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Received wisdom versus reality: height, nutrition, and urbanization in mid-nineteenth-century France

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Abstract	Since the pioneering study of Le Roy Ladurie and his team, the idea that mean height can be considered as a reliable indicator of the standard of living has emerged from a long debate among historians and economists. Considering height in this respect, nineteenth-century France, unlike most Western countries, did not pay an urban penalty. Thanks to a substantial set of individual data (105,324 observations), based on the draft lottery of Frenchmen born in the year 1848, we are able to prove that this “French exception” did not, in fact, exist. The larger the town, the shorter were the conscripts. Among the towns, Paris had the shortest conscripts. By combining individual data with the agricultural survey of 1852, we are able to identify those factors that compensated for this urban penalty—that were positively correlated with height: nutritional availability, the literacy rate, and life expectancy.
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2 **Received wisdom versus reality: height, nutrition,**
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7 **Abstract** Since the pioneering study of Le Roy Ladurie and his team, the idea that
8 mean height can be considered as a reliable indicator of the standard of living has
9 emerged from a long debate among historians and economists. Considering height
10 in this respect, nineteenth-century France, unlike most Western countries, did not
11 pay an urban penalty. Thanks to a substantial set of individual data (105,324
12 observations), based on the draft lottery of Frenchmen born in the year 1848, we are
13 able to prove that this “French exception” did not, in fact, exist. The larger the
14 town, the shorter were the conscripts. Among the towns, Paris had the shortest
15 conscripts. By combining individual data with the agricultural survey of 1852, we
16 are able to identify those factors that compensated for this urban penalty—that were
17 positively correlated with height: nutritional availability, the literacy rate, and life
18 expectancy.

21 **1 Introduction**

22 Since Le Roy Ladurie’s pioneering study of early-nineteenth-century French
23 conscripts (Aron et al. 1972), further research, undertaken in the field of
24 anthropometrics, has revealed that during the first phase of industrialization, the
25 mean height (a measurement that is considered a reliable indicator of net nutrition)
26 of both Europeans and Americans declined, despite the fact that the standard
27 economic indexes indicate that the standard of living was stable if not rising: a pair
28 of phenomena known, respectively, as the early-industrial-growth puzzle and the
29 Antebellum puzzle (Komlos 1998; Steckel 1998).

30 Historians in the field of anthropometrics have yet to reach a consensus
31 concerning this paradox of a height decline during a period of economic growth,

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32 although market integration and the rapid pace of urbanization are frequently
 33 mentioned as key factors. That the urban setting had a negative influence on height
 34 has been established by numerous studies of capital cities throughout the world.¹
 35 For Komlos, urbanites were relatively short during the early stages of industrial-
 36 ization not only because they consumed fewer calories and less protein than did
 37 their rural counterparts (on account of the higher cost of food in the urban market)
 38 but also because the supply systems were inefficient, favoring both producers and
 39 consumers on the market's periphery when it came to variety and quality as well as
 40 to price (Komlos 1995, 2003). For Steckel, Riley, and the like, gross nutrition—
 41 nutritional intake—is not the only explanation: one must also take into consideration
 42 the unfavorable epidemiological context of urban areas. (Komlos 1995, 2003). In
 43 the absence of a sewage system, of piped drinkable water, and of the public-health
 44 reforms instigated by the discoveries of Pasteur, the extremely dense population of
 45 nineteenth-century cities meant that contagions were far more frequent and spread
 46 far more rapidly there than in the countryside.

47 In this respect, France would seem to be a rare double exception, in that she is one
 48 of the few countries in which industrialization was not directly correlated with an
 49 overall height decline and, moreover, in which, along with Spain, the concomitant
 50 urbanization was in fact directly correlated with taller heights (Van Meerten 1990;
 51 Weir 1997; Martínez Carrión and Moreno-Lázaro 2007). Spain and France would
 52 seem to constitute a sort of latter-day version of an archaic Latin model whereby, in
 53 the absence of genuine industrial growth, small towns would benefit from their status
 54 as centers of traditional administrative, financial, and commercial concerns, since
 55 such a thriving economy would generate a relatively elevated standard of living, as
 56 indicated by a relatively elevated mean height.² However, it has been proved that
 57 certain regions of France experienced a height decline at the end of the eighteenth
 58 century or during the first half of the nineteenth century; a number of researchers,
 59 equipped with very different analytical techniques, have demonstrated that Parisians
 60 were shorter than their rural counterparts (Koch and Schubert 2011; Heyberger 2007;
 61 Komlos 1993; Soudjian 2008; Postel-Vinay and Sahn 2010).

62 The purpose of this study is to gauge, by applying to the hitherto blurred and
 63 obscure field of explanatory factors a new and improved analytical gauge, permitting
 64 an analysis with a resolution far finer than that of previous analyses, which as a rule
 65 have got no closer than the departmental-data level—the impact of urbanization on
 66 the height of French conscripts born in the middle of the nineteenth century.³ The
 67 crux of our analysis is a comparison of the influence on height of nutritional
 68 availability (protein and calories) and energy expenditure (diseases, in an epidemi-
 69 ological context). We incorporate ancillary evidence of the importance of factors
 70 such as literacy as determinants of net nutrition that there is a correlation as
 71 demonstrated in the case of France both by Weir and by Postel-Vinay and Sahn but is

1FL01 ¹ Australia (Whitwell et al. 1997), Canada (Cranfield and Inwood 2007), Germany (Cinnirella 2008),
 1FL02 northern Italy (A'Hearn 2003), UK (Floud et al. 1990; Riley 1994; Ó'Gráda 1996), and the US (Haines
 1FL03 1998; Chanda et al. 2008).

2FL01 ² This was also the case in Munich-Bavaria (Baten 1999a, 2009).

3FL01 ³ A French department is roughly the size of a county.

72 often neglected in analyses of other countries (Weir 1997; Postel-Vinay and Sahn
 73 2010). We also discuss the relative impact on height of nutritional elements in terms
 74 of both diet and nutritional availability. By “diet”, we mean the consumption of
 75 foods of particular importance for anthropometric growth, chiefly milk (in line with
 76 Baten’s “milk hypothesis”: Baten 1999a, b, 2009; Baten and Murray 2000; Baten
 77 and Komlos 2004), and by “nutrition”, an estimate of nutritional availability broken
 78 down into its various elements (calories, protein, etc.).

79 Given that France’s national railway system was being constructed during the
 80 growth years of the conscripts in this study, we also consider what impact it may have
 81 had on height, since it has been shown that in the US, the development of the railway
 82 system was correlated with shorter height (Haines 1998; Haines et al. 2003). Finally,
 83 when it comes to methodology, since recent research underlines the necessity of
 84 calling into question the postulate of normality on the basis of anthropometric
 85 history,⁴ we compare our regressions by making the endogenous variable the mean
 86 height, on the one hand, and the stunted proportion of conscripts, on the other.⁵

87 For anybody intending to tackle these questions, the nineteenth century offers an
 88 array of resources. It is certainly true that throughout the century, France remained an
 89 essentially rural country, the urban population being smaller than the rural one until
 90 as late as 1931; nevertheless, it was as early as the reign of Napoleon III (1852–1870)
 91 that massive immigration, draining the countryside of its agricultural workforce,
 92 caused an urban population explosion.⁶ According to Soudjian (2008), the Parisian
 93 conscripts’ mean height declined over the course of the first half of the century,
 94 reaching its nadir with the 1851/1852 birth cohorts.⁷ The same chronological pattern
 95 prevailed in Mulhouse, “the French Manchester,” and the explanation for it is not a
 96 massive influx of poor peasants (Heyberger 2007). Since our data set consists of
 97 measurements of conscripts born in 1848, it permits us to calculate the net-nutrition
 98 level in French towns and cities at what seems to be—according to these two pieces
 99 of anthropometric evidence and from an anthropometric angle—the most critical
 100 moment in the half-century-long period of industrialization.

101 The middle of the century also marked a rupture in the organization of the
 102 market, which may have contributed to the evolution of anthropometrical trends on
 103 a larger time scale.⁸ Until mid-century, wheat, which had always been the basis of

4FL01 ⁴ In regard to this postulate, see Komlos 2004; on the issue of calling into question, see A’Hearn et al.
 4FL02 (2009) and Postel-Vinay and Sahn (2010).

5FL01 ⁵ We accept the definition of “stunted” found in Postel-Vinay and Sahn (2010), since this figure is
 5FL02 considered generally valid. It corresponds to conscripts “whose heights were less than or equal to
 5FL03 1.6247 m, which corresponds to -2 standard deviation scores of the WHO growth standards.”

6FL01 ⁶ The percentage of the French population living in a town or city (defined as an agglomeration of 2,000
 6FL02 or more persons) increased from 25.5 % in 1851 to 34.8 % in 1881 and then to 41 % in 1901 (Bourillon
 6FL03 1992).

7FL01 ⁷ Komlos reaches the same conclusion regarding the socio-economically privileged students of the Ecole
 7FL02 Polytechnic (Komlos 1993). It is therefore extremely likely that the reasons for this decline were
 7FL03 epidemiological and affected the entire urban population (conscripts and students), rather than nutritional,
 7FL04 the effect of which would have been in indirect proportion to one’s socio-economic level and thus would
 7FL05 have had a greater impact on conscripts than on students.

8FL01 ⁸ On transportation and the transformation of the agricultural market system, see Renouard (1960),
 8FL02 Grantham (1997), Laurent (1978), Margairaz (1982), Demonet (1990), Persson and Ejrnæs (2000).

104 the French diet, was undoubtedly marketed throughout the country, but mostly (all
 105 but 13 %) at the local—district or *arrondissement*—level, not far from where it had
 106 been harvested.⁹ Improvements in agriculture and hence diet were virtually
 107 nonexistent (Toutain 1971; Grantham 1995; Morineau 1971, 1972, 1974). In 1850,
 108 the diet of the vast majority of the French population consisted of an age-old diet in
 109 which protein was derived primarily from grains, but this was about to change, for
 110 the second half of the century would be notable for an unprecedented increase in the
 111 consumption of foods, chiefly meat and milk, that provide animal protein (Bonnain-
 112 Moerdijk 1975; Toutain 1971).

113 When it comes to conjunctures of crises, the mid-century in France, and
 114 elsewhere in Europe as well, was marked by a series of crises that were agricultural
 115 as well as demographic. Nevertheless, when height is considered at the national
 116 level, one finds no difference between the 1848 birth cohort and the previous birth
 117 decade—surprising, since one would expect a height decline during such hard times,
 118 due to an increase in the malnutrition of the poorest.¹⁰ Furthermore, at the local
 119 level, there is no evidence that the 1848 birth cohort represents the worst year of the
 120 century.¹¹ It is therefore not evident that these crises have any particular impact on
 121 the height of young men born in 1848.

122 2 The sources and the data set

123 In the models that we have constructed, the endogenous variable is the individual
 124 stature or the average height of conscripts and the explanatory variables are the
 125 conscripts' profession and educational level, the degree of urbanization and the
 126 presence or absence of a railway line in their canton of residence, the nutritional
 127 availabilities at the district level, the department of residence, and the infantile
 128 mortality and life-expectancy rates at the departmental level. The agricultural
 129 survey of 1852 presented data at the district—*arrondissement*—level, not just the
 130 departmental one, as would be the case with later surveys, thus providing us with a
 131 correspondingly more detailed picture of the standard French diet (Ministère de
 132 l'agriculture, du commerce et des travaux publics 1858 and 1860). Thanks to this
 133 survey—which, when it has been tapped for its statistics, has proved to be extremely

9FL01 ⁹ Demonet (1990). Nineteen percent of all foodstuffs were marketed outside the district in which they
 9FL02 were produced, and wheat constituted more than a third of such non-local commerce.

10FL01 ¹⁰ Mean height birth cohorts 1838–1847: 164.7 cm; mean height birth cohort 1848: 164.7 cm (Weir
 10FL02 1997).

11FL01 ¹¹ For those who could be considered among the shortest in France (Saint-Yrieix and Bellac districts,
 11FL02 department of Haute-Vienne, Limousin), the century minimum is not reached with the 1848 birth cohort
 11FL03 but with that of 1826; as for the tallest (Melun district, department of Seine-et-Marne, Ile-de-France), the
 11FL04 century maximum is reached in 1856, after three decades of growth, whereas for Mulhouse (department
 11FL05 of Haut-Rhin, Alsace), the only urban area included in this regional analysis, height declined during the
 11FL06 first half of the century and did not touch bottom until 1859 (Heyberger 2005).

137 reliable (Désert 1975; Demonet 1990; Postel-Vinay and Robin 1992)—we have
 138 been able to construct the nutritional variables of our models at the district level¹²:
 139 variables that permit us to gauge the nutritional availability according to
 140 consumption patterns of both grains and meat and fish, the two principal sources
 141 of calories and proteins.¹³ Our estimate of calcium availability is based on cow's-
 142 milk production, excluding Paris's consumption of dairy products.¹⁴

143 Our purpose in using this variable is to test the nutritional importance of milk—
 144 Baten's "milk hypothesis"—on anthropometric growth. Milk constitutes an
 145 inexpensive and nutritionally complete product, rich in both proteins and calcium,
 146 and therefore may be, when it comes to such growth, the most important of all
 147 animal-protein sources. We also have production figures for vegetables, including
 148 potatoes, but they are of little importance as sources of nutrition at the national
 149 level, even if potatoes were far more consumed in some regions of our sample.¹⁵
 150 Because the agricultural survey does not provide data for the city of Paris which

12FL01 ¹² See Table 1. Other variables have been incorporated into models that are not included here for lack of
 12FL02 satisfactory results: the annual number of work hours attributable to child labor, the extent of the
 12FL03 migration of agricultural workers between districts, and various estimates of agricultural wages (whether
 12FL04 real or nominal). It is surprising that there are no definitive results regarding wages, since their impact has
 12FL05 been convincingly demonstrated at the departmental level (Weir 1997; Postel-Vinay and Sahn 2010). One
 12FL06 possible explanation is that agricultural wages increased significantly during the reign of Napoleon III,
 12FL07 benefiting members of the 1848 birth cohort shortly before they were measured as part of the conscription
 12FL08 process, and thus blurring the height-wages correlation that might have been evident in 1852, when the
 12FL09 conscripts were just toddlers. It is unfortunate that the agricultural surveys undertaken during the 1860s
 12FL10 do not provide district-level wage data, which would have permitted us to test this hypothesis. Moreover,
 12FL11 it is important to bear in mind that our analysis of the relation between height and agricultural wages is
 12FL12 based on a more local division (France counts 363 districts spread among 86 departments), capable of
 12FL13 generating different results, than has previously been used. The proportion of agricultural workers varies
 12FL14 considerably from one district to another; in fact, it is nonexistent or nearly so in a number of districts
 12FL15 despite their being essentially rural. The composition of the active population is thus too complex and
 12FL16 varied at the district level for the wages of a given category of workers to have a significant impact on
 12FL17 individual height. For the same reason, even though the regressions conducted at the individual level (the
 12FL18 endogenous variable being individual height) demonstrate the importance of the job structure as a factor
 12FL19 in the anthropometric disparities that we observe, the introduction of job-category variables into the
 12FL20 regressions conducted at the aggregated level (the endogenous variable being mean height per district)
 12FL21 does not provide an explanation of those disparities. In fact, the two categories that not only are the most
 12FL22 populous but also compose the shortest mean-height category (agricultural and textile workers) constitute
 12FL23 such a small proportion of the total that their introduction as a poverty-level marker does not improve the
 12FL24 models' capacity to explain the situation.

13FL01 ¹³ We have given priority to the methodology and hypotheses of Demonet (1990) since they are more
 13FL02 plausible than those of Toutain (1971), but we turned to the latter whenever Demonet's seemed to
 13FL03 overestimate or underestimate some figures in comparison with what is usually used in international
 13FL04 standard consumption studies. For a detailed presentation of the methodology adopted for the conversion
 13FL05 of the agricultural-survey data into nutritional availability, see Heyberger (2009).

14FL01 ¹⁴ By the nineteenth century, Paris was already the largest city in France. The 1851 census numbered the
 14FL02 city's population at more than a million, far ahead of second-place Marseille, at only 195,257 (Le Mée
 14FL03 1989).

15FL01 ¹⁵ For France taken as a whole, potatoes furnished a daily supply of only 86 calories per capita but our
 15FL02 sample includes 6 of the 10 departments where the per capita rate was the highest (150 calories and
 15FL03 above: Hautes-Alpes, Aveyron, Moselle, Bas-Rhin, Haute-Vienne and Vosges). All of the production-
 15FL04 based estimates exclude animal consumption when necessary. The calculation of the entire collection of
 15FL05 estimations (whether they are based on production or consumption figures) takes into account losses due
 15FL06 to storage and transport and includes only edible parts of foodstuffs.

151 would permit us to calculate the nutritional content of the diet there, we have instead
152 used the reference work of Armand Husson.¹⁶

153 The draft-lottery lists for the 1868 “classes” include the other important source
154 for this study.¹⁷ These individual records, which date from early 1869, provide us
155 with the height, profession, educational level, and canton in which the conscripts—
156 comprising Frenchmen born in 1848 and still alive in 1868—legally reside.¹⁸ The
157 individual data contained in the lists drive from 45 departments spanning the
158 country (Fig. 1). For the purposes of this analysis, we have selected 105,324
159 individual conscript files, spanning 134 districts that together constitute 41.6 % of
160 the total French population at the time of the 1851 census.¹⁹ Our sample is not a
161 random sample, rather a “convenience sample”.²⁰ However, it is large enough to
162 make historical arguments about the populations as a whole (Table 1).

163 The mean height in our sample is 165.61 cm (Table 2),²¹ whereas the median
164 height of Weir’s 1848 birth cohort is only 164.70 cm (Weir 1997). The average of
165 the sample is thus somewhat taller, and by extension better off, than the average for
166 the whole of France. This is quite surprising, since this sample covers to an equal
167 extent departments both to the north and to the south of the Saint-Malo-Genève line
168 (Fig. 1).

169 The pioneering study of Dupin (1827) proved that Frenchmen living to the south
170 of this line were, as a rule, shorter than their northern counterparts.²² However, the
171 average height of the southern conscripts in this sample is the same as Weir’s
172 national average (164.6 cm, $N = 53,910$), even though the poorest regions, Brittany

16FL01 ¹⁶ Husson (1856). In converting Husson’s food-consumption data into nutritional intake, we respect both
16FL02 his hypothesis (in regard to the proportion of those who purchased their food at markets in and around
16FL03 Paris—with the exception of certain categories, such as hospitals and military units—black-market
16FL04 transactions both *extra* and *intra muros*, etc.) and the methodology used in the agricultural survey.

17FL01 ¹⁷ They are preserved in the series R of the departmental archives, located in the prefecture of each
17FL02 department.

18FL01 ¹⁸ See Table 2. For a complete presentation of this type of source, see Heyberger (2005). The French
18FL02 administrative units are, from smallest to largest, the commune, the canton, the district, and the
18FL03 department; thus, canton-level data provide a high degree of material detail and hence permit an equally
18FL04 high degree of analytical accuracy.

19FL01 ¹⁹ Because we lack data permitting us to calculate nutritional availability on a scale smaller than that of
19FL02 the commune, the urban districts of large cities are combined into one. In selecting the 134 districts, we
19FL03 rejected those whose registers included height data for fewer than 100 conscripts—certain registers being
19FL04 incomplete or even blank, on account of bureaucratic negligence—and those in which the distribution of
19FL05 height below the mean was not normal. (The fact that heights below the military’s minimum of 155 cm
19FL06 were not always recorded goes far to explain the small size of certain standard deviations.) It is necessary
19FL07 to impose these selection criteria if one intends to compare the pattern of average height with that of the
19FL08 stunted percentage in regressions that, for the same reason, also have to display exactly the same
19FL09 explanatory variables and N of endogenous variables. In addition, we eliminated one district in which the
19FL10 conscripts’ educational level could not be determined, since without this information, we could not
19FL11 calculate the literacy rate, a figure needed for the aggregate-level regressions.

20FL01 ²⁰ The 35 student volunteers who helped me to collect the data, between 2004 and 2008, did so in
20FL02 departments of their own choosing, based on their geographical origins or family ties. I myself collected
20FL03 data in 10 departments (Bouches-du-Rhône, Corrèze, Creuse, Loire-Inférieure, Maine-et-Loire, Moselle,
20FL04 Bas-Rhin, Haut-Rhin, Seine-et-Marne, and Haute-Vienne).

21FL01 ²¹ Standard deviation: 6.43 cm.

22FL01 ²² Weir’s data are not published at the departmental level.

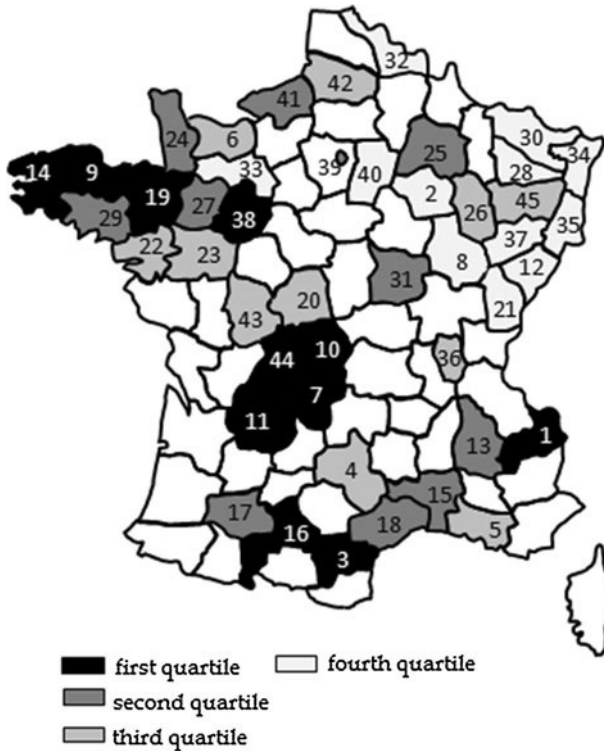


Fig. 1 First quartile: 162.24–164.49 cm; second quartile: 164.55–165.60 cm, third quartile: 165.69–166.80 cm, fourth quartile: 166.88–169.2 cm. *Source* see note 17. 1 Alpes (Hautes), 2 Aube, 3 Aude, 4 Aveyron, 5 Bouches-du-Rhône, 6 Calvados, 7 Corrèze, 8 Côte-d’Or, 9 Côtes-du-Nord, 10 Creuse, 11 Dordogne, 12 Doubs, 13 Drôme, 14 Finistère, 15 Gard, 16 Garonne (Haute), 17 Gers, 18 Hérault, 19 Ille-et-Vilaine, 20 Indre, 21 Jura, 22 Loire-Inférieure, 23 Maine-et-Loire, 24 Manche, 25 Marne, 26 Marne (Haute), 27 Mayenne, 28 Meurthe, 29 Morbihan, 30 Moselle, 31 Nièvre, 32 Nord, 33 Orne, 34 Rhin (Bas), 35 Rhin (Haut), 36 Rhône, 37 Saône (Haute), 38 Sarthe, 39 Seine, 40 Seine-et-Marne, 41 Seine-Inférieure, 42 Somme, 43 Vienne, 44 Vienne (Haute), 45 Vosges

173 and the Limousin, are included—if also the relatively prosperous southern
 174 departments, such as Rhône and Bouches-du-Rhône—whereas the northern
 175 conscripts were somewhat taller (166.6 cm, $N = 51,414$, see Fig. 1). Nevertheless,
 176 one must bear in mind that here we are comparing our data set (the individual
 177 heights of all the young men born in 1848 and still alive in 1869) with that of Weir
 178 (the median height of all of those deemed fit for service). It seems only logical that
 179 the median height of those conscripts deemed fit for service would have been greater
 180 than the average height of the entire birth cohort; one must not forget that Weir had
 181 to correct his data because of the minimum-height requirement, which may have
 182 made for underestimation, and above all that the aggregated data used by Weir are
 183 apparently unreliable: “the observed distribution diverges, sometimes to a
 184 ridiculous extent, from the bell curve (Bassino and Dormois 2009, p. 113; see
 185 also Duclos et al. 2011), whereas in our data, the distribution of the individual

Table 1 Variables observed at the canton or district of residence level used in Tables 4 and 5 (names, definitions, and descriptive statistics)

Variable (V)	Definition	Mean	SD	N of observations ^a
Variables observed at the canton of residence level ($N = 1,057$ cantons)				
Railway 1853	Equal to 1 if conscript resides in a canton served by the railway in 1853			30,802
Railway 1868	Equal to 1 if conscript resides in a canton served by the railway in 1868			63,445
Urban				
Paris	Equal to 1 if conscript resides in Paris			8,347
Large towns (cities)	Equal to 1 if conscript resides in a city of more than 75,000 inhabitants			3,726
Medium-size towns	Equal to 1 if conscript resides in a town of 20,000 to 74,999 inhabitants			7,278
Small towns	Equal to 1 if conscript resides in a town of 5,000 to 19,999 inhabitants			18,050
Rural	Equal to 1 if conscript resides in a canton that does not contain a town			67,923
Variables observed at the district of residence level ($N = 134$ districts)				
Calorie availability	Mean daily calorie (cal.) availability per inhabitant	2,268	542	
Total protein availability	Mean daily total protein (g) availability per inhabitant	74.64	18.19	
Animal-protein availability	Mean daily animal-protein (g) availability per inhabitant	24.49	12.53	
Calcium availability	Mean daily calcium (mg) availability per inhabitant	437.45	333.67	
Crude nutrition Index	Mean of calories, vegetal-protein, animal-protein, and calcium availabilities indexes (in %) ^b	39.44	11.49	

Sources Ministère de l'agriculture (1858 and 1860), Le Mée (1989), Husson (1856); and see notes 17 and 24

^a In the case of binary variables, if $V = 1$

^b For each item, the index is calibrated from 0 (minimal value in absolute terms for the variable under consideration) to 100 (maximal value in absolute terms for the variable under consideration)

186 heights, checked by Komlos's recommended method (Komlos 2004), displays no
187 such anomalies.

188 A final, double, caution regarding our difficulties with these data: on the one
189 hand, in some departments, the extant height records at the district level are
190 incomplete; on the other hand, for reasons of methodology not all of those records
191 that were at our disposal could, in fact, be included.²³

192 By combing the conscription lists for all references to the conscripts'
193 employment status, we turned up more than 2,000 different job titles. In their

23FL01 ²³ See footnote 19.

Table 2 Variables observed at the individual level used in Tables 4 and 5 (names, definitions, and descriptive statistics)

Variable (V)	Definition	Mean	SD	<i>N</i> of observations ^a
Observed variables in the individual files (<i>N</i> = 105,324 conscripts)				
Height	Height in centimeters	165.61	6.43	
Occupation				
Artisan (misc.)	Equal to 1 if conscript is artisan (misc.), otherwise 0			5,045
Building trade	Equal to 1 if conscript works in building trade			6,357
Carpentry	Equal to 1 if conscript works in carpentry trade			6,615
Clothing manufacture ^b	Equal to 1 if conscript works in clothing manufacture			3,791
Employee ^c	Equal to 1 if conscript is employee			1,980
Farmer	Equal to 1 if conscript is farm-owner			37,845
Farm-worker	Equal to 1 if conscript is farm-worker			13,738
Industry	Equal to 1 if conscript works in industry (unspecified)			1,203
Metallurgy	Equal to 1 if conscript works in metallurgy sector			5,599
Mining	Equal to 1 if conscript works in mining sector			1,233
Misc.	Equal to 1 if conscript does not belong to any other professional category			4,036
Trader	Equal to 1 if conscript works in trade			3,228
Food-production trade	Equal to 1 if conscript works in food-production trade			3,679
Public education/clergy/white collar	Equal to 1 if conscript is teacher, member of clergy or white collar			1,306
Student	Equal to 1 if conscript is student			767
Textiles ^d	Equal to 1 if conscript works in textiles sector			5,101
Transportation	Equal to 1 if conscript works in transportation sector (land or sea)			2,731
Unknown	Equal to 1 if profession is unknown			1,070
Educational level				
Illiterate	Equal to 1 if conscript is illiterate (can neither read nor write)			21,595
Semiliterate	Equal to 1 if conscript is semi-literate (can read but not write)			2,603
Literate	Equal to 1 if conscript is literate (can read and write)			77,544



Table 2 continued

Variable (V)	Definition	Mean	SD	N of observations ^a
Educational level unknown	Equal to 1 if conscript's educational level is unknown			3,582

Sources see note 17

^a In the case of binary variables, if $V = 1$

^b Two first occupations: shoemakers ($N = 2,052$) and tailors ($N = 832$)

^c Two first occupations: employees ($N = 991$) and law-clerks ($N = 284$)

^d Involved in spinning, weaving, knitting, etc

194 research based on a nineteenth-century French data set of similar size, Dupâquier
195 and Pélissier encountered the same sort of job-description material; we have
196 therefore adopted their method of classification (Dupâquier and Pélissier 1992).
197 Selecting seventeen job categories was a necessary compromise between the need
198 for synthesis—in the face of such a huge number of specialties—and a need for
199 accuracy—faced with the social complexity that these data describe.

200 From the canton-of-residence variable, we are able to derive the living milieu and
201 railway variables, in line with the thresholds shown in Table 1.²⁴ These variables
202 are very finely calibrated, since a district in our sample consists, on average, of eight
203 cantons, whereas the average department, the size of which is roughly the equivalent
204 of a county, consists of four districts.

205 The threshold between “town” and “country” that we have chosen to apply
206 (5,000) is the one currently used by specialists in urban history and by certain
207 economic historians, because it distinguishes between rural villages and genuine
208 towns.²⁵ We have chosen to express the urbanization variable in its discrete form,
209 because this permits us to gauge it at each threshold, a measurement obscured by
210 Weir’s approach, without altering the sign associated with the coefficients of the
211 “town” variables.²⁶ Last but not least, this approach enables us to evaluate directly

24FL01 ²⁴ Sources: maps of the national railway system as it existed in 1853 and 1868 (Bibliothèque nationale de
24FL02 France, GE FF 9832 and VP-145) and Malte Brun (1881–1884) for the railway variables; and Le Mée
24FL03 (1989), for the urban and rural variables.

25FL01 ²⁵ The legal threshold, being much lower (2,000), does not permit this. See Pinol and Walter (2003); the
25FL02 entirety of Bairoch’s work since 1985; and Baten and Murray (2000). As for the upper threshold, we kept
25FL03 it at 75,000 so that we could categorize Lille (pop. 75,795) as a large city. The other threshold (20,000)
25FL04 was chosen in order to obtain an even size distribution of the various classes. In regard to the impact of
25FL05 these thresholds on the results, see also the next note.

26FL01 ²⁶ Because the urbanization rate in many of the cantons, and even in 29 of the districts, is at zero—a
26FL02 figure that cannot be converted into a decimal logarithm—we have used scaled-down samples to test the
26FL03 impact of urbanization, expressed as the urbanization rate and its logarithm; in both cases, the sign
26FL04 associated with the coefficient of the urbanization variable remains the same as the one that is observed
26FL05 when the urbanization variable is expressed in a discontinuous form. In the interests of brevity, we do not
26FL06 present the results in this paper.

212 and concretely—in cm—the impact on height of the socio-economic milieu of Paris
213 and other cities as well.²⁷

214 The railway variable indicates that a track crosses the canton, but not necessarily
215 the presence of a station. In nineteenth-century France, the construction of a railway
216 line could prompt the emergence of diseases new to the region which were liable to
217 sap the victims' strength and thus cause height to decline (Beaugrand 1874). In
218 order to factor in the totality of both the positive and the negative side effects of
219 railway construction, a railway-line model is more relevant than a railway-station
220 one. The population density of France greatly exceeded that of the US; it thus makes
221 sense to conduct an analysis of the French railway network's impact at the cantonal
222 level, since it is safe to assume that in France the lines ran through densely
223 populated regions and could be reached on foot in no more than one or 2 h; thus, the
224 canton-level data are sufficiently substantial to offer a far more accurate picture of
225 the situation than would those at the district level.²⁸ The variable was created in
226 order to gauge the impact of the railway network in its first year of existence (1853),
227 only a year after the 1852 agricultural survey, and coinciding with the infancy of the
228 conscripts, even though only 11.6 % of the rural ones lived in a canton that
229 benefited from a railway line.

230 Nevertheless, the national network was largely constructed during the reign of
231 Napoleon III; 43.9 % of the rural conscripts lived in a canton that benefited from
232 train service in 1868.²⁹ It is therefore important to measure the impact of the railway
233 in 1868.

234 A final point: Although the variables “life expectancy” at birth for female
235 (Bonneuill 1997) and infant mortality (Le Bras and Todd 1981) can be calculated
236 only at the departmental level (Table 3), they are crucial figures, providing the only
237 reliable approximations we have of the epidemiological environment and thus of the
238 average energy-expenditure rate.

239 One can, in fact, consider height to be a measure of net nutrition obtained by
240 subtracting expended energy from gross nutrition (Baten 1999a). These energy
241 expenditures range from basal metabolism to child labor by way of diseases
242 contracted during the growth years. Basal metabolism constitutes an irreducible
243 expenditure, whereas child labor is very difficult to quantify. An analysis of energy
244 expenditures therefore usually (including here) comes down to the impact of the
245 epidemiological context, estimated in terms of the infant mortality rate and life

27FL01 ²⁷ The breadth and depth of our sample—comprising as it does 5 of the 9 French cities with populations
27FL02 over 75,000 (in order of diminishing size: Paris, Marseille, Lyon, Rouen, Lille), numerous moderate-size
27FL03 ones (e.g., Aix-en-Provence, Montpellier, Amiens, Brest, and Limoges), and a raft of smaller ones,
27FL04 including Beaune, Fontainebleau, Gap, Nevers, and Saumur—goes far to ensure the reliability of our
27FL05 results regarding the influence of the urban milieu on height. In fact, the cities are markedly over-
27FL06 represented, since in 1851, the urbanization rate (using the population threshold of 5,000) of the 134
27FL07 districts is 35.5%, whereas the national average (using the legal population threshold: 2,000) is only
27FL08 25.5%.

28FL01 ²⁸ In the case of the US, the railway-line variable is analyzed at the county level (Haines 1998; Haines
28FL02 et al. 2003), or in some cases that of the state (Solakoglu 2007); such a large-scale dataset increases the
28FL03 risk of ecological fallacy.

29FL01 ²⁹ Between 1852 and 1869, the number of railway passengers increased eightfold, the quantity of freight
29FL02 more than 12-fold.



Table 3 Variables observed at the department of residence level ($N = 45$ departments) used in Tables 4 and 5 (names, definitions, and descriptive statistics)

Department ^a	Stature. N of observations	Infant mortality ^b	Life expectancy ^c
Alpes (Hautes)	533	239	31.2
Aube: Troyes*	760	293	45.8
Aude: Carcassonne	2,070	170	41.7
Aveyron	3,056	191	43.3
Bouches-du-Rhône: Aix, Arles, Marseille	3,316	284	38.4
Calvados: Caen*	1,298	180	47
Corrèze	875	165	28.1
Côte-d' Or: Dijon*	1,395	223	45.6
Côtes-du-Nord	5,222	240	36.4
Creuse	2,136	148	37.5
Dordogