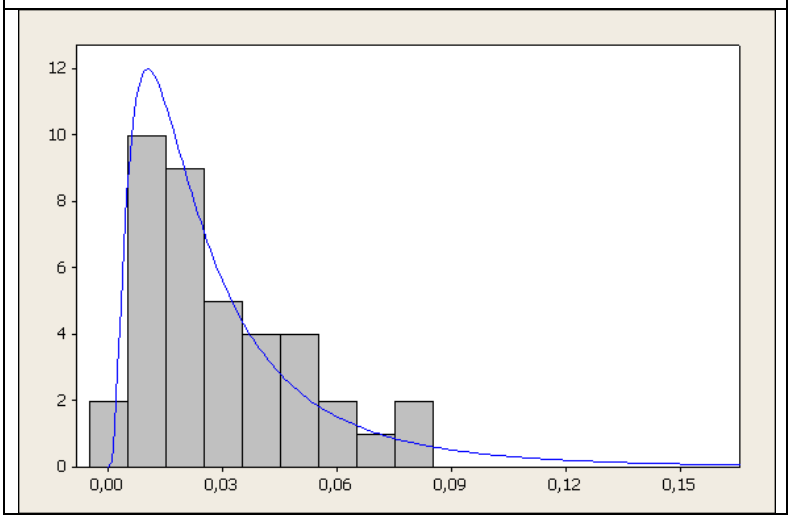
Fig 8. *Theil Index histogram for all adult male population in all the municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

Nevertheless, comparing Fig 8 with Fig 4 obtained for taxpayers only the double peak of municipalities around two different levels of inequality has disappeared. This interesting result also appears in the separated histograms for municipalities with different land usages. Fig 9 shows a distribution of cereal-cropping municipalities similar to that observed for the whole dataset in Fig 8, with again similar mean and median values.

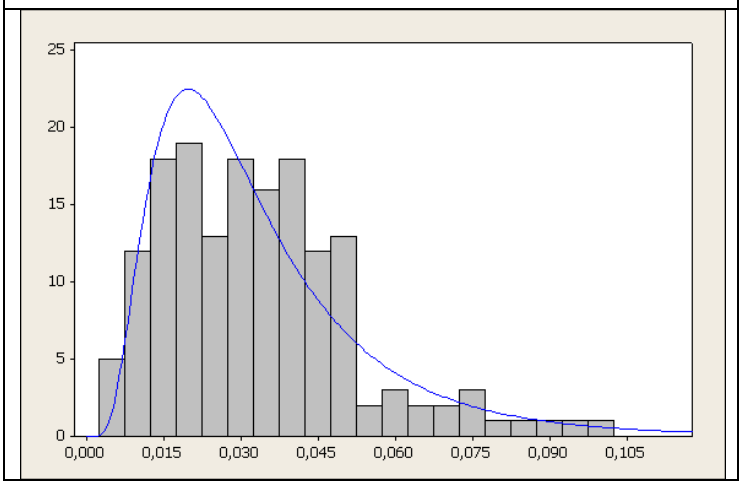
Fig 9. *Theil Index histogram for all adult male population only in cereal cropping municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

In forest and pasture municipalities the density distribution approaches to a normal. The main impact of the new dataset in shaping the whole distribution is a widening of the range around the mean. Now the mean and the median are also much closer than in the original distribution (Fig 10):

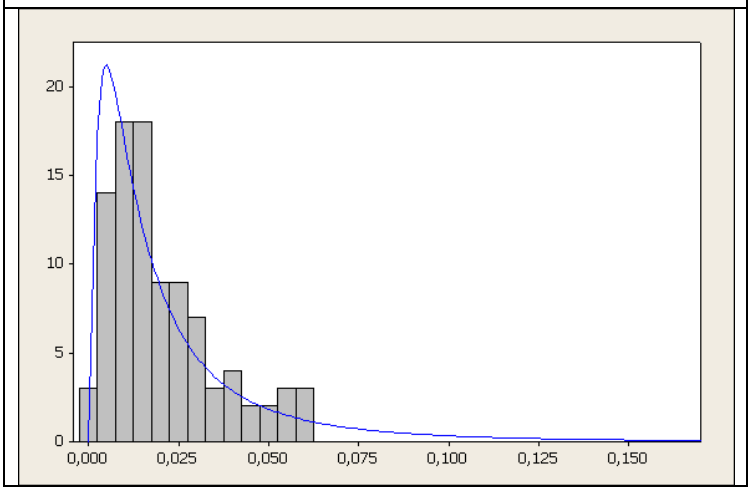
Fig 10. *Theil Index histogram for all adult male population only in forest municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

