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ORIGINAL PAPER

The urban–rural height gap: evidence from late nineteenth-century Catalonia

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Abstract
This paper aims to establish whether there was a gap in biological living standards between urban and rural areas in late nineteenth-century Catalonia, and if so, to determine its extent. The study makes use of a large new dataset based on military records for the cohort of males born in the year 1890 and enlisted in the year 1911. By combining individual heights with information at municipal level, we conclude that the 1890 cohort of conscripts living in rural areas were shorter than those that resided in towns and cities with populations of more than 20,000 people. We also hypothesise about the reasons why urban dwellers in late nineteenth-century Catalonia were taller than their rural counterparts by considering the potential role of rural–urban migration, improvements in public sanitation and health care, and progresses in the quantity and quality of food availability for urban dwellers.

Keywords Biological living standards · Well-being · Urban penalty · Urban premium

JEL Classification N33 · N93 · I14 · I31

1 Introduction

The comparison of historical human heights between urban and rural populations has become a well-established area of research. Mean human height is a measure of biological living standards and is a good indicator of the nutritional status and

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the health of populations. A comparison between populations of different sizes and functions may therefore contribute to a better understanding of health inequality (Blum 2016, p. 180), a central topic in social sciences and policy-making.

The analysis of urban biological living standards in contrast to rural areas has attracted the attention of a large number of scholars. This is particularly true in north-western Europe; there, a large body of historical research shows that in the first stages of modern economic growth between the late-eighteenth and the mid-nineteenth centuries the combination of industrialisation and rapid population growth resulted in an urban height penalty (e.g. Komlos 1985; Sandberg and Steckel 1988; Mokyr and Ó Gráda 1989; Floud et al. 1990; Mokyr and Ó Gráda 1994; Riggs 1994; Mokyr and Ó Gráda 1996; Ó Gráda 1996; Drukker and Tassenaar 1997; Komlos 1998; Baten and Murray 2000; A'Hearn 2003; Haines 2004; Heyberger 2007; Cinnirella 2008; de Beer 2010; Heyberger 2014; Kok et al. 2018; Tassenaar 2019; Groote and Tassenaar 2020; and for summaries Steckel and Floud 1997a; Komlos and Baten 2004; Floud et al. 2011; Blum 2016; Meinzer and Baten 2016; Meinzer et al. 2018).[1]

Various reasons contribute to explaining why the heights of urban dwellers decreased relative to rural heights. Workload, nutrition and diseases influence height; and in urban areas these factors evolved in a way that negatively affected the physical stature of the population. In Britain, for example, several cities grew up in parallel to the spread of factory-based industrialisation, and this process transformed both working and living conditions. Apart from the more regular, monotonous and disciplined working patterns of the mechanised factories, leisure time declined as working hours increased by around 20–35 percent in the century after 1750 (Thompson 1967; Clark 1994; Voth 1998, 2001, 2003). Child labour was also used intensively during the Industrial Revolution (e.g. Humphries 2010, 2013). While working conditions probably became harder between the mid-eighteenth and the mid-nineteenth centuries, this was compensated, to some extent at least, by gains in other indicators of living standards such as real wages over the first half of the nineteenth century (e.g. Feinstein 1998; Clark 2005; Allen 2009; Gallardo-Albarrán and de Jong 2021). On the other hand, according to some estimates, food consumption (measured by trends in daily calories per person) declined or, at best, remained stagnant between 1750 and 1850 (e.g. Meredith and Oxley 2014a, b; Broadberry et al. 2015; Harris et al. 2015; Harris 2016). In addition, diets were in general less diverse and poorer in industrial than in rural areas (e.g. Meinzer and Baten 2016), and food supply tended to be more dependent on the market, making urban dwellers more vulnerable to periodical food shortages due to transport limitations and crop fluctuations (Komlos 1998). Moreover, urban factory workers were probably less exposed to sunlight and the production of vitamin D than rural labourers, a circumstance that

[1] Nevertheless, for the particular case of Alsace, Heyberger (2007, p. 237) found similar heights in urban and rural areas until about the 1840s, "when the two diverged until the end of the century, as is expected for the height of urban inhabitants". This author argued that "it is unusual that the rural–urban divergence in height happened relatively late in Alsace (1840s) and even at its peak in the 1850s birth cohorts it was only about 1 cm-lower than in many other parts of the world". On the other hand, Kok et al. (2018) stress the importance of the compositional effect in explaining urban–rural differences, e.g. poorer families are more likely to be found in cities.

may also have influenced height trends across these two subgroups (Carson 2009). Finally, the new industrial cities of Britain and elsewhere tended to be overcrowded and had poor housing and sanitary conditions (Floud et al. 2011, p. 171). Clean water was often in short supply and the sewerage systems were substandard (Hassan 1985). All this created an unhealthy environment that promoted the transmission of infectious and contagious diseases.[2]

The emergence of an urban height penalty is, in fact, associated with a more general issue: the "early industrial growth paradox or puzzle", namely a fall in physical stature in a period when economy was growing. A similar pattern was found in the USA, termed the "Antebellum Puzzle" (Komlos 1998). Recently, the existence of an industrialisation puzzle has been questioned (Bodenhorn et al. 2017); the most recent papers support the presence of shrinking heights in a growing economy (Heyberger 2007; Komlos 2019; Zimran 2019; Komlos and A'Hearn 2019), but the debate is still open.

The urban height penalty did not last forever. The gap between rural and urban heights declined over time and finally the urban penalty reversed into an urban premium. The construction of the railways, and domestic and international market integration, increased the supply of food products in urban areas, making the earlier nutritional advantages of rural settings less apparent (e.g. Blum 2016). Public investment in clean water supply and sanitation such as sewerage systems improved health conditions in the urban areas (e.g. Hassan 1985; Szreter 1988; Bell and Millward 1998; and also the more recent studies quoted in Sect. 4), and medical services tended to expand more rapidly in cities and large towns than in rural areas (e.g. Lucey and Crossman 2014). As a result, from the final decades of the nineteenth century onwards the gap between urban and rural heights closed or simply vanished and, finally, urban populations became taller than their rural counterparts (e.g. Komlos and Baten 2004; Tassenaar 2019; Groote and Tassenaar 2020).

This general account of an urban height penalty reversing into an urban height premium was, nevertheless, far from universal. For eastern Belgium, Alter et al. (2004) found that urban-born men remained taller than their rural counterparts throughout the nineteenth century. Twarog (1997) reached similar conclusions by comparing rural areas and small towns in the southern German territory of Württemberg. Also in Germany, Baten (2009) concluded that in the first half of the nineteenth century "urban men were relatively tall in Bavaria", whereas "the areas near towns (…) [were] among the districts with lower average height", partially because the former drained food from the latter (Baten 2009, p. 175, see also Lantzsch and Schuster 2009, p. 50). For Switzerland, Schoch et al. (2012, p. 160) argued that "no urban height penalty existed in nineteenth century Switzerland" and that "the conscripts from rural areas of canton Bern never have been taller than the conscripts from the city of Bern" in the cohorts of 19-year-old conscripts measured in the late nineteenth and the first half of the twentieth centuries.

[2] This also might contribute to explaining why life expectancy at birth in cities above 100,000 inhabitants in England and Wales was lower and did not converge with the country's average in the first decades of the nineteenth century (Szreter and Mooney 1998). Nevertheless, R. J. Davenport has recently challenged Szreter and Mooney's account (Davenport 2020, see also Davenport et al. 2019). For a discussion, see, Szreter and Mooney (2021) and Davenport (2021).

In contrast, there is also evidence showing a permanent rural advantage relative to urban heights both in north-western Europe and in the USA. For example, Riggs and Cuff (2013) reported a height advantage of about 2 cm in the rural cohorts born in late nineteenth-century Scotland by comparing rural and urban members of the military forces serving in World War I. Zehetmayer (2013) concluded that the cohorts of US soldiers born in rural counties between 1847 and 1890 were taller than those born in the 10 largest cities in the USA or in the 90 next-largest cities (1.5 and 0.9 cm taller, respectively). A rural height premium was also found in nineteenth-century Pennsylvania (Carson 2008). Nevertheless, Zehetmayer also observed that urban height converged over time: in the mid-nineteenth century "the best urban place to live in terms of height were small cities, while in the end of the nineteenth century, it was in larger cities with about 250,000 inhabitants, but not in the largest cities" (Zehetmayer 2013, p. 175).

The urban–rural gap is also found in nineteenth- and early-twentieth-century southern Europe, and the Iberian Peninsula provides a good example of its complexity. With a lower per capita income and a shorter height than their north-western European counterparts (Hatton and Bray 2010), rural and urban dwellers in Iberia also presented height disparities. In Spain, aggregate country-level analyses show that young males living in provincial capitals and towns with more than 10,000 inhabitants were taller than their rural counterparts for the cohorts born in the last quarter of the nineteenth century and that this situation continued at least until the birth cohorts of the 1920s (Quiroga 2001).

At regional level, the absence of an urban penalty is also found in south-eastern Spain in males born between 1837 and 1900. Yet, rural heights experienced a strong process of convergence towards the urban ones from this latter birth cohort to that of 1915 (Martínez-Carrión and Moreno-Lázaro 2007, see also Martínez-Carrión and Pérez-Castejón 1998 for particular towns). Urban conscripts born in the central Spanish region of Castile-La Mancha were on average slightly taller than rural ones from the birth cohort of 1887 to 1933 and were able to widen their height advantage from then until the cohorts born in the early 1960s (Cañabate-Cabezuelos and Martínez-Carrión 2017). Similarly, the region of Extremadura and the Canary Islands presented a permanent rural height penalty from the mid-nineteenth century to the late twentieth century (Linares-Luján and Parejo-Moruno 2021; Martínez-Carrión et al. 2022).

Portugal provides another example of urban heights being higher than rural heights, this time throughout the nineteenth century. The biological standard of living in Lisbon—a large city by European standards—was not lower than in the rest of the (mostly rural) country: conscripts from Lisbon were, in fact, slightly taller than those from outside the capital (Reis 2009).

While the absence of an urban height penalty seems to have prevailed in Iberia, this cannot be said of the protoindustrial and industrial areas. In the central region of Castile and Leon, rural and urban heights were roughly the same between the 1830s and the 1860s, but from then until the 1910s urban heights increased and intermittently surpassed rural heights (Martínez-Carrión and Moreno-Lázaro 2007; see also Hernández and Moreno 2011 for more detailed analysis). More importantly, in the central decades of the nineteenth century, there were episodes of urban penalty in proto-industrial areas of Castile and Leon owing to the over-exploitation of the workforce and, in fact, between the birth cohorts of 1851–1855 and 1861–1865 urban conscripts became shorter than their rural counterparts (Moreno-Lázaro and Martínez-Carrión 2010). The same is found in the south-eastern industrial town of Alcoi, particularly for the cohorts born between the early 1860s and the late 1870s, and perhaps also in Antequera, a town in southern Spain, for the cohorts born in the third quarter of the nineteenth century (Puche and Cañabate-Cabezuelos 2016, for Alcoi; Martínez-Carrión and Cámara 2015, for Antequera; see also Martínez-Carrión et al. 2014; Gallardo-Albarrán and García-Gómez 2022). Height data for the Mediterranean region of Valencia also show that rural conscripts were between 0.5 and 1.0 cm taller than their urban counterparts. Although a process of convergence took place, in the first third of the twentieth century, inhabitants of rural irrigated areas remained taller than their peers in the cities (Ayuda and Puche-Gil 2014). A similar picture of urban–rural convergence but an enduring rural height premium also applies to the province of Biscay in the Basque Country, as far as the cohorts born between 1856 and 1915 are concerned (Pérez-Castroviejo and Martínez-Carrión 2018). Finally, in Catalonia, an urban height penalty was also found for the cohorts of males born during the first two-thirds of the nineteenth century, but not for subsequent cohorts up until World War I (Ramon-Muñoz 2009, 2011). This pattern seems to have been more apparent in the industrial areas and in other more densely populated towns (Ramon-Muñoz and Ramon-Muñoz 2015, 2016).

Owing to the diversity of the situations, categorical conclusions on the evolution of the urban–rural height gap are not easy to obtain. The presence (or absence) of an urban penalty, as well as its magnitude and its time course, is a contextual phenomenon that may differ both across countries and across regions. Moreover, it is a phenomenon that can be easily associated with the characteristics and intensity of industrialisation and its consequences on the biological standard of living of the population in the early stages of modern economic growth.

This paper contributes to the well-established literature on industrialisation, living standards and urban–rural inequality in physical stature. It explores the case of Catalonia, a prosperous industrial area in north-eastern Iberia with a per capita income in the second half of the nineteenth century that was converging with that of Western Europe (Carreras 2019). This is not the only factor that makes Catalonia an interesting case study. With around 30 per cent of its workforce employed in industry in 1900, Catalonia had also become a leading manufacturing centre as well as one of the regions with the highest per capita income in Southern Europe (Nadal 1975; Nicolau 1990; Díez-Minguela et al. 2018; Rosés and Wolf 2018).

In addition, the demographic pattern of this north-eastern Iberian region presents certain notable features of its own. For a territory on the European periphery, Catalonia was relatively modern; fertility rates were low (Nadal 1966; Cabré 1999), with 171.4 live births per 1000 married women aged 16–50 in 1900 (Livi-Bacci 1968), a rate substantially lower than those recorded in Spain, southern Europe as a whole, and several western European regions (Coale and Treadway 1986). Death rates did not compare so well with other territories. However, infant mortality rates were 138.8 per 1000 live births in 1901–1905 (Dopico 1985), among the lowest in Spain and below those observed in other Mediterranean areas (Raftakis 2021; Klüsener et al. 2014 for 1910 data). In Catalonia, fertility and death rates began to decline simultaneously in the first half of the nineteenth century (Nadal 1959;

Nadal and Sáez 1972; and above all, Ferrer Alòs 2021), mirroring the pattern of demographic transition that had previously characterised France (e.g. Perrin 2022).

Industrial growth and relatively high GDP per capita also led to respectable levels of urbanisation. By the late nineteenth century, the population living in localities with more than 5000 inhabitants was between 35 and 45 per cent, depending on the estimation method used (Gómez Mendoza and Luna Rodrigo 1986). These rates were above the Spanish mean, although some other less industrialised regions had higher urbanisation levels. They were also above the mean urbanisation rates prevailing in other countries bordering the Mediterranean basin (Bairoch and Goertz 1986) and the population density (61 inhabitants per square kilometre) was in line with those of some of the most densely territories populated in this area (Martí-Henneberg 2005).

In spite of its notable similarities with the rest of southern Europe, in terms of the timing of economic transformation Catalonia was certainly one of the pioneers in southern Europe. Whether and to what extent this also resulted in a specific urban–rural height gap pattern relative to other southern European regions is an intriguing topic. Did Catalonia's industrialisation and modern economic growth lead to the emergence of height differences between rural and urban areas? We attempt to answer this question by using a unique dataset that includes height data for a large percentage of males born in 1890 who were living in Catalonia in 1911.

A second contribution made by this paper is indeed to do with the data it uses and, partially as a result, with the approach it adopts. The currently available literature generally investigates the urban–rural gap based on samples consisting of a small number of villages, towns and cities.[3] Limited by the data and the samples used, many studies in this field also tend to follow a binary classification of population settlements: sites are simply classified as urban or rural, and no gradients in population size can be established. This study attempts to contribute to filling these gaps. It uses a large new dataset (comprising almost 18,000 observations) based on military records for the cohort of males born in the year 1890 and enlisted in the year 1911, at a time when (though some exceptions continued until one year later) universal compulsory military service was introduced (e.g. Molina 2012). The dataset has been designed to provide height evidence at individual level for each of the almost 950 current Catalan municipalities (See Fig. 1). This large geographical coverage represents a novelty with regard to previous studies. Our dataset also offers a clear advantage (as does the paper by Groote and Tassenaar 2020 for the province of Fryslân, the Netherlands) over previous analyses by overcoming a dichotomic classification of territory into rural and urban, and, therefore, to test for linear (or nonlinear) relationships between height and the size and economic nature of villages, towns and cities.

The remainder of this paper is organised as follows: Based on primary and secondary sources, Sect. 2 provides a brief overview of the evolution of biological living standards in nineteenth-century Catalonia. Section 3 presents the new dataset and some preliminary results. Section 4 applies an econometric model to test for the relationship between population size and biological living standards as well as to

3 For the particular case of Spain, this applies to all the studies quoted with the exception of Quiroga (2001), who uses provincial samples.

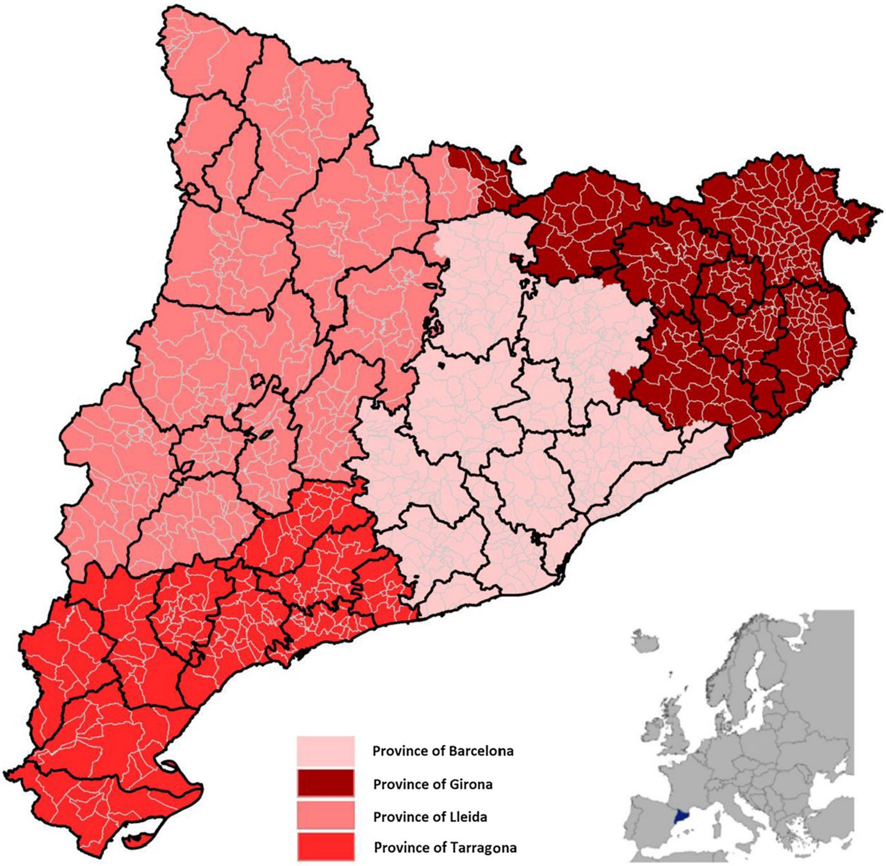

Fig. 1 Map of Catalonia: provinces, counties and municipalities. *Notes and sources*: Based on Eurostat (http://epp.eurostat.ec.europa.eu) and Municat (http://municat.gencat.cat)

discuss the results of this test. Section 5 concludes by pointing out the existence of an urban premium in late nineteenth-century Catalonia.

2 The evolution of biological living standards in nineteenth-century Catalonia: an overview

Catalonia underwent industrialisation unusually early compared with other regions on the European periphery (Pollard 1981). The origins and the development of Catalan industrialisation have been well researched. Initially, they were associated with the establishment of calico printing and, later on, with the progressive growth of cotton spinning and weaving (Sánchez 1989; Thomson 1992, 2005). Catalan industrialisation took a step forward in the early 1830s, when cotton manufacture began an intensive process of mechanisation and, partially as a result, the factory-system emerged (Nadal 1975; Sánchez 1989). Between 1835 and 1850, the number of mule-jennies multiplied by a factor of more than 17, from 27,220 to 475,490 (Nadal 1975, p. 196). As modern manufacturing developed, industrial production expanded rapidly in Catalonia: in the 1830s it grew at an annual rate of more than 7 percent, and in the 1840s and 1850s this rate was 5.4 and 5.7 percent, respectively (Maluquer de Motes 1994, p. 61; see also Carreras 1985, 1990).

Did industrial and economic growth influence biological living standards? In the UK, and in other north-western European countries, the early stages of modern economic growth coincided with a decline in heights, giving rise to the so-called early-industrial growth puzzle (e.g. Komlos 1998). The estimates by Cinnirella (2008) show, for example, that in Britain the mean height of a young man aged 18 years declined by around 4 cm during the second half of the eighteenth century and by around 3 cm during the 1820s and the 1840s.

In Catalonia, there is also some evidence of an "early-industrial growth puzzle". The case of Igualada, a medium-sized industrial town located some 60 kms west of Barcelona, is illustrative in this respect. Around the middle of the nineteenth century, the town's economy experienced rapid growth due mainly to the expansion of the cotton industry. Large new factories were built and by the 1840s Igualada and its surrounding area had become Catalonia's largest cotton centre, in terms of the numbers of both workers and spindles. However, at the time that this local economy was emerging as a factory-based industrial centre and was attracting immigration, the mean height of the males dropped. In particular, the mean height of the cohorts of conscripts born in Igualada between the 1830s and the 1860s decreased by more than 3 cm, from around 165 cm to around 162 cm. The data presented in Fig. 2 suggest that the pattern seen in Igualada can be extended to other towns and, perhaps, to the whole of industrial Catalonia, at least for the cohorts born between the early 1840s and the early 1860s. Interestingly, put in the Iberian context, the fall in the Catalan urban male heights during the early stages of industrialisation was something of an exception (Ramon-Muñoz and Ramon-Muñoz 2015, 2016).

With urban male heights declining between the 1840s and the 1860s, one might expect the emergence of an urban penalty in Catalonia. Indeed, this is what the data displayed in Fig. 3 suggest. By the early 1840s, Catalan rural conscripts were already taller (+0.6 cm) than their urban counterparts ($t=-1.899$; $p=0.058$). As Fig. 3 shows, rural heights dropped after the 1840s, paralleling the urban trend. The duration of this declining period was, nevertheless, restricted to the decade of 1850 and contrasts with the evolution of urban heights; in this latter case, reductions in physical stature were permanent and lasted until the 1860s. By then, rural conscripts were again taller (+0.5 cm) than their urban peers ($t=-1.810$, $p=0.070$).

A new cycle in the evolution of Catalan heights emerged in the last third of the nineteenth century. With regard to urban heights, Fig. 3 shows an increase of more than 3 cm for the cohorts born between the 1860s and the early 1910s. The possible explanations for this remarkable improvement are discussed in Sect. 1. Nevertheless, one might also suggest that it was precisely during the last third of the nineteenth century when the expected productivity gains derived from industrialisation began to be distributed more equally. In the industrial town of Igualada, for example, height inequality (measured using the coefficient of variation) increased throughout

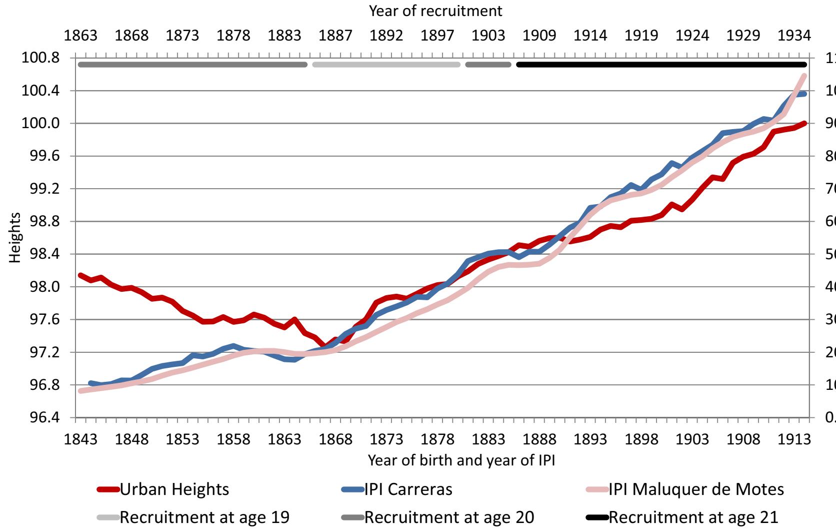

Fig. 2 Industrial production index (IPI) and urban heights trend in Catalonia, 1840–1914 (five-year moving averages, 1914 = 100). *Notes and sources*: Based on data from Carreras (1985), Maluquer de Motes (1994) and Ramon-Muñoz and Ramon-Muñoz (2021, pp. 41, Table A1). Urban heights include three urban industrial Catalan cities in central and southern Catalonia, Igualada, Manresa and Reus

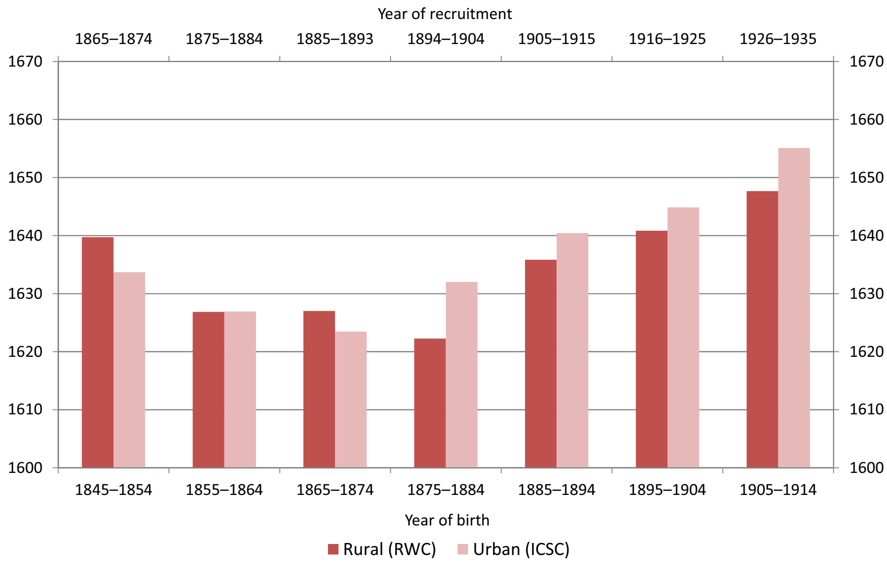

Fig. 3 Heights of conscripts from rural and urban Catalonia in the nineteenth and early twentieth centuries (in millimetres). *Notes and sources*: Ramon-Muñoz and Ramon-Muñoz (2021, pp. 41, Table A1). Rural and urban data refer to Rural Western Catalonia (RWC) and to Industrial Central & Southern Catalonia (ICSC), respectively. The rural data include the rural towns of Balaguer, Cervera, Juneda and Tàrrega, and for the urban data, see Fig. 2

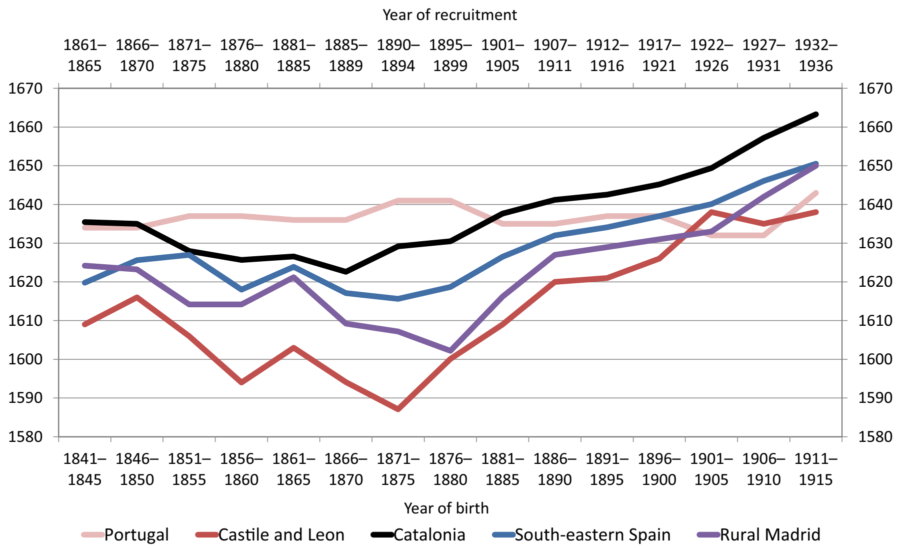

Fig. 4 Mean male height trends in Iberia, 1840–1914 (in millimetres). *Notes and sources*: For Portugal, height data include six Portuguese districts and are only available for the cohorts born in 1840, 1850, 1860, 1870, 1880, 1890, 1900 and 1910. Based on data from Cámara et al. (2019), García Montero (2009), Martínez-Carrión and Moreno-Lázaro (2007), Ramon-Muñoz (2009, 2011, updated data), Ramon-Muñoz and Ramon Muñoz (2016) and Stolz et al. (2013). We exclude from the sample regions with samples comprising fewer than five municipalities as well as regions for which data are not available

the third quarter of the nineteenth century; however, it fell sharply over the following years, a period in which the mean height also began to rise (Ramon-Muñoz and Ramon-Muñoz 2015, 2016).

If urban heights evolved positively, there is also evidence that in Catalonia the heights of the cohorts of rural conscripts born from the 1870s onwards followed a similar pattern (see also Ramon-Muñoz and Ramon-Muñoz 2018 for the long-term evolution of biological living standards in rural Catalonia). Although the causes of the emergence of a positive trend in rural heights require further analysis, there is evidence of a positive association between rural heights and rural wages for the cohorts born between the mid-1890s and the early 1910s. A similar association may be established when agricultural production and land productivity are taken into consideration (Ramon-Muñoz 2009).

The improvement of Catalan heights in both urban and rural areas had an important consequence: the emergence of Catalonia as one of Iberia's leading regions in terms of biological living standards. On the eve of World War I, the mean height of the male cohorts born at that time was 166 cm in Catalonia, compared with 165 cm in rural Madrid and south-eastern Spain, 164 cm in Portugal and 163 cm in Castile and Leon (Fig. 4).[4] At that time, Catalonia had already become "Spain's factory" and was also

[4] Additional evidence confirms Catalonia's height leadership observed in Fig. 4 for male cohorts born some years before the outbreak of World War I, at least as far Spain is concerned. In contrast, for the cohorts born in the late nineteenth century the available evidence is less conclusive. See Quiroga (2001, 2002), Gómez Mendoza and Pérez Moreda (1985), and Martínez-Carrión et al. (2016).

the Spanish region with the highest GDP per capita (Nadal 1985; Parejo 2001; Díez-Minguela et al. 2018; Rosés and Wolf 2018).

Interesting as it may be, this account of the evolution of biological living standards in nineteenth-century Catalonia needs to be complemented. The cycle of growth in Catalan heights that began in the late 1860s went hand in hand with a reversal in the urban penalty. In fact, by the last quarter of the nineteenth century urban heights were above rural ones and continued so for the next four decades. The available evidence suggests, therefore, that during the second half of the nineteenth century the urban–rural height gap in Catalonia evolved from an urban height penalty to an urban height premium. Unfortunately, the Catalan data upon which this interpretation depends are still quite fragmentary, based on five rural municipalities and three industrial towns, which means that the currently available dataset covers a very low percentage of the Catalan geography. In order to fill this gap, a new dataset has been constructed. The next section describes its main features as well as its potential shortcomings.

3 A unique new dataset on heights in late nineteenth-century Catalonia

The dataset used in this paper is based on military records generated during the enlistment process for military service in early twentieth-century Spain. In particular, mainly due to data availability, the information we collected refers to the recruitment year of 1911, which corresponds to the birth cohort of 1890.[5] For this cohort, legal exemptions still prevented a certain number of young males from effectively joining the army. These exemptions were in force until 1912 (thus affecting the cohort of 1891), when a new law was enacted (e.g. Molina 2012). In practice, however, the recruitment and enlistment process for the birth cohort on which our data relies was universal and compulsory. In 1911, all 21-year-old men were called up for military service and inspected. In other words, conscripts who finally decided to pay in order to avoid conscription are also included in our dataset.[6] It is important to stress this point, since it shows that our study sample is minimally affected (if at all) by the potential biases suggested by the literature (Komlos 2004; Bodenhorn et al. 2017; Schneider 2020).

A first step in the recruitment and enlistment process involved measurement and medical inspection, which was conducted at local level. The authorities of every single municipality had to prepare local lists of recruitment, the *Actas de Clasificación y Declaración de Soldados* (Acts of Classification and Declaration of Soldiers), which included, among other data, the name, birth year, and the physical stature of

[5] Indeed, the primary and fundamental reason for our selection of this birth cohort is that this is the only year we found height information for almost all localities in Catalonia. In addition, data for the birth cohort of 1890 (corresponding to the recruitment year of 1911) may shed light on the possible reversal of fortune in the biological living standards of Catalan urban dwellers. As shown in Sect. 2, the last two decades of the nineteenth century appear to have been a critical period in the development of the urban–rural height gap, as urban heights may have surpassed rural ones.

[6] In fact, exemptions from military service were made effective once the enlistment process ended (Nicolau and Fatjó 2016).

Table 1 Number of conscripts and municipalities included in the current dataset

Province	Total conscripts	Conscripts with height data	Number of municipalities (currently)		Number of localities (in 1910)	
			Province	Dataset	Province	Dataset
Barcelona	10,076	9055	314	299	316	310
Girona	3135	3011	222	216	247	247
Lleida	3227	2792	227	226	325	325
Tarragona	3248	3110	184	178	185	185
Total	19,686	17,968	947	919	1073	1067

Authors' calculation from the Recruitment Books kept in the archives of provincial councils of Barcelona, Girona, Lleida and Tarragona (see text)

the draftees. Based on height measurements and other additional information, local boards established whether or not conscripts were fit to serve.

The second step in the process took place at provincial level (Cámara 2006). The Recruitment and Replacement Act of 1896 established the creation of examination commissions in the provinces, known as the *Comisión Mixta* (Mixed Commission). These commissions were designed to rule on applications made by the draftees to be excused from obligatory military service. The information collected in both the local and the provincial recruitment rounds was summarised in the *Libros de Reemplazo* (Recruitment Books).

A third step in the process took place once the inspection procedure had finished. All conscripts fit to serve were included in a local lottery, a public event designed to select the conscripts who would finally join the Spanish army. The exact number of conscripts selected varied from one year to another, depending on the army's requirements. The number was established at the beginning of each year by the Spanish government, which then distributed the required number of conscripts by provinces and in accordance with the population of each province. Then, the provincial authorities did the same and, therefore, established the corresponding distribution at municipal level. In any case, the provincial authorities were asked to send the Ministry of War detailed information about each conscript who was finally to join the army (Molina 2012). This information was summarised in the *Hojas de Filiación de los Expedientes Reglamentarios de Tropa* (Registration Records from the Troops' Statutory Files).

Our dataset uses height data originating from the second of the phases that made up the conscription process. Thus, it comprises information collected from the Recruitment Books of the conscripts enlisted in the recruitment year of 1911. In terms of the number of conscripts included by the source, the Recruitment Books cover as many conscripts as in the Acts of Classification and Declaration of Soldiers. In fact, they sometimes include even more, as they added conscripts that were not present in the municipalities in which they officially resided on the day of military inspection. The Recruitment Books also include more conscripts than the Registration Records from the Troops' Statutory Files. In total, we use information from 19,686 individuals and height data from 17,968 (Table 1). The difference between these two figures is related to several factors. Although all young men were called up for military service, some

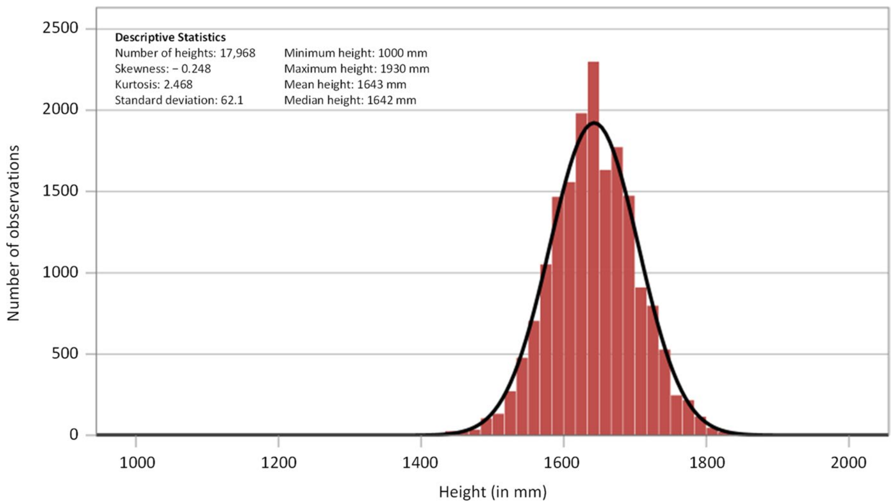

Fig. 5 Distribution of heights of Catalan conscripts and descriptive statistics (male cohort born in 1890 and enlisted in 1911). *Notes and sources*: See text

of the draftees deserted before inspection, and so height information is lacking for some individuals. In addition, some conscripts were living outside their official places of residence at the time of enlistment, and so they were not always able to respond to the call of the local or provincial authorities. Finally, inaccuracies and changes in the criteria used in the registration process might have prevented us from using a larger set of height data. Nevertheless, the dataset we have constructed is able to cover a very large percentage of the cohort of men born in 1890 and living in Catalonia in 1911. In fact, the mean heights of this birth cohort differ little from most of the available estimates (Ramon-Muñoz and Ramon-Muñoz 2021, pp. 42, Figs. A1 and A2, respectively), which are based on aggregate data (Gómez Mendoza and Pérez Moreda 1985) or on smaller samples (Ramon-Muñoz 2011).

So are the heights in our dataset normally distributed? Figure 5 suggests that the answer is affirmative. More precisely, it shows that our data follow a quasi-normal (Gaussian) pattern, with a negative skew due to the existence of several extremely low heights, which are not necessarily explained by measurement errors. Finally, and very importantly, the distribution presented in Fig. 5 also suggests that our dataset is not affected by truncation, one of the main potential shortcomings in military samples (e.g. Komlos 2004). This makes the dataset we use for late nineteenth-century Catalonia something of an exception compared to other height samples used in the international anthropometric literature.

Our dataset covers a large percentage of the male cohort born in 1890 and living in Catalonia in 1911, and it also has a broad geographical range, including data for 919 out of the 947 municipalities existing in Catalonia today and for 1067 out of the 1073 municipalities in Catalonia in 1910 (Table 1). In other words, the municipalities covered

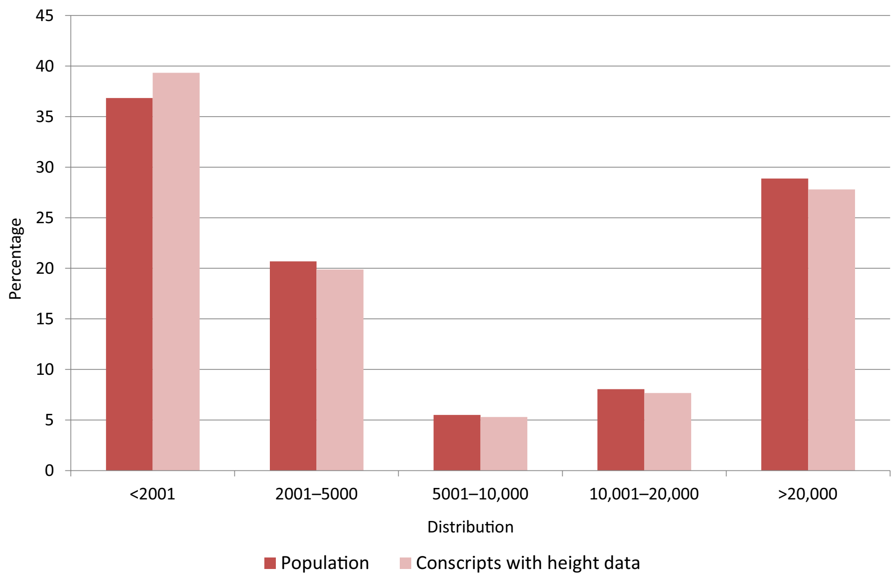

Fig. 6 The distribution of conscripts and population by population size of the municipalities in Catalonia (male cohort born in 1890 and enlisted in 1911). *Notes and sources*: See text

by this dataset account for 99.9 per cent of the population residing in Catalonia around 1890. Even more interestingly, perhaps, the distribution of both sets of conscripts fits extraordinarily well to the distribution of population by municipality size as measured by the number of inhabitants (Fig. 6). To be sure, the geographical coverage of the dataset used in this study represents a novelty with regard to other datasets available for Iberia as well as for some other European countries and regions. For example, the largest dataset for nineteenth-century Iberia has been constructed for the region of Castile and Leon (Hernández and Moreno 2009, 2011), including almost 68,000 observations for the male cohorts born between 1839 and 1915. It takes into account the largest towns in the region as well as a considerable number of rural areas. For obvious reasons, however, the total number of localities included in this dataset is limited: namely, 25 localities out of the 2248 municipalities that currently make up the region of Castile and Leon.[7]

Of course, the dataset that we developed is not without certain limitations. Firstly, we do not have information on the place of birth for most of the conscripts, only on the place of residence. This is simply because places of birth are not specified in most of the data sources at our disposal. Therefore, we had to

[7] Certainly, there are other broad datasets in Iberia, although they are not always designed to search for the existence of a urban–rural height gap. The datasets that include a large number of localities refer to Extremadura (35 localities, cohorts of males born from 1855 to 1979), rural Catalonia (102 localities, cohorts of males born from 1879 to 1896) and rural Madrid (18 localities, cohorts of males born from 1837 to 1915). See García Montero (2009), Linares-Luján and Parejo-Moruno (2021), and Ramon-Muñoz et al. (2022), respectively. In contrast, the database with the largest number of observations ($n = 358{,}253$) with male cohorts born between 1840 and 1964 includes only 19 localities. See Cámara et al. (2019).

Table 2 Distribution of the Catalan population by place of birth, 1910 (percentages)

Province	In the same province	In other provinces	Abroad	Unknown
Barcelona	72.53	26.27	0.86	0.34
Girona	91.82	7.39	0.79	0.00
Lleida	94.50	5.04	0.35	0.11
Tarragona	93.58	6.21	0.20	0.01
Total	81.91	17.22	0.67	0.20
Barcelona*	58.22	39.85	1.36	0.57

(*) City of Barcelona. Based on data from the Population Census of 1910

arrange conscripts' heights by municipality of residence at the time of enlistment rather than by municipality of their birth. What is more, we did so using present-day municipal boundaries. As will be explained below, this point has to be taken into account when interpreting the results, particularly regarding the municipalities in the province of Barcelona (Table 2). Nevertheless, the data reported by the Spanish Population Census of 1910 show that for the rest of the Catalan provinces, i.e. Girona, Lleida and Tarragona, more than 90 percent of the inhabitants resided in the same province (and perhaps locality) as the one in which they had been born.

Secondly, during the process of data collection we noticed that for certain localities the information available on conscripts' heights might be affected by censuring. In these cases, the sources we used offered no information on the stature of the conscripts below 1540 mm, which was the minimum height required to join the army at that time. However, the sources did detail the number of conscripts below the minimum stature required. While they were mostly concentrated in the province of Barcelona, the number of records affected by censoring was fortunately quite low: 52 out of 17,968 records. We estimated these heights and included them in our dataset. The estimation procedure of these 52 heights is based on the assumption that the left-hand distribution of our local samples was similar to the right-hand distribution, for which we have complete data.

To sum up, in spite of these limitations, we believe that the dataset we developed is reliable and able to produce robust, non-biased and valuable results on the relationship between population size and biological living standards. One of these results is shown in Fig. 7, which suggests a positive, linear relationship between height and population size. As the conscripts residing in municipalities with fewer than 5001 inhabitants were shorter than the rest, the data seem also to support the existence of an urban premium (and a rural penalty) in late nineteenth-century Catalonia. Interesting as it is, the picture emerging from Fig. 7 is, nevertheless, far from being conclusive; it is through the use of quantitative methods that we may assess the robustness of our findings.

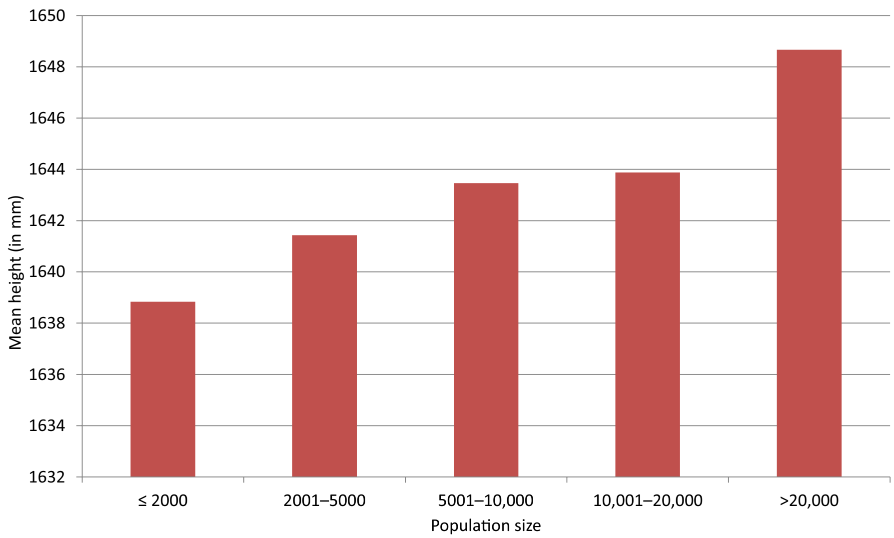

Fig. 7 The mean height of conscripts by population size of the municipalities in Catalonia (in mm) (male cohort born in 1890 and enlisted in 1911). *Notes and sources*: See text

4 Testing for the relationship between population size and height: model and results

This section aims to test the relationship between population size and height. It analyses whether (and if so, to what extent) econometric analysis confirms the late nineteenth-century urban premium, and the positive linear relationship between population size and height suggested in Sects. 2 and 3. To this end, we apply a model that uses cross-sectional data and is based on ordinary least squares (OLS), summarised in Eq. (1).

$$\text{HEIGHT}_{ji} = \beta_0 + \beta_1\text{CATMUNPOPSIZE}_{ji} + \beta_2 Z_{ji} + \mu_{ji} \tag{1}$$

In this model, the dependent variable is the height of most of the young Catalan males who were called up for military inspection in the 1911 draft. As previously explained, they were born in 1890 and were measured and enlisted at the age of 21. The total number of conscripts with height data is set at 17,968, belonging to 919 municipalities. In Eq. (1), the notation $HEIGHT_{ji}$ thus refers to the height of the recruit j residing in municipality i born in 1890. The other variables included in the model are $CATMUNPOPSIZE_{ji}$ and Z_{ji}. $CATMUNPOPSIZE_{ji}$ is the main independent variable. It refers to the category of municipality i (by population size in the census year of 1887) where the recruit j, born in 1890 and inspected in 1911, officially resided at the time of enlistment. The variable Z_{ji} designates a series of controls, namely population density, literacy rate, relative presence of railway stations, distance from ports and altitude of the municipalities where the given conscript resided, and, finally, the error term μ_{ji}.

Regarding the independent variables included in the econometric model, there are three preliminary issues that need to be mentioned. Firstly, the independent variables we use always refer to the period around the year of birth of the conscripts. This decision has a simple explanation: in line with most studies in anthropometric history, we assume that the stature of the 21-year-old Catalan conscripts was influenced most by environmental and nutritional factors during the conscripts' first years of life rather than during their teenage years (e.g. Tanner 1978; van Zanden et al. 2014; Schneider 2020; Gao and Schneider 2021).

Secondly, due to limitations in the data sources, the independent variables included in the econometric analysis are variables at municipal level. This means that we link the individual height information for each of the 17,968 conscripts that form our dataset with some factors characteristic of the 919 municipalities where the given conscript officially resided at the time of military inspection. Unfortunately, as mentioned in the previous section, limitations in data sources also prevent us from having precise information on the localities where the conscripts were born and lived during their early childhood.

Thirdly, we were unable to include other potential independent variables in our model, such as sanitation. A growing body of literature has made it clear that clean water supply and adequate sewerage systems were essential for eliminating waterborne diseases and, therefore, for mortality rates to decline.[8] We might hypothesise that the same applies to biological living standards. Thus, we might argue that municipalities with access—or early access—to clean water and with better sanitation facilities had healthier populations as proxied by height. Unfortunately, due to data constraints we are unable to test this hypothesis. For example, in some Catalan municipalities, the 1860s saw the introduction of piped clean water supplies, which expanded during the last third of the nineteenth century; in contrast, other localities did not enjoy this amenity until early in the twentieth century (e.g. Capel and Tatjer 1991; Larrosa 1992; Riba Gabarró 2006; Guàrdia et al. 2014; Serra 2016; Fernández Álvarez 2017; Matés-Barco 2019). However, we cannot provide consistent and systematic data on the year, amount and coverage of the waterworks and sewerage systems constructed in Catalonia at the municipal level in the nineteenth and early twentieth centuries. We will come back to these issues later in this section.

Bearing all this in mind, we have constructed six different independent variables to be included in the model (Table 3). The main variable of interest is the population size of the municipality where conscripts in question resided when they were measured and enlisted. Population data have been taken from Spain's population census of 1887, which is the closest census to the birth cohort of 1890. In line with other studies (e.g. Zehetmayer 2013; Heyberger 2014), we have constructed several categories of municipalities in order to take account of municipal population size. These categories are: below 2001 inhabitants, between 2001 and 5000 inhabitants, between 5001 and 10,000 inhabitants, between 10,001 and 20,000 inhabitants, and more than 20,000 inhabitants.

[8] See, for example, the more recent studies by Alsan and Goldin (2019), Chapman (2019, 2022), de Looper et al. (2019); Floris and Kaspar Staub (2019), Harris and Helgertz (2019), Harris and Hinde (2019), Helgertz and Önnerfors (2019), Peltola and Saaritsa (2019), Gallardo-Albarrán (2020), Raftakis (2021), Troesken et al. (2021).

Table 3 Summary statistics for selected variables

Province	Obs	Mean	SD	Min	Max
Individual height (mm)	17,968	1643	62.1	1000	1930
Population size of municipalities (no. of inhabitants):					
≤ 2000 inhabitants	759	894	464.2	126	1992
2001–5000 inhabitants	128	2978	773.1	2001	4933
5001–10,000 inhabitants	16	6358	1324.7	5021	9219
10,001–20,000 inhabitants	10	14,856	3032.1	10,201	19,645
> 20,000 inhabitants	6	88,675	155,437.5	21,885	405,913
Total	919	2005	13,577.6	126	405,913
Municipal area (sq. km)	919	34.3	35.2	0.4	302.8
Municipal population density (inhabitants per sq. km)	919	82.0	186.3	2.9	4005.1
Municipal literacy rate (%)	919	25.4	9.4	2.2	61.2
Municipal railway stations (no. of railway stations per municipality, 100 sq. km)	919	1.2	4.3	0.0	59.0
Municipal distance from a port (m)	919	44,303.3	36,784.2	246.3	195,832.4
Altitude per municipality (m)	919	373.4	319.1	3.0	1539.0

The first two categories can be considered as coming clearly under the definition of rural areas (Gómez Mendoza and Luna Rodrigo 1986), whereas a definition for the remaining groups is more difficult to establish. In late nineteenth-century Catalonia, municipalities between 5001 and 20,000 inhabitants might be defined as towns of different population sizes, even if some scholars would perhaps prefer to include them under the category of rural areas. Finally, municipalities with more than 20,000 inhabitants conform clearly to the definition of urban areas and, in some cases, they might be defined as industrial cities. These five categories of municipalities have entered into the regression as dummy variables (e.g. if the conscript resides in a municipality of fewer than 2001 inhabitants 1, otherwise 0). Descriptive statistics suggest a positive relationship between population size and height.

Population size of the municipalities is the main variable of interest, but we also consider other potential factors that might affect the stature of the young Catalan males called up for military service. These factors are included as controls in the regression. The first (and perhaps obvious) variable we take into consideration is population density. Certainly, this variable is highly (and positively) correlated with population size (Table 4). Nevertheless, population size is included in the regression as a categorical variable and, in the end, population density may contribute to capturing the potential (negative) impact of overcrowding on biological living standards, as discussed above in the introduction. Population data have again been taken from Spain's population census of 1887. As we use the current municipal boundaries, we have taken information on municipal areas from the Statistical Institute of Catalonia (IDESCAT) for 2021.[9]

The second control variable we take into consideration is literacy rate. While literacy is considered a proxy for human capital, it also reflects differences in socioeconomic

[9] See http://www.idescat.cat/en/ (last accessed July 5, 2021).

Table 4 Matrix of correlations for selected continuous variables

	Height	Population	Area	Pop. density	Literacy rate	Railway sta.	Port dist.	Altitude
Height	1.000							
Population	0.048	1.000						
Area	0.021	0.455	1.000					
Pop. density	0.049	0.995	0.415	1.000				
Literacy rate	0.049	0.701	0.122	0.734	1.000			
Railway sta.	0.039	0.503	0.058	0.536	0.555	1.000		
Port dist.	−0.073	−0.444	0.038	−0.467	−0.508	−0.396	1.000	
Altitude	−0.089	−0.453	−0.092	−0.474	−0.495	−0.391	0.799	1.000

All results are statistically significant at the 1 per cent level. Except for height, all variables are defined at the municipal level. See Table 3 and text

status between individuals. The anthropometric literature has generally suggested a positive relationship between literacy and height, with literate males being significantly taller than the illiterate ones (e.g. Ayuda and Puche-Gil 2014; Palma and Reis 2021 for Iberia). Unfortunately, we are only able to capture literacy rates at municipal level. This means that our data provide information on the percentage of the population able to read and write in the municipality in which the conscript resided, but not on the literacy of the individual draftee. Again, we use data referred to the closest birth year of the conscript, namely local literacy rates taken from Spain's population census of 1887. Bivariate correlations suggest a positive and statistically significant relationship between literacy rates and height in late nineteenth-century Catalonia (Table 4).

The third and fourth variables of control included in our regression aims to measure access to railway and water transport and, therefore, market access and market integration. The third variable refers to railway transport. There is a large body of literature that shows that the railway had an influence on heights. On the one hand, this influence tends to be positive in the case of urban dwellers since railways facilitated the transport of foodstuffs from rural to urban areas. As a result, foodstuffs became cheaper and more abundant in towns and cities, a circumstance that may well have helped to improve the nutrition of urban dwellers (e.g. Guven Solakoglu 2006; Yoo 2012; Zehetmayer 2013). However, railways might be detrimental to the biological living standards of the rural population. Firstly, they might facilitate the spread of diseases from cities to rural areas, and secondly, they might contribute to depriving country-dwellers of proteins and other nutrients, thus negatively affecting the height of rural communities (e.g. Komlos 1987; Haines 1998, 2004; Haines et al. 2003). In order to capture these potential impacts, we have constructed a variable that states the number of railway stations per 100 sq. km, in the municipality where the conscript in question resided. Using data provided by Pascual (2016, Appendixes) as well as other complementary information, this variable only considers the municipalities that had a station in broad gauge railway lines in 1890, coinciding with the year of the conscripts' birth. In that year, the railway lines with broad gauge accounted for more than 90 percent of all railway lines operating in Catalonia (Pascual 2016, p. 27–30). We have complemented the information on railways by considering water transport. Thus, our fourth control variable measures the distance (in metres) between the locality where the focus conscript resided and the closest custom port.[10] The reasons for including this variable are similar to those taken into account for railways.

The last control variable we consider in our econometric model is the altitude of the municipalities where the conscript was officially residing at the time of inspection. This variable, which we have taken directly from IDESCAT, has been considered in several studies on biological living standards. For example, in Argentina, Bejarano et al. (2009) found a negative relationship between mean height and geographical altitude in a sample of 48,589 conscripts born between 1870 and 1960. By reviewing the findings of a Portuguese physical anthropologist, Da Costa Leite (1998, p. 460) observed that in the 1890s men were "shorter in the areas of higher altitude" of Northern Portugal. Ramon-Muñoz et al. (2022) arrived at similar conclusions for late nineteenth-century western Catalonia using a sample of 16,389 conscripts born between 1879 and 1890. This negative association between stature and altitude might reflect a number of factors, including, among others, climatic conditions, agriculture orientation, poor economic conditions in highlands, transport costs, isolation, as well as difficulties in accessing to richer and more abundant resources. In addition, altitude is also correlated to other variables that might negatively affect height. In our dataset, and as expected, it is significantly and negatively correlated with population size and population density (Table 4). However, in both cases the R^2 is not as strong as one might have expected (around 0.25). Interestingly, the matrix of correlations presented in Table 4 also shows a negative relationship between altitude and height, while, as suggested above, height correlates positively with both population density and population size.

Finally, we also add territorial dummy controls to some of the specifications in our model. We consider that the territories where the conscripts lived differed in some unobservable way that might affect our dependent variable. Based on the information provided by the IDESCAT, we have considered eight different territorial areas: Alt Pirineu i Aran, Camp de Tarragona, Comarques Centrals, Comarques Gironines, Àmbit Metropolità de Barcelona, Penedès, Ponent, and Terres de l'Ebre.[11] While these areas include quite homogeneous counties, they also differ one from each other geographically as well as economically. This internal homogeneity combined with heterogeneity across territories would have been more difficult to identify if we had used dummies at provincial level.

Table 5 presents different specifications of the model. The results indicate a positive and statistically significant association between male heights and population

[10] Esteban-Oliver (2020). The custom ports are Alcanar, Arenys de Mar, Badalona, Barcelona, Blanes, Cadaqués, Cambrils, l'Escala, Lloret de Mar, Malgrat, Masnou, Mataró, Palafrugell, Palamós, Roses, Salou, la Ràpita, Sant Feliu de Guíxols, el Port de la Selva, Sitges, Tarragona, Torredembarra, Tortosa, Tossa de Mar, el Vendrell, Vilanova i la Geltrú.

[11] See https://www.idescat.cat/codis/?id=50&n=28 (last accessed July 5, 2021), and Ramon-Muñoz and Ramon-Muñoz (2021, pp. 45, Figure A6).

Table 5 The impact of population size on male heights in Catalonia in the cohort born in 1890 (dependent variable: Individual male height, mm

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Population size:							
≤2000 inhabitants	−9.833***	−11.766***	−11.409***	−11.953***	−10.181***	−7.806***	−5.544***
	(1.102)	(2.389)	(2.434)	(2.463)	(1.931)	(2.036)	(1.947)
2001–5000 inhabitants	−7.235***	−9.129***	−9.060***	−9.631***	−8.728***	−7.144***	−5.434***
	(1.391)	(2.485)	(2.517)	(2.572)	(2.037)	(2.085)	(1.815)
5001–10,000 inhabitants	−5.203*	−7.008*	−7.240**	−7.555**	−6.743**	−5.335	−3.876
	(2.994)	(3.598)	(3.592)	(3.623)	(3.134)	(3.332)	(3.097)
10,001–20,000 inhabitants	−4.789	−6.425*	−7.022*	−7.287*	−7.237**	−5.872*	−3.264
	(3.053)	(3.625)	(3.870)	(3.784)	(3.286)	(3.082)	(2.930)
> 20,000 inhabitants	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Population density		−0.001	−0.001	−0.001*	−0.001**	−0.001**	− 0.000
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Literacy rate			0.067	0.030	−0.031	−0.032	0.039
			(0.080)	(0.086)	(0.084)	(0.082)	(0.095)
Railway stations				0.269*	0.149	0.093	0.162
				(0.160)	(0.142)	(0.135)	(0.138)
Distance from a port					− 0.000***	− 0.000	− 0.000
					(0.000)	(0.000)	(0.000)
Altitude						−0.017***	−0.013***
						(0.004)	(0.004)
Dummies at territorial level	No	No	No	No	No	No	Yes
Constant	1649***	1651***	1649***	1650***	1655***	1654***	1647***
	(0.646)	(2.250)	(3.188)	(3.327)	(3.029)	(2.958)	(4.489)
R-squared	0.004	0.004	0.004	0.005	0.007	0.009	0.010
Observations	17,968	17,968	17,968	17,968	17,968	17,968	17,968

***$p<0.01$, **$p<0.05$, *$p<0.10$. Clustered robust standard errors in brackets. See text size, although this significance is not universal in all municipality categories. In the absence of control variables, this association is statistically significant in the three first categories, namely up to 10,000 inhabitants (Table 5, Column 1). Relative to the conscripts that resided in cities with more than 20,000 inhabitants, which is the reference category, residents of these areas were –5.2, –7.2 and –9.8 mm shorter, depending on whether they lived in small towns (5001–10,000 inhabitants) or in larger (2001–5000 inhabitants) and smaller villages (less than 2001 inhabitants), respectively.

This urban advantage is not negligible, but it is lower than that recorded in other areas of the Iberian Peninsula that shared an urban height premium by around 1890. For example, we observe an urban advantage of between 15 and 20 mm in eastern Andalusia, south-eastern Spain and the Canary Islands (Martínez-Carrión and Pérez-Castejón 1998; Cámara 2007; Martínez-Carrión and Moreno-Lázaro 2007; Cañabate-Cabezuelos 2015; Cañabate-Cabezuelos and Martínez-Carrión 2017; Martínez-Carrión et al. 2022). The exceptions to this general rule are regions in central Spain, including Castile and Leon and Extremadura, where the height of urban dwellers exceeded that of the rural conscripts by around 5 mm (Hernández and Moreno 2011; Linares-Luján and Parejo-Moruno 2021). Moreover, Reis (2009, p. 83) found an urban premium of less than half a centimetre for Portugal. All these areas had lower levels of industrialisation than Catalonia. Furthermore, they mostly experienced a permanent urban premium throughout the nineteenth century, suggesting that the sectoral composition of the towns and cities might be as crucial as urbanisation in explaining urban–rural differences in biological living standards.

This relationship seems to find partial confirmation in Fig. 8. This figure contains the information referring to the above-mentioned regions and, in addition, the Valencian Community (Puche 2011) and the Basque Country (Pérez-Castroviejo and Martínez-Carrión 2018). While the results in Fig. 8 show that less industrialised areas tend to experience higher urban height advantages, they also leave an unresolved puzzle. Catalonia was more industrialised than Castile and Leon, located in central Spain, and the Mediterranean coastal Valencian Community, characterised by dynamic commercial agriculture and the emergence of some notable industrial towns in the nineteenth century. However, by the 1890s, the urban height advantage we find for Catalonia was higher than for these two regions. In fact, in the latter region, rural conscripts were taller than their urban counterparts. A rural height advantage is also recorded in the province of Biscay (Basque Country, northern Iberian Peninsula), with relatively high levels of industrialisation, although lower than those for the province of Barcelona.

Resolving this potential puzzle is beyond the scope of this article. Nevertheless, it highlights a relevant methodological issue: the care we should take when comparing data sets with different characteristics. Whereas our analysis considers almost the whole of Catalonia and practically the entire male population enlisted in 1911, the rest of the historical research in Iberia uses samples from towns, which sometimes do not include localities with fewer than 5001 inhabitants. On other occasions, studies have excluded the region's largest cities. Occasionally, they take a single locality and differentiate within the same town or city according to type of environment.

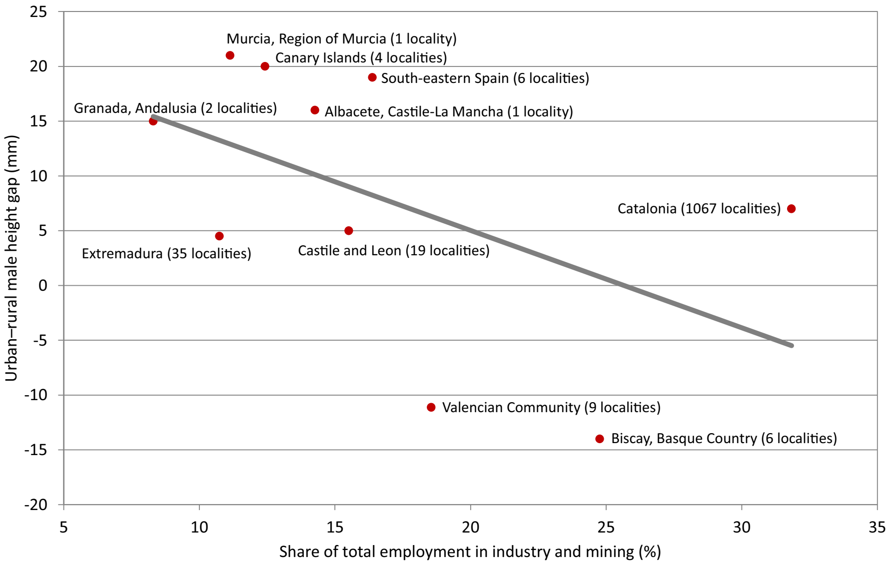

Fig. 8 The relationship between the urban–rural height male gap and the share of total employment in industry in Spain by regions, c. 1890. *Notes and sources*: We obtained the share of employment in the industry from the 1887 Population Census (Instituto Geográfico Estadístico 1892) and the urban–rural height gap from the references quoted in the text. Regarding employment, the actual figure refers to the districts of the localities included in the samples. As far as height is concerned, we estimated the urban–rural male height gap for Castile and Leon and Biscay by visually examining the graphs provided by the authors in their publications. For references, see the text

Last but not least, the criteria to define urban and rural settlements may vary from one study to the other, a circumstance that complicates comparative analysis.

Using a comprehensive dataset, we find an urban height premium for the young males living in Catalan cities with more than 20,000 inhabitants. The addition of control variables to the basic regression does not change the direction of the association between population size and height. However, coefficients and their statistical significance tend to vary. First, the linear relationship observed between population size and height, at least for the categories of municipalities of up to 10,000 inhabitants, becomes less clear. This is the case when, in addition to population density, number of railway stations, and literacy rate, we also control for the distance from a custom port and the municipality's altitude. The same is true when we include dummies at territorial level in our model.[12] In early nineteenth-century England

[12] As a robustness check, and to control for potential multicollinearity between independent variables, we examined other specifications of the model. Thus, we dropped from the regression the variable municipal population density, which, as already argued, is highly correlated with municipal population size. In the same vein, we also substituted the population density variable with the variable municipal area, which, to some extent, might indirectly reflect the important issue of overcrowding. Appendix (Table 8) presents the results we obtained after controlling for the variables literacy rates, railway station, distance from a custom port, altitude, and territorial dummies. Although coefficients may vary slightly, they confirm that the young males resident in rural municipalities were shorter than those living in cities of more than 20,000 people.

and Wales, Humphries and Leunig (2009a, p. 468) found that population became a significant (and negative) determinant of height only in towns with a population of more than 8000 inhabitants, and particularly in big cities. In the USA, Zehetmayer (2013, p. 175) found an inverse U-shaped relationship in which height reaches its maximum value in cities with about 250,000 inhabitants and then declined thereafter for the cohorts born in late nineteenth century. In Catalonia, we find no substantial differences in height between the residents in villages of up to 2000 inhabitants and those living in municipalities between 2001 and 5000 inhabitants (Table 5, columns 6 and 7), probably because these localities shared a rural environment, and differences in physical stature are mainly explained by factors other than population size. Perhaps more surprisingly, in our last econometric model specification, we also find no statistically significant differences in height in the draftees living in municipalities between 5001 and 20,000 inhabitants relative to our reference group. Clearly, these results point to the absence of a linear relationship between population size and height.

Second, after controlling for population density, literacy rate, number of railway stations, distance to a custom port and altitude, the differences between the heights of conscripts residing in municipalities with fewer than 5001 inhabitants and those living in towns (> 5000 inhabitants) and particularly cities (> 20,000 inhabitants) drop substantially (Table 5, column 6). Nevertheless, rural residents remain significantly shorter, and so the existence of an urban premium for late nineteenth-century Catalonia is confirmed. Evidence suggests a height gap of between one-half and three quarters of a centimetre between young males living in rural areas (≤ 5000 inhabitants) and those living in cities (> 20,000 inhabitants) (Table 5, columns 6 and 7). Although this difference might be regarded as slight, urban–rural height gaps of less than 1 cm are not uncommon in the context of nineteenth-century Europe when the relationship between height and population size is controlled for other factors.[13] In addition, though moderate, this urban–rural height gap is by no means irrelevant, particularly if we agree that height positively correlates with cognitive ability and is a good proxy for human capital, thus determining person's life opportunities and outcomes. A recent review of the modern evidence linking childhood stunting and undernutrition to economic outcomes concluded that a 1-cm increase in adult height was associated with a "4 percent increase in wages for men and a 6 percent increase in wages for women" (McGovern et al. 2017, p. 17). Seen in this way, an urban premium of between one-half and three quarters of a centimetre might be considered less negligible than it initially appears, particularly in terms of long-term inequality across individuals and territories.

The confirmation of an urban premium for the cohorts born in the late nineteenth century is also a novelty relative to the European regions that experienced an urban penalty before 1900. In Spain, there are two areas that fall into this category: the

[13] See, for example, Humphries and Leunig (2009a, pp. 466–69), and Jaadla, Shaw-Taylor and Davenport (2020, p. 13) for England and Wales in the early nineteenth century, Cinnirella (2008, p. 340) for early and mid-nineteenth-century Britain, and Heyberger (2014, pp. 128–30) for mid-nineteenth-century France. In all these cases, urban heights are lower.

already-mentioned province of Biscay, and the Valencian Community. The existing studies for these two territories do not always control for other variables and do not consider all the municipalities of the province or region they analyse. Nevertheless, they show a permanent urban penalty that persisted for the cohorts born in the first decade of the twentieth century and even later.

In western Europe, many regions and countries experienced an urban height penalty before the late nineteenth century. However, the available evidence suggests that only a limited number of them presented an urban height premium before or around 1900: examples are Sweden and the Netherlands, which we will now discuss.

For Sweden, the height data collected by Sandberg and Steckel (1988) show the emergence of a regional divide in the first half of the nineteenth century. Thus, the stature of the males born in the east and the north of the country increased between 1818–1837 and 1838–1856. The opposite was true for the “densely populated and child intensive West” and in the “urban, and especially unhealthy, environment” of Stockholm, where males’ heights declined (Sandberg and Steckel 1988, p. 1 and 7). Therefore, in the 1838–1856 period, the mean height of these two latter regions had fallen below the Swedish mean, although probably less than initially considered (Heintel et al. 1998). However, this penalty was not permanent; in fact, it reversed into an urban height premium at some point in the second half of the nineteenth century or the first years of the twentieth. By 1905–1906, there was already “no evidence of an ‘urban penalty’ in height in the largest cities in Sweden” (Öberg and Collin 2017, p. 141); the males living in the urban counties of Stockholm and Gothenburg and Bohus were already significantly taller than the mean for Sweden as a whole. The precise point in time when Sweden’s urban premium emerged is uncertain, but at least regarding trends in the urban–rural height male gap, it does not seem to differ substantially from Catalonia.

In the Netherlands, Tassenaar (2019) found an urban male height premium from the 1860s onwards, at least for smaller and medium-sized cities. This chronology is similar to what our sample data for Catalonia show, namely the emergence of an urban premium starting in the 1870s that we can confirm for the 1890 birth cohort. For the province of Fryslân, Groote and Tassenaar (2020) also found an urban height advantage, which in that province began to emerge as early as the late 1850s. This is also what de Beer (2010, p. 70) concluded in analysing prisoner registers in the Netherlands. However, Tassenaar’s data suggest a less clear height advantage for the country’s two largest cities, which was not the case in Sweden. Thus, in the conscription years 1889–1913, the height of Amsterdam’s young males was 8 mm above the national male mean height, but it “lagged behind their counterparts from smaller urban residencies” (Tassenaar 2019, p. 158). In Rotterdam, young males were not only shorter than their counterparts in Amsterdam, but they fell more than 10 mm below the national mean and that of some rural provinces (Tassenaar 2019, p. 159). In contrast, in Sweden, the mean male height in the biggest cities was always above the national mean: the county of Stockholm had a height advantage of 14 mm and that of Gothenburg and Bohus of around 4 mm (Öberg and Collin 2017 table A1). After controlling for several variables, the results from Catalonia also suggest a qualified urban premium, as in the Netherlands. An urban advantage is apparent when we compare villages and towns of up to 5000 inhabitants and towns and cities of more than 20,000. In contrast, height differences are not statistically significant in the rest of the settlements (Table 5).

For other regions and countries in western Europe, the important point is the absence of a clear and consistent reversal of the urban height penalty before 1900. A first limitation in analysing this reversal is the small number of studies on long-term regional trends in the urban–rural height gap as compared to those that focus on the decades prior to the mid-nineteenth century. As a result, detailing whether, when, and to what extent urban height disadvantages turned into an urban height premium is a challenge. Table 6 provides some of the available evidence on the topic. To construct this table, we used three criteria. First, we considered only those regions that experienced a persistent urban penalty sometime in the nineteenth century; second, we selected only published papers whose data covered at least the cohorts born around 1850; and third, we included only studies whose regression analysis used

Table 6 The urban–rural male height gap in Bavaria, Britain, France, and northern Italy in the nineteenth century: selected studies

Geographic area	Birth cohorts	Category of settlement and/or no. of inhabitants	Urban vs. rural (mm)
Bavaria	1812–1886	Munich	[3.0]
		> 5000	– 18.8
England, Wales & Scotland	1801 – 1865	London	– 24.0
		> 100,000	– 7.5
Scotland	1800 –1840	Glasgow	– 27.9
		Other cities and towns ("Urban Scotland")	– 17.8
Scotland	1860s – 1890s	Urban counties (all soldiers)	– 19.8
		Urban counties (adult soldiers)	– 18.7/– 20.2
France	1848	Paris	– 11.8/– 6.5
		> 75,000	– 5.1/– 14.1
		20,000 – 74,999	– 2.9/– 6.2
		5000 – 19,999	[0.6] / [0.0]
Northern Italy	1720s – 1850s	Metropolis	– 21.8
		Provincial capital	[12.0]

Based on: Bavaria, 1582 observations (obs.), population for the year 1852, Baten and Murray (2000, p. 360); England, Wales and Scotland, 23,031 obs., population for the year 1851, Cinnirella (2008, p. 337); Scotland (1800–1840), 2678 obs., Riggs (1994, p. 66); Scotland (1860s–1890s), 4986 obs. and 1941 obs., respectively, Riggs & Cuff (2013, p. 73); France, 105,324 obs., population for the year 1851, Heyberger (2014, p. 128 and 130); Northern Italy, 7979 obs., A'Hearn (2003, p. 363). A negative sign means an urban height disadvantage. Data in brackets mean that the coefficient is not statistically significant. Rural heights are generally the reference group that authors consider in their regressions. The data underlying these estimates generally refer to army recruits or soldiers, except for Bavaria and Scotland (birth cohorts of 1800–1840). In these two cases, the data come from prisoners and convicts. For England, Wales, and Scotland, we consider that the cohorts of 1801–1865 are formed by males recruited after 1820. For France, we present two sets of results: first, those of regressions at the individual level and explanatory variables, without dummies for departments (Table 4, model 4); second, the results of regressions at the individual level and explanatory variables, with dummies for departments (Table 5, model 1) control variables when testing for a potential urban–rural height gap. From this evidence, we can tentatively conclude that by the late nineteenth century, in contrast to Catalonia, the Netherlands, and perhaps Sweden, a qualified urban height disadvantage remained in Bavaria and Scotland. Additional evidence for the French region of Alsace points in the same direction: for the birth cohorts of 1890–1895, the males from the urban and industrial town of Mulhouse were shorter than those from the rural district of Sélestat (Heyberger 2007, p. 238).

The case of Scotland is particularly illuminating. The studies by Riggs (1994) and Riggs and Cuff (2013) show a height disadvantage of around 2 cm in the first half of the nineteenth century for cohorts of males living in Scottish cities and urban counties. This gap remained up to the end of the century. Further evidence on child heights suggests that in Scotland this height penalty in the urban environment might have persisted until the first decades of the twentieth century (Harris 1993; Riggs and Cuff 2013). Interestingly, in Alsace, the same occurs between Mulhouse and Sélestat, at least until the birth cohorts 1910–1920.

Since we observe a reversed urban height male penalty for Catalonia, our case study differs from the northern European regions and countries with a permanent urban premium throughout the nineteenth century. Examples are eastern Belgium, the German region of Württemberg, and Switzerland. With an urban male height advantage of less than 1 cm between villages and cities in the 1890 birth cohort, Catalonia is nevertheless comparable with the canton of Bern. Perhaps as expected, the late nineteenth-century Catalan urban premium was substantially lower than in the rest of western European regions that had avoided an urban penalty. This includes the Swiss cantons of Zurich and Basel and Württemberg in Germany, where urban dwellers were between 1.5 and 3 cm taller than their rural counterparts.[14]

In short, urban–rural height differences were far from uncommon in modern Europe, but the direction of this gap, its magnitude, and its evolution differed across territories. There was no single pattern in the reversal of urban height male disadvantages. Similarly, one might expect the reversal patterns to be associated with the timing and intensity of the transformation of the cities into better health environments from the last decades of the nineteenth century onwards (e.g. Hatton 2014).

So, what are the reasons for the urban premium in late nineteenth-century Catalonia? As suggested in previous sections, improvements in public health and food supply are the obvious candidates. In the context of this study, however, an additional factor has to be considered: migration. The dataset we use provides information on the place of residence of conscripts, but not on their place of birth. Therefore, it might be that the urban–rural height gap we observe in our data was mainly the result of rural boys and young males who, at a certain time point between their birth (1890) and the enlistment years (1911) left their place of birth to settle in other areas, particularly cities. This was not uncommon in nineteenth-century Catalonia (e.g. Camps 1995; Cabré 1999). Fostered by the labour opportunities (and probably the higher wages) provided by industrial growth, a notably high number of Catalans born in villages and small towns emigrated to the city of Barcelona and to other

[14] For the Swiss cantons, see Schoch et al. (2012) and also see Alter et al. (2004) and Twarog (1993, 1997) for eastern Belgium and Württemberg, respectively.

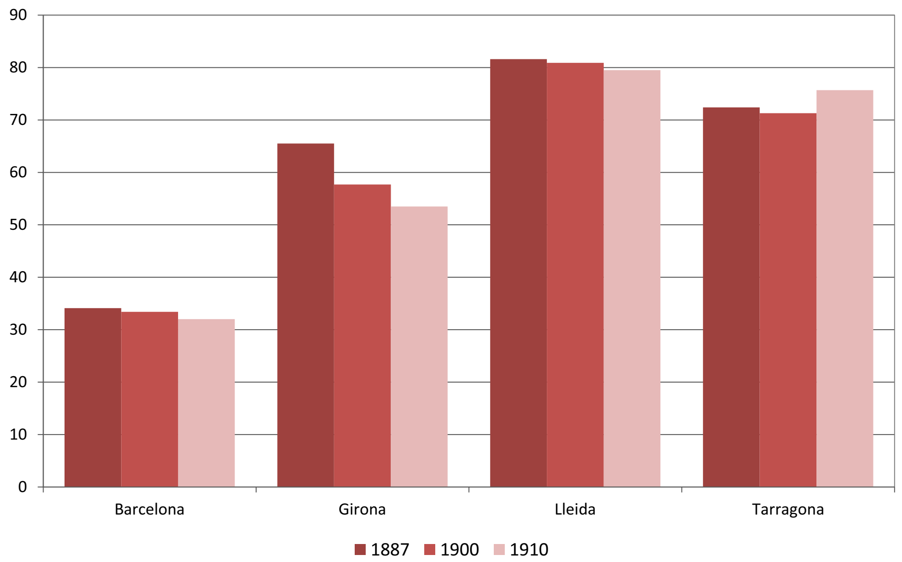

Fig. 9 Male population employed in the agricultural sector in Catalonia, 1887–1910 (in percentages). *Notes and sources*: Based on data from Nicolau (1990, p. 53)

towns on its outskirts where industrial and service activities had become predominant (Fig. 9). The same was true of the population born in the neighbouring regions of Aragón and València, who had also begun to settle in the province of Barcelona in the last decades of the nineteenth century (e.g. Silvestre 2003; Pinilla and Silvestre 2017; Pitarch Calero et al. 2018), mainly in the city of Barcelona, which attracted the bulk of Catalonia's immigration.

Interestingly, the evidence available for the city of Barcelona also suggests that the migration pattern experienced significant transformations over the two decades and a half following the census year of 1887 (see Table 7). First, migration growth—including intra-Catalan migration—decelerated between 1900 and World War I compared to 1887–1900. Second, perhaps more critical in our discussion, non-Catalan migration to Catalonia outperformed intra-Catalan migration. As a result, the percentage of Catalan-born population in Barcelona tended to decline between 1887 and 1910.

The question of whether or not migration influenced the late nineteenth-century Catalonia urban–rural height gap needs to be addressed. The evidence in Table 7 suggests that this influence was probably less intense than expected, at least regarding the Catalan-born population. In 1910, the male Catalan population born outside Barcelona accounted for only 10 per cent of the total male population of this large urban area; in contrast, males born outside Catalonia made up about one-third. In other words, if urban Catalan conscripts were taller than their rural counterparts, this does not seem to be because rural conscripts were moving to urban areas. However, this issue needs to be explored in more depth.

Table 7 Distribution of the population living in the city of Barcelona by place of birth and gender, 1887–1910 (percentages)

	As a percentage of total male or female population			Annual growth rates (%)		
	1887	1900	1910	1887–1900	1900–1910	1887–1910
Male population						
Born in Barcelona	60.4	59.3	56.9	2.4	0.3	1.5
Born in Catalonia	11.8	9.8	10.0	1.1	0.8	1.0
Born in Spain	25.7	28.6	31.0	3.4	1.5	2.5
Born in other countries	1.9	1.6	1.5	0.9	0.2	0.6
Total male population*	100.0	100.0	100.0	2.5	0.7	1.7
	(188,222)	(260,114)	(278,285)			
Female population						
Born in Barcelona	60.2	59.1	57.1	1.9	0.9	1.5
Born in Catalonia	13.1	9.8	9.2	−0.2	0.6	0.2
Born in Spain	25.1	29.1	31.9	3.2	2.2	2.8
Born in other countries	1.5	1.3	1.3	1.2	1.1	1.2
Total female population*	100.0	100.0	100.0	2.1	1.3	1.7
	(209,089)	(272,886)	(309,126)			

Born in Catalonia, excluding Barcelona; Born in Spain, excluding Catalonia. (*) total population also includes population whose place of birth is unknown. See also Ramon-Muñoz and Ramon-Muñoz (2022a)

In order to do so, we have collected data for a sample of towns located in the province of Barcelona which had a population of more than 10,000 inhabitants in the census year of 1887. We call these localities "urban towns". Our dataset comprises the cohorts born in 1890, 1891 and 1892, who were enlisted in 1911, 1912 and 1913, respectively, and include about 3200 observations. We have classified the conscripts of these towns by place of birth.

Figure 10 summarises the raw results obtained. First, in the enlistment period of 1911–1913, conscripts born in urban towns were taller than others born elsewhere, who accounted for 30 percent of the total observations. Perhaps as expected, residents born outside Catalonia were shorter than Catalan-born conscripts, whether or not they were born in the towns considered as urban. Second, as conscripts born elsewhere were shorter than Catalan-born conscripts, our calculations record a fall in the mean height of the residents in industrial towns in 1911–1913 (birth cohorts of 1890–1892) when those born outside Catalonia are included. While these data await a more formal analysis, these preliminary results suggest that our urban height data are to some extent a lower-bound representation of urban-born heights.

Unfortunately, at the present stage of research it is still difficult to fully assess whether the Catalan rural-born males living in urban areas in 1911 were taller (or shorter) than their rural-born and rural-resident counterparts. The literature available indicates a higher physical stature for rural-born movers compared to rural-born stayers (e.g. Humphries and Leunig 2009b; Juif and Quiroga 2019, and for international movements Kosack and Ward 2014; Blum and Rei 2018). However, our

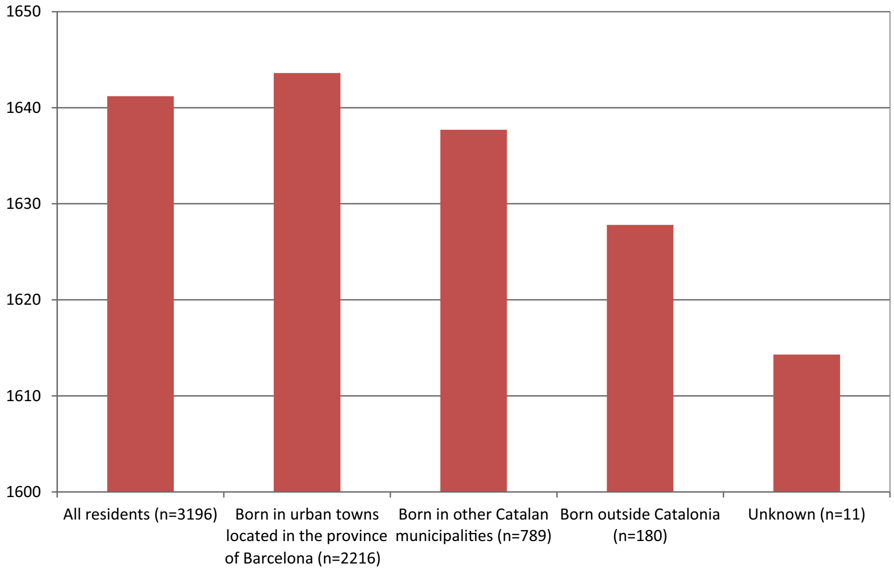

Fig. 10 The mean height of a sample of conscripts residing in the province of Barcelona in municipalities with more than 10,000 inhabitants by place of birth (male cohorts born in 1890–1892 and enlisted in 1911–1913, in mm). *Notes and sources*: Based on data for Badalona, Igualada, Manresa, Sabadell, Terrassa, Vic and Vilanova i la Geltrú from the *Actas de Clasificación y Declaración de Soldados* (Acts of Classification and Declaration of Soldiers), 1911–1913, and Ramon-Muñoz and Ramon-Muñoz (2022a)

sample data suggest otherwise: the mean height of those conscripts born in rural Catalan areas (in villages and towns of up to 5000 inhabitants) residing in urban municipalities (in towns with more than 10,000 inhabitants) in 1911 was 1640 mm. This figure is very similar to the 1639 mm we obtain as the mean height of the rural draftees born in 1890 who were still living in rural areas in 1911, which, if confirmed by further analysis, would suggest that internal migration had only a modest impact on the urban premium we find in late nineteenth-century Catalonia. It might also suggest a higher urban premium than our data indicate. Although referring to the male birth cohorts of 1900–1904, additional information for a sample of 1382 conscripts residing in the Barcelona neighbourhood of Sarrià between 1921 and 1925 points in the same direction: migration may have reduced the mean height of urban areas (Fig. 11).[15]

[15] According to this information, conscripts born in Barcelona were taller than their peers: between 3 and 9 mm taller, depending on the place of birth. Not surprisingly, the difference between the conscripts born in Barcelona and those born in other Catalan municipalities would be 5 mm instead of 3 mm if we exclude young males born in the province of Barcelona, where urban settlements were predominant.

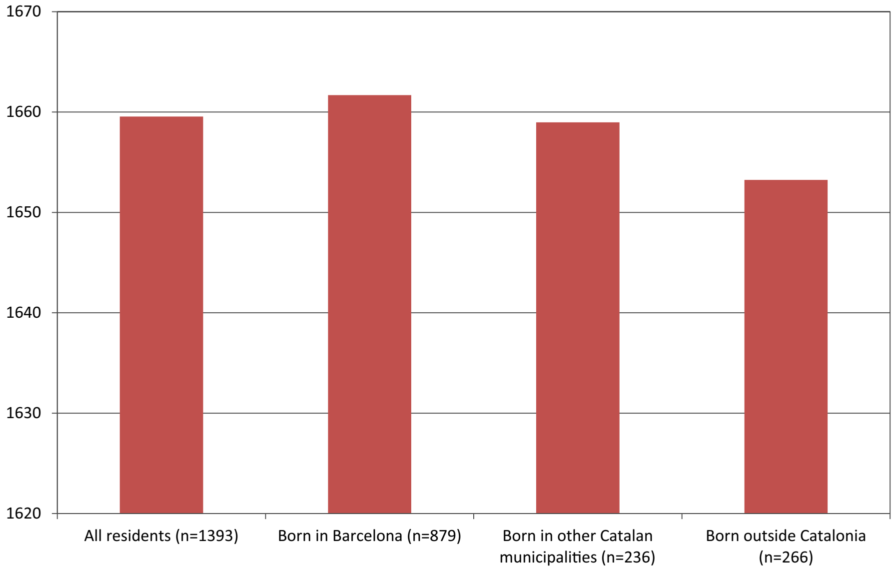

Fig. 11 The mean height of a sample of conscripts residing in the Barcelona neighbourhood of Sarrià by place of birth (male cohorts born in 1901–1905 and enlisted in 1921–1925, in mm). *Notes and sources*: "Born outside Catalonia" excludes conscripts born outside Spain. "All residents" also includes conscripts born outside Spain (11 obs.) and those whose place of birth is unknown (1 ob.). Based on data from the *Actas de Clasificación y Declaración de Soldados* (Acts of Classification and Declaration of Soldiers), 1921–1925, and Ramon-Muñoz and Ramon-Muñoz (2022a)

Among other possible explanations of the urban premium observed, we have already mentioned the potential improvements in public sanitation and in housing conditions, as well as better and more widespread access to medical services in cities. In spite of these measures, however, contemporary descriptions do not always suggest very optimistic conclusions with regard to the extent of the progress achieved, above all for the city of Barcelona and the cohorts born before the early 1890s (e.g. Capel and Tatjer 1991; Martín Pascual 2009, 2011; Tello and Ostos 2012; Guàrdia et al. 2014; Sabaté 2017). Water supply and the sewerage system were still very deficient, which favoured the emergence and transmission of infectious diseases such as the 1885 cholera epidemic. Housing conditions do not appear to have been much better. Perhaps an exception to this grim picture is healthcare: indeed, the last two decades of the nineteenth century witnessed notable improvements in health services, mainly as a result of the opening of new hospitals, organisation of municipal medical services and, in general, an increase in local budget allocations. While the 1885 cholera epidemic accelerated the authorities' intervention in public health, it was only from the 1890s onwards that systematic action was taken to improve the water supply and sanitation.[16] In the years around 1890, mortality rates in the city of Barcelona were still higher than in the rest of the province. This pattern is also found in other Catalan and Spanish provinces (e.g. Ramiro-Fariñas and Sanz-Gimeno 2000; Reher 2001; Escudero and Nicolau 2014; Pérez Moreda et al. 2018; Ramon-Muñoz and Ramon-Muñoz 2022b).

If the information above on mortality reflects environmental conditions and, therefore, improvements in public sanitation and healthcare, one might hypothesise that the urban height premium we find for the cohorts born in late nineteenth-century Catalonia had little to do with "care and cure" factors. If so, the Catalan case would differ from some recent well-researched cases in northern Europe (e.g. Heyberger 2014; Groote and Tassenaar 2020). Nevertheless, the data we have at our disposal, namely crude mortality rates and the number of doctors per 1000 inhabitants at district (county) level ($n=35$), suggest that environmental factors may also have played a non-negligible role in explaining the Catalan urban–rural height gaps (Figs. 12 and 13). Crude mortality rates correlate negatively with height, and this bivariate correlation is statistically significant (p-value$=0.010$). The number of doctors per 1000 inhabitants correlates positively with height at district level, and once again the correlation is significant (p-value $= 0.001$). While both data sets tell the same story, the latter is not influenced by the age composition of the population and thus may be more accurate as a proxy for environmental conditions.

Another group of factors that might also explain the urban premium in late nineteenth-century Catalonia is to do with improvements in the quantity and quality of

[16] By the mid-nineteenth century, in Barcelona, the water supply and its network had increased substantially relative to the 1820s (Tello and Ostos 2012, p. 349). However, according to Guàrdia et al. (2014, p. 418), "technically speaking, the facility was not very different from the system that had existed (…) during ancient Roman times". From the 1860s onwards, several projects and works to improve and increase access to clean water also took place. They represented a breakpoint in water supply; and two of them have been considered "the beginning of the first (…) modern supplies provided by private companies in Barcelona" (Martín Pascual 2011, p. 70; the translation is ours). As for the first project, Matés-Barco (2019, p. 62, the translation is ours) also argued that the "incorporation of the modern drinking water system can be traced back to 1867, with the construction of the Torre de las Aguas [Torre de les Aigües, Water Tower] by the Sociedad de Crédito y Fomento de Barcelona [Barcelona Credit and Development Society]. By the early 1870s, another private company—the Companyia d'Aigües de Barcelona [Barcelona Water Company]—had a water network in operation that served two Barcelona neighbourhoods (Guàrdia et al. 2014, p. 419). This was the second modern project. Nevertheless, in the mid-1880s water supply and sanitation still showed "important deficiencies" (Martín Pascual 2011, p. 71, the translation is ours). Advances in sanitation appeared only later. A crucial decade in the organisation of the "fight against disease and death" was that of 1885–1895 (Capel and Tatjer 1991, p. 51). In 1884, the local authorities set up a Commission to analyse the situation of the sewage system, the conclusions of which were published in 1886; as a result, five years later, in 1891, a project for reforming this system was approved. In that year, a new project was also passed to increase water supply, partly to meet the expected sewer requirements. Nevertheless, it was only in 1902 that the renewal of the sewer system began (Guàrdia et al. 2014, p. 423). In addition, the available estimates show that per capita urban water consumption remained unchanged until the mid-twentieth century (Tello and Ostos 2012, p. 349).

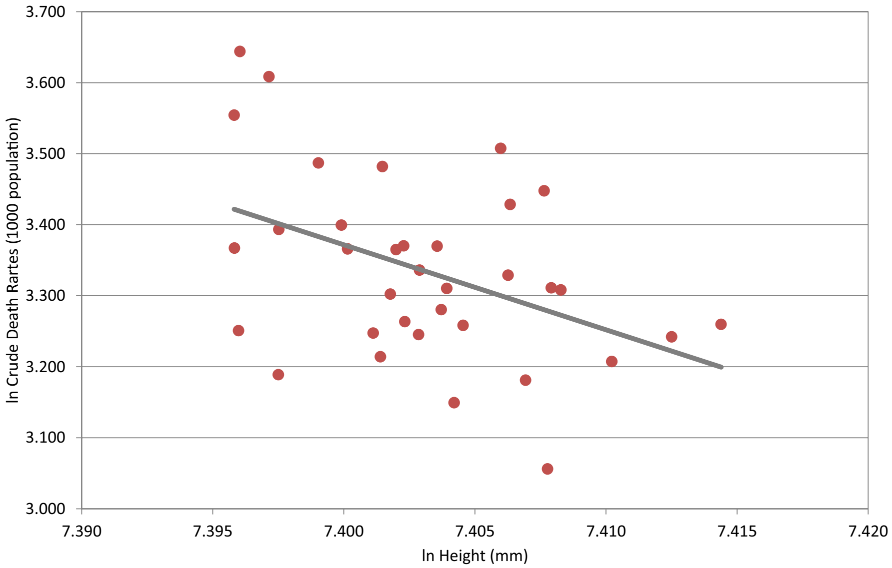

Fig. 12 Relationship between mean height (mm) and crude death rates (per 1000 population) in Catalonia by districts, c. 1890. *Notes and sources*: Instituto Geográfico y Estadístico (1895). The y and x axes display the data in logarithms

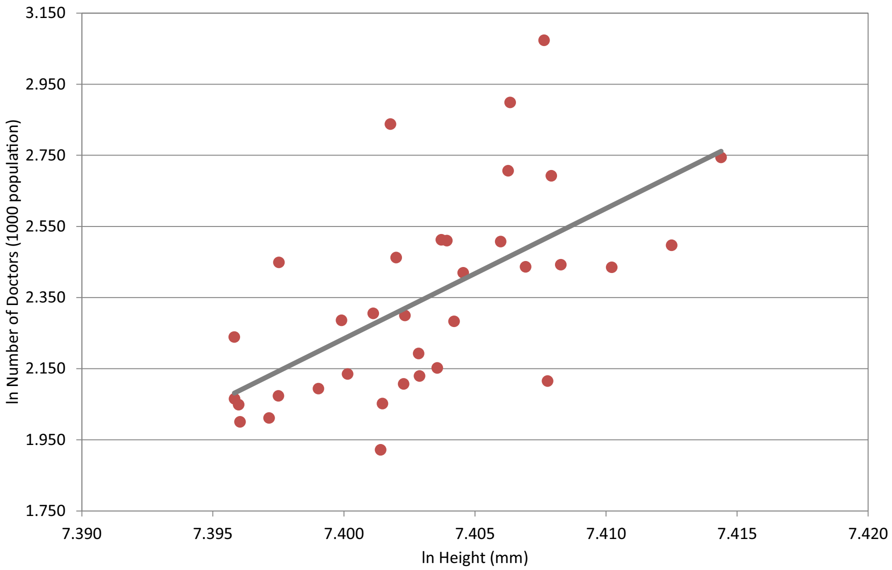

Fig. 13 Relationship between mean height (mm) and the number of doctors (per 1000 population) in Catalonia by districts, c. 1890. *Notes and sources*: Instituto Geográfico y Estadístico (1892). The y and x axes display the data in logarithms

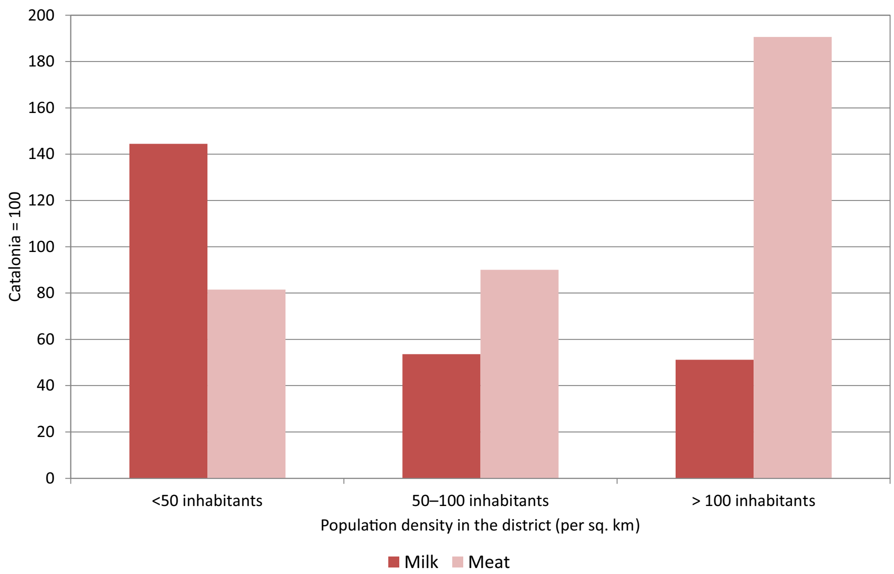

Fig. 14 Estimates of per capita consumption of milk and meat according to population density in Catalan districts, c. 1890 (Catalonia = 100). *Notes and sources*: See text

food availability for urban dwellers (e.g. see Steckel and Floud 1997b for an overview of the role of nutritional factors in explaining biological living standards). Table 5 shows that the overall influence of the railway on height is, in general, not statistically significant. The possibility that the results would have been different if we had used a different proxy for measuring the impact of railways on height cannot be ruled out (Heyberger 2014). In fact, the existing evidence suggests that food availability improved in the last decades of the nineteenth century, thanks above all to the greater intake of high-protein products (e.g. Cussó and Garrabou 2004, p. 73). Estimates in Barcelona, for example, show that per capita meat consumption increased by 44 percent between 1881 and 1900; and perhaps more importantly, per capita milk consumption more than tripled between 1865 and 1900 (Nicolau and Pujol 2005, p. 117; Hernández-Adell and Pujol 2017, p. 89). Milk is a high-protein product, whose intake has been, in general, positively associated with physical stature (e.g. Takahashi 1984; Baten 2009; de Beer 2012).

This rapid increase in the availability of high-protein products deserves further comment. As expected, our preliminary estimates based on the available Spanish cattle censuses (Giralt 1990) show that, by the turn of the nineteenth century, per capita milk consumption (as proxied by milk availability) was still higher in the rural areas of northern Catalonia than in urban centres such as Barcelona (Fig. 14), although it was in the districts with higher population density where per capita consumption had grown the most since the 1860s (Fig. 15). In addition,

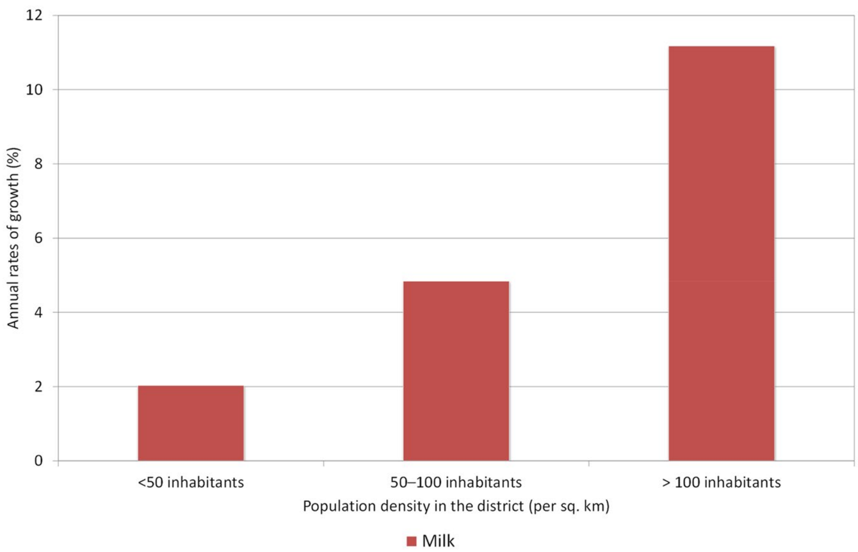

Fig. 15 Estimates of the increase in per capita milk consumption according to population density in the Catalan districts, 1865–1891 (annual rates of growth, %). *Notes and sources*: See text

the same estimates suggest that, as far as meat is concerned, per capita levels of consumption were lower in rural than in urban districts. These estimates are based on cattle slaughtered in slaughterhouses for public consumption, a measure which probably underestimates the consumption of meat products in rural areas. In spite of this, the higher levels of per capita meat consumption in cities do not seem surprising in the light of the available evidence for Spain (e.g. Pérez Moreda et al. 2018 p. 312).

5 Conclusions

This study has explored whether (and if so, to what extent) there was an urban–rural height gap in the north-eastern Iberian region of Catalonia in the nineteenth century. By using long-term data on heights, it first showed that as industrial production grew between the early 1840s and the late 1860s urban heights declined and that urban dwellers remained on average shorter than their rural counterparts. These findings suggest both the existence of an "early industrial growth paradox" and the emergence of an "urban penalty" in the middle decades of the nineteenth century. From the late 1860s onwards, urban heights began an upward trend and in the last quarter of the nineteenth century the previous urban penalty turned into an urban premium.

The urban height premium which emerged in Catalonia in the last quarter of the nineteenth century is further confirmed by the construction of a unique new dataset consisting of almost 18,000 observations for the cohort of males born in the year 1890 and enlisted in the year 1911 and covering almost all the municipalities that form present-day Catalonia. The broad geographical coverage of our dataset represents a real novelty in the context of historical anthropometrics in Iberia. It also represents a step forward in the existing international literature on the topic. A long list of publications have focused on the decades before the mid-nineteenth century, showing the emergence of an urban height penalty. Unfortunately, this list is considerably shorter for the last decades of the nineteenth century, and this circumstance has prevented us from establishing with clarity when an earlier urban height disadvantage might have transformed into a premium.

By applying cross-sectional data and an ordinary least squares (OLS) model, the urban premium is confirmed after controlling for population density, presence of a rail station, distance to seaports, literacy rate, and altitude. The results of our test show an urban premium of between one-half and three quarters of a centimetre for young males living in cities ($>$20,000 inhabitants) compared to those residing in rural areas ($\leq$5000 inhabitants), which, though moderate, is not unsubstantial if we place this height difference in a broader context. Gaps of similar magnitude were not uncommon in nineteenth-century Europe. In terms of economic outcomes, the implications of this urban–rural height differential do not seem negligible, as discussed throughout the previous sections. A linear relationship between physical stature and population size is, nevertheless, not observed when control variables are included in the regressions. Other studies using large samples have suggested a lack of a linear relationship between height and population size, and this also seems to be the case of Catalonia.

The main findings of this research contribute to the literature on industrialisation, living standards and urban–rural inequality in physical stature in several ways. First, they qualify previous studies suggesting the absence of an urban penalty in the Iberian Peninsula.[17] While the economic growth pattern in Catalonia differed from most Iberian regions, the same applies to the urban–rural height gap. Although very tentative and subject to qualifications, the comparative evidence presented in this article points to this direction: it suggests that in late nineteenth-century Spain, less industrialised areas tended to experience higher urban height advantages. In the international context, we also find a distinctive pattern in Catalonia relative to eastern Belgium, Württemberg, and Switzerland, where scholars have found a permanent urban premium in the nineteenth century.

Second, we found that Catalonia appears to have overcome the adverse health effects caused by urban agglomerations rather earlier than might perhaps have been expected. It has been argued that "urban populations were generally shorter than

[17] See Sect. 1 for references.

rural ones until the early twentieth century" (Komlos and Baten 2004, p. 195; see also Komlos 1998). However, by controlling for several variables, we can confirm that in Catalonia, a qualified urban premium had already emerged for the 1890 birth cohort. Interestingly, comparing our case study with areas that also experienced an urban penalty, we also found the emergence of an urban premium earlier than in some territories in Britain, France, Spain and perhaps also Germany, but in line with other regions and countries in northern Europe; in Scotland, Alsace, and the Basque province of Biscay for example, urban dwellers remained generally shorter than their rural counterparts until the first decades of the twentieth century. In our study, we confirm an urban height premium in Catalonia for the male cohorts born in 1890. We also report notable similarities between Catalonia and the Netherlands, which places Catalonia in the context of the European regions that experienced a transition from an urban penalty to an urban premium during the second half of the nineteenth century. Sweden followed the same transition as Catalonia and the Netherlands. Nevertheless, in the case of Sweden, we can only confirm an absence of height disadvantages for urban males in the first years of the twentieth century.

Third, in comparing Catalonia with other European regions, this paper shows that several patterns emerged in nineteenth-century Europe in the relationship between population size and height. As observed, this pattern may vary substantially within the same country, a fact which underlines the relevance of the regional analysis in strengthening and sometimes qualifying approaches based on broader geographical classifications. For the same reason, it also highlights why regions follow one pattern or another in height inequality according to the type of settlement and, as suggested when comparing regions in Spain, according to regional productive specialisation.

Fourth, this paper has also explored the reasons why urban dwellers in late nineteenth-century Catalonia were taller than their rural counterparts. At present, we can only hypothesise that internal migration exerted no clear effect. Further analysis should confirm whether the urban height premium in late nineteenth-century Catalonia is better explained by the epidemiological environment or by nutritional factors, and, if so, to what extent.

Finally, this research has provided new insights into the urban–rural divide in well-being in areas and over a period of critical economic transformations, such as nineteenth-century Europe. Using a rich new dataset and focusing the analysis on the late nineteenth century, this paper has shown that a binary classification of population settlements may be misleading. When it emerged, the urban–rural gap was not linear; it was associated with a kind of threshold from which population size differences translated into differences in biological living standards. Moreover, this urban–rural gap could change its direction over time. By extending and focusing the analysis of the urban–rural height gap to the last decades of the nineteenth century, this research suggests that, in Europe, an urban height premium may have emerged earlier and may have been more widespread, than previously believed.

Appendix

Table 8 The impact of population size on male heights in Catalonia in the cohort born in 1890 (dependent variable: individual male height, mm)

Variables	(A)	(B)	(C)
Population size			
≤ 2000 inhabitants	− 5.544***	− 4.941***	− 7.303***
	(1.947)	(1.817)	(2.800)
2001–5000 inhabitants	− 5.434***	− 4.805***	− 6.559***
	(1.815)	(1.660)	(2.388)
5001–10,000 inhabitants	−3.876	− 3.273	− 4.879
	(3.097)	(3.076)	(3.386)
10,001–20,000 inhabitants	− 3.264	− 2.588	− 4.188
	(2.930)	(2.614)	(2.679)
> 20,000 inhabitants	Ref	Ref	Ref
Population density	– 0.000		
	(0.001)		
Area			− 0.021
			(0.018)
Literacy rate	0.039	0.034	0.007
	(0.095)	(0.093)	(0.100)
Railway stations	0.162	0.156	0.147
	(0.138)	(0.136)	(0.135)
Distance from a port	– 0.000	– 0.000	– 0.000
	(0.000)	(0.000)	(0.000)
Altitude	− 0.013***	− 0.013***	− 0.013***
	(0.004)	(0.004)	(0.004)
Dummies at territorial level	Yes	Yes	Yes
Constant	1647***	1646***	1649***
	(4.489)	(4.405)	(5.787)
R-squared	0.010	0.010	0.011
Observations	17,968	17,968	17,968

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Clustered robust standard errors in brackets. For comparative purposes, column A includes the results already shown in Table 5, column 7

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Declaration

Conflict of interests No conflict of interest.

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