Finally, Fig 11 shows that in winegrowing municipalities the new distribution adopts a similar behaviour as in cereal-cropping ones, i.e. a high concentration of observations around values of greater equality together with some dispersion towards greater inequality.

Fig 11. *Theil Index histogram for all adult male population only in winegrowing municipalities of the Barcelona province*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

Taking this strong shift towards a more even distribution into account, from now on we can only consider the differences between the new Theil indices obtained in each municipality and not their absolute values significant. The key question is how different are the new distributions from the previous ones obtained with only taxpayers. Is the equality increase of all municipalities in the dataset comparable to that of each different land-use category? Are the relative distances in inequality levels between winegrowing, cereal-cropping and forest municipalities maintained, increased or reduced?

Table 6. *Average Theil index in the original dataset compared with the ones calculated for estimated agrarian incomes of all male adult population, according to the prevailing land-use in each municipality of the Barcelona province*				
	All municipalities	Mainly winegrowing	Mainly cereal cropping	Mainly forest
Number	295	95	39	161
Theil index of only taxpayers	0,195	0,172	0,188	0,210
Theil index of all adult male population	0,029	0,020	0,030	0,033
% variation for taxpayer's average	100,0	88,2	96,4	107,7
% variation for the average of all population	100,0	69,0	103,4	113,8

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852.

The results obtained with the new dataset do show in Table 6 an apparent change in the relative position of municipal inequality levels according to the main land-use. Contrary to the original dataset, the new mean Theil index becomes higher in cereal-cropping municipalities than the average of the whole distribution. At the same time, in winegrowing municipalities the new Theil index becomes more equal than the mean in cereal-cropping and forest municipalities, as well as more even than in the previous distribution for this land-use category with taxpayers only.

Taking population size into account

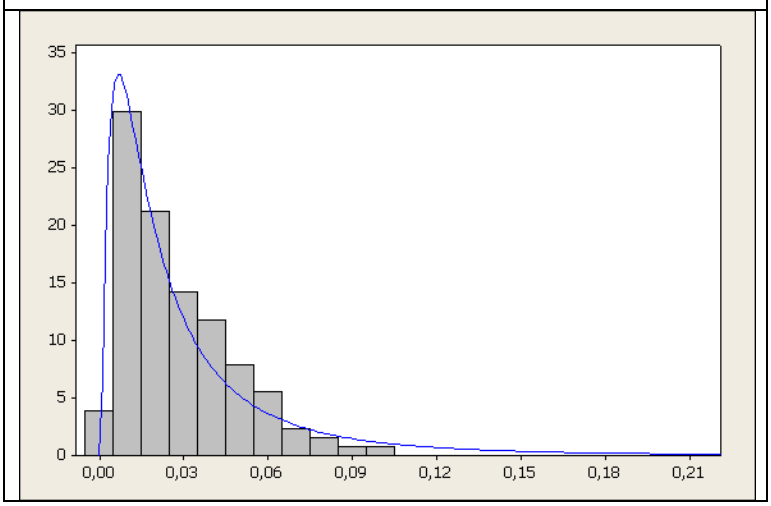
Another possible factor that could bias the inequality values obtained with our dataset is the distortion due to very different population densities. Following Boserup (1981) we have established at 65 inhab./km^2 an upper threshold of population density able to be sustained with a highly intensive agrarian economy, and considered that any population density greater than 70 inhab./km^2 had to rely on other industrious or industrial economic activities at the time. To conduct an initial sensitivity analysis we have assembled in a new sample the Theil indices of municipalities that had population densities above 70 inhab./km^2 in 1857, or were the capital of a district. The data has been obtained from the population density of each municipality weighed against the population density of the neighboring municipalities, in order to correct for possible bias due to the existence of administrative units with different size (Table 7):

Table 7. *Average Theil index of municipalities with population densities >70 inhab./km^2 weighted against neighbouring ones, or being capital of a district in the Barcelona province*		
	Capital of a district	>70 inhab./km^2
Number	11	127
Theil index of only taxpayers	0,124	0,185
Theil index of all adult male population	0,015	0,028
% variation for taxpayer's average	63,6	94,9
% variation for the average of all population	51,7	96,6

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852.

Looking at the right column in Table 7, and comparing with Table 6, we find out that the inequality indices of municipalities with population densities greater than 70 inhab./km^2 were rather similar than the ones obtained for the whole dataset. The histogram for these municipalities shown in Fig 12 resembles the distribution found in winegrowing municipalities, with a high concentration of observations around low levels of inequality, slightly above the values obtained from the sample mean, and showing a marked difference between the mean and median values:

Fig 12. *Theil Index histogram for all adult male population only in municipalities of the Barcelona province with population densities >70 inhab./km^2*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852. The corresponding lognormal distribution has been fit in blue.

In contrast, comparing with Table 6 the left column in Table 7 we can find inequality values in municipalities that were capitals of a district lower than the provincial average. This result is significantly enhanced when all adult male population is

included. Owing to the fact that this group has only 11 observations, we will analyze each of them in detail (Table 8).

Table 8. *Theil inequality indices of taxpayers or all adult male population in municipalities being capital of a district in the Barcelona province*

Capitals of districts	Taxpayers	All adult male population
Barcelona	0,089	0,010
Arenys	0,090	0,031
Berga	0,120	0,012
Granollers	0,176	0,028
Igualada	0,062	0,007
Manresa	0,146	0,016
Mataró	0,111	0,016
Sant Feliu de Llobregat	0,117	0,002
Terrassa	0,136	0,013
Vic	0,160	0,013
Vilafranca del Penedès	0,126	0,012
Mean of the Barcelona province	0,124	0,015
Median of the Barcelona province	0,123	0,013

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852.

The reasons that made the city of Barcelona and its surroundings a very special case are quite clear in Table 8. Only five municipalities had in 1852 a number of taxpayers greater than a thousand: Manresa (1,686), Terrassa (1,671), Mataró (1,319), Vic (1,284) and Vilanova i la Geltrú (1,071). In the area where the city of Barcelona now stands there were instead 9,353 property owners included in the tax list. In this latter case they were mostly house owners or possessors of built-up land, not agricultural or forest landowners. Moreover, as it was the only city bringing together a population of 235,643 inhabitants in 1857 (while Mataró was only 16,595, Manresa 15,264, Sabadell 13,945, Vic 13,712, Vilanova i la Geltrú 11,395 and Terrassa 8,721), the proportion of taxpayers among residents of Barcelona was one of the lowest in the province: one in 25, while in the other six cases it ranged from 5 to 16.

The overall results shown in Table 8 also highlight the lower inequality degree of income distribution existing in larger towns and cities, compared with average values in the rest of rural municipalities. Among these urban areas the lowest inequality appeared in Barcelona, Arenys de Mar and Igualada district capitals. This result contrasts with the comparatively higher inequality found in urban municipalities that could be considered more industrial at the time.

Establishing the inequality possible frontier (IPF) and extraction ratio (IER)

After having incorporated the previous corrections and caveats in the calculation of Theil indices, we have to now face the most difficult task: how to overcome the lack of a visible clear pattern when comparing the land-use maps of the mid-19th century with the distribution of rural income inequality in the province of Barcelona, as shown in Fig 2. The main idea we get from this spatial comparison is that there was a greater historical contingency in the geographical patterns of agrarian wealth inequality than in the geographical distribution of prevailing land usage. This might be due to diverging local paths: while the landowners of a municipality may have decided to use their forest and pasture lands in the traditional manner, to raise livestock and sell timber, firewood or charcoal, others may have chosen to welcome a great number of *rabassa* tenants who transformed the same sorts of marginal lands into vineyards. These different occasional decisions could have reinforced themselves over time in neighbouring areas, leading to path dependent processes juxtaposed to contrasting spatial realities within the same territory.

For us historians, the question that arises is whether or not we can find any omitted variables which capture and explain this intriguing contingency. The type of feudal jurisdiction –whether manorial or royal– the degree of inequality, and population densities at the beginning of this process are considered to be good candidates. However, an important aspect to consider is that once the landowners of a place had decided to offer an opportunity to establish immigrants, or disinherited people, as winegrowing tenants on their marginal lands, this entailed consequences with regards to population sizes and levels of wealth within each community. If there was a relationship between the level of wealth and inequality in a rural community, it would provide an interesting entryway to capture the disturbing degree of local contingency found. This is why we decided to start working with the idea of an inequality possible frontier (IPF as follows) which depends upon the level of agrarian wealth, as put forward by Milanovic et al. (2007). When the wealth of a community increases, so does the IPF, because it could generate a greater distance between the vast majorities kept at subsistence level, and the tiny elite where the rest of income could concentrate.

Therefore, we are going to use the IPF in order to calculate new inequality indices of personal agrarian incomes in the mid-19th century municipalities of the Barcelona province, adjusted to different levels of rural wealth. The first step is to work out the maximum values of income inequality in each municipality. Following Milanovic et al. (2007) the average income of the elite is:

$$Y_e = \frac{\mu \cdot N - s \cdot N \cdot (1-\varepsilon)}{\varepsilon \cdot N} = \frac{1}{\varepsilon}[\mu - s \cdot (1-\varepsilon)] \quad (4)$$

Where μ is the average income of the municipality, N is the total adult male population, s is the subsistence income and ε is the percentage of population that represents the elite also in this municipality.

To obtain the Theil index for the IPF ($Theil_{IPF}$) of each municipality, we use equation (1). Then, the local population is divided into two groups; the first has the subsistence income, the second obtains the surplus of the municipality, as shown in equation (5).

$$Theil_{IPF} = \frac{1}{N}\left[(N - \varepsilon \cdot N) \cdot \frac{s}{\mu} \ln\left(\frac{s}{\mu}\right)\right] + \frac{1}{N}\left[\varepsilon \cdot N \cdot \frac{Y_e}{\mu} \ln\left(\frac{Y_e}{\mu}\right)\right] \quad (5)$$

If we take μ=α·s, that is, we consider that the average income of the municipality is a multiple α of the subsistence income, then s= μ/α :

$$Theil_{IPF} = \frac{1}{N}\left[(N - \varepsilon \cdot N) \cdot \frac{\mu}{\alpha \cdot \mu} \ln\left(\frac{\mu}{\alpha \cdot \mu}\right) + \varepsilon \cdot N \cdot \frac{Y_e}{\mu} \ln\left(\frac{Y_e}{\mu}\right)\right] = \frac{1}{N}\left[\frac{N \cdot (1-\varepsilon)}{\alpha} \cdot \ln\left(\frac{1}{\alpha}\right) + \varepsilon \cdot N \cdot \frac{Y_e}{\mu} \ln\left(\frac{Y_e}{\mu}\right)\right] \quad (6)$$

If we modify equation (4) assuming s= μ/α, then we have:

$$Y_e = \frac{1}{\varepsilon}\left[\mu - \frac{\mu}{\alpha} \cdot (1 - \varepsilon)\right] = \frac{\mu}{\varepsilon}\left[1 - \frac{(1-\varepsilon)}{\alpha}\right] \quad (7)$$

And if we include this expression in equation (6), we have:

$$Theil_{IPF} = \frac{1}{N}\left[\frac{N \cdot (1-\varepsilon)}{\alpha} \cdot \ln\left(\frac{1}{\alpha}\right) + \varepsilon \cdot N \cdot \frac{\frac{\mu}{\varepsilon}\left[1 - \frac{(1-\varepsilon)}{\alpha}\right]}{\mu} \ln\left(\frac{\frac{\mu}{\varepsilon}\left[1 - \frac{(1-\varepsilon)}{\alpha}\right]}{\mu}\right)\right] = \frac{(1-\varepsilon)}{\alpha} \cdot \ln\left(\frac{1}{\alpha}\right) + \left[1 - \frac{(1-\varepsilon)}{\alpha}\right] \cdot \ln\left(\frac{1}{\varepsilon} \cdot \left[1 - \frac{(1-\varepsilon)}{\alpha}\right]\right) \quad (8)$$

Lastly, to make this index comparable with the rest of the values obtained for the entire dataset we have normalized equation (8), depending on N. That is why we calculate the IPF for this indicator, assuming that N-1 members of the municipality receive the subsistence income, while one member receives the rest. In this case we consider that ε·N=1, that is, $\varepsilon = {}^{1}/_{N}$ and then:

$$Theil_{IPF-MAX} = \frac{(1-{}^{1}/_{N})}{\alpha} \cdot \ln\left(\frac{1}{\alpha}\right) + \left[1 - \frac{(1-{}^{1}/_{N})}{\alpha}\right] \cdot \ln\left(\frac{1}{{}^{1}/_{N}} \cdot \left[1 - \frac{(1-{}^{1}/_{N})}{\alpha}\right]\right) = \frac{(N-1)}{N \cdot \alpha} \cdot \ln\left(\frac{1}{\alpha}\right) + \left[1 - \frac{(N-1)}{N \cdot \alpha}\right] \cdot \ln\left(N \cdot \left[1 - \frac{(N-1)}{N \cdot \alpha}\right]\right) \quad (9)$$

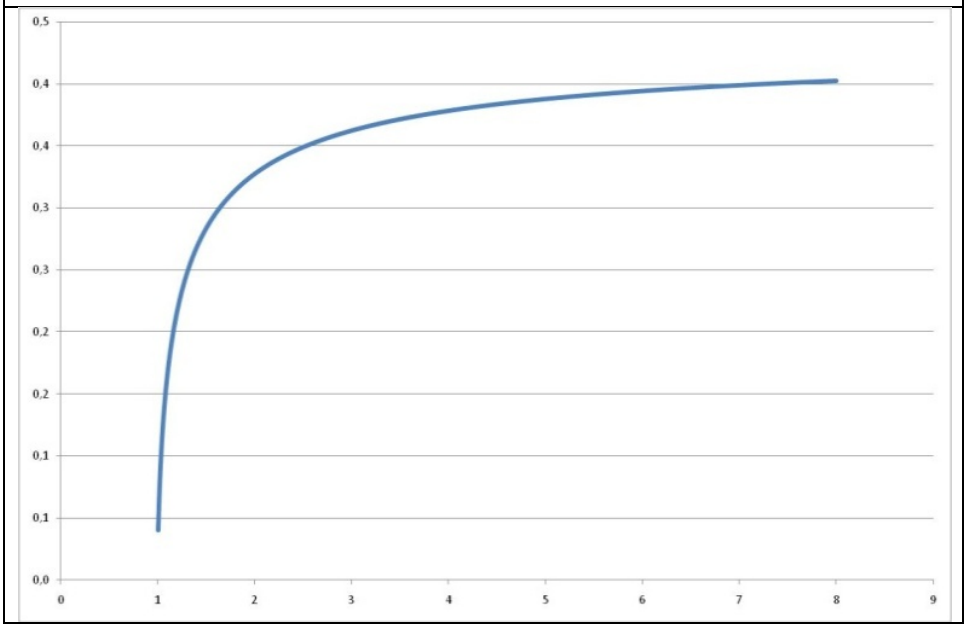
Therefore, the normalized $Theil_{IPF}$ index corresponds to:

$$Theil'_{IPF} = \frac{Theil_{IPF}}{Theil_{IPF-MAX}} \quad (10)$$

In Fig 13 we can observe the behaviour of the $Theil'_{IPF}$ depending on α, which is expressed as the number of times the average taxpayers' income exceeds the average

subsistence value of the total adult male population for a fixed number N in each municipality (thus assuming that all municipalities have the same dimension).

Fig 13. *An example of inequality possible frontier (IPF) expressed as the Theil'$_{IPF}$ indices resulting from α (the average income of the municipality as a multiple of the subsistence income)*



Source: our own, with equation (9) considering ε=0.05 and N=1000.

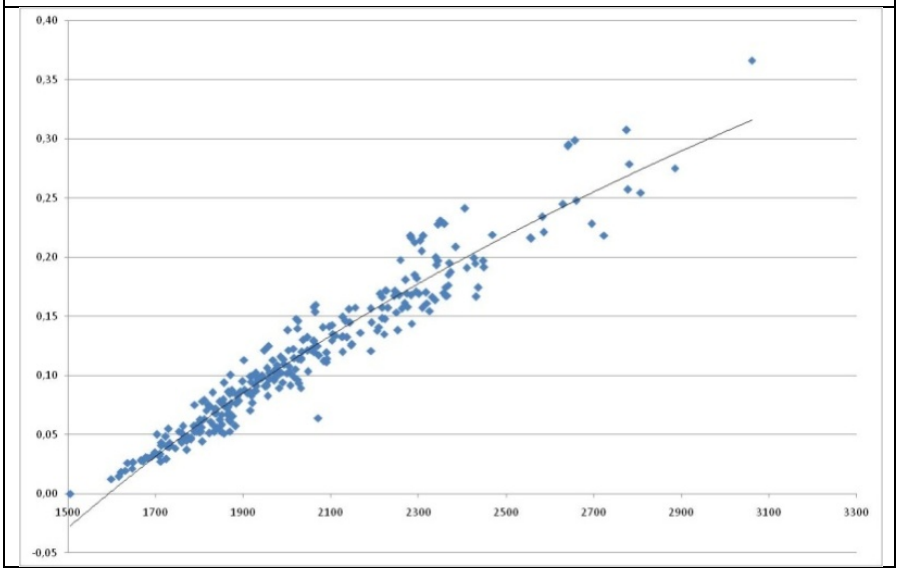
Using the calculus of the Theil'$_{IPF}$ we can obtain the inequality extraction ration (IER as follows) for each municipality, considering:

$$IER = \frac{Theil}{Theil'_{IPF}} \tag{11}$$

IER indicates the percentage of the actual inequality that existed in each municipality with respect to the IPF, which is the maximum potential of inequality possible with a defined value for ε and α. To do this, we calculated $Theil'_{IPF}$ from (9), assuming ε = 0.01 (the elite is 1% of the total population), N is the value of the adult male population of the municipality, and approaching α to the number of times that the average income exceeds the mean income of the municipality. In this case, when ER → 0 the value indicates that the actual level of inequality registered in the municipality was well below the potential maximum value, that is, it tended towards potential high levels of equality. In the other extreme, when ER → 100% the level of inequality obtained is close to the level of the maximum potential inequality. From (8) and (9) we can affirm that the maximum value of inequality may depend on, besides the values of α and ε, the size of the municipality considered. This bias is corrected when we consider IER.

The distortion created in the calculation of the maximum $Theil_{IPF}$ index by the impact of the different population sizes of municipalities can be seen by comparing Fig 13 and 14. Despite a clear upward trend, that is, a potential increase in inequality as the average income level grows, we observe in Fig 14 some deviations, depending on the population size of the municipality.

Fig 14. *Theil'$_{IPF}$ indices resulting from average income of the municipality in Spanish* reales *a year for the whole dataset*



Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852.

The last result confirms that the calculation of the IER may be a good approximation of inequality values related to the maximum IPF of each municipality, which also helps us to correct potential errors resulting from the varying population sizes in the database (see Table 9).

Table 9. *Extraction ratio (IER) as % of actual Theil index compared with the maximum IPF in agrarian income distribution, according to prevailing land uses, population densities and other features in the municipalities of the Barcelona province in 1852-1858*

	extraction ratio (IER)	number of municipalities
In all municipalities of the dataset	24.9%	295
Mainly winegrowing	22.0%	95
Mainly cereal cropping	25.2%	39
Mainly devoted to forest use	26.5%	161
With > 70 inhabitants per km^2	23.4%	127
District capitals only	25.0%	11

Source: our own, from the *Distribution of Personal Wealth in Real Estate Ownership* of 1852, the population census of 1857 and the *Land-Use Statistics of the Province of Barcelona* compiled in 1858 by the topographer Pedro Moreno Ramírez. To calculate the $Theil_{IPF}$ indices of each municipality, when the result was grater than 1 we considered that 1% of the population was the local elite. If not, we considered the elite made up of one person.

Table 9 confirms many of the previously reported results, with an additional perspective. Winegrowing municipalities were further away from potential levels of inequality, while municipalities with mainly cereal-cropping and forest land usage were closer to their maximum IPF: 3.2% and 4.5% points, respectively higher than in winegrowing areas. It is important to stress that this happens despite having previously included in our database a vital minimum income for all male adults, which inevitably entailed the compression of all Theil indices around very low absolute values of income inequality. Although the percentage differences discovered in IER values are of the same order of magnitude as those in the Gini indices obtained with the original property values shown in Fig 3, they become more relevant when the abovementioned bias is taken into account. The results are also especially significant for the capitals of a district: before taking IPF into account this group recorded lower inequality values than in winegrowing municipalities, but their IER appears to be higher, closer to the average. This evidence allows us to confirm that the study of income inequality using the IER approach has revealed some important, previously hidden, aspects of this topic.[1]

[1] For example, while the One way Anova test suggests different IER averages when we consider the land-use categories (at a 5% confidence level), the same test for mean IERs becomes statistically not significant when we consider other variables like different jurisdictional domains (manorial, royal or under the church) that prevailed in each municipality up to the abolition of feudalism in 1836.

Conclusions and future prospects

We conclude that, despite the high degree of contingency found in the spatial location of Gini indices (Fig 2), and the lack of any simple correlation between inequality indices and other variables tested, relevant patterns of inequality in personal agrarian wealth or income distribution, related to the prevailing land-use in the mid-19th century municipalities of the Barcelona province, have been discovered. These land-use inequality profiles have been confirmed and enhanced using Theil indices of estimated income distribution for the entire local adult population, and applying the inequality possible frontier (IPF) approach to compare the actual extraction ratio (IER) with the maximum attainable one.

The results confirm that landownership inequality was lower in winegrowing municipalities than in cereal cropping or forest ones, in spite of the fact that developing a commercial vineyard specialization, and attaining higher population densities, could also have meant an extended frontier of possible inequality through a greater potential extraction ratio by the agrarian elites. This outcome can be interpreted as a historical process of empowerment, achieved by the Catalan rural class of wine-growing tenants as a result of the ongoing social struggle fought from the 18th century onwards, as other diachronic and more descriptive case studies have already suggested. In this sense, the statistical cross-section analysis, conducted with a remarkably large database of more than 86,000 recorded taxpayers in 295 municipalities, has provided, for the first time, solid quantitative answers to a set of questions posed by Catalan rural historians over a long period.

Beyond the analysis of agrarian inequality conducted here from a land-use standpoint, this large database offers many possibilities to be exploited from other perspectives. In future research, we will use the different indices, obtained from this in-depth analysis on personal agrarian inequality, to extend a previously developed model that identifies the main driving forces that led to vineyard specialization in the Barcelona province (Tello et al. 2008, Garrabou et al. 2009 and in press). This will allow us to include wealth and income distribution as new variables in the model, together with population density, time-distances to the main seaports, main agronomical and environmental features of the territory --like average slopes, rainfall or temperature--, and the type of manorial or royal feudal jurisdiction, communal lands and common rights that existed prior to their abolition in 1836.

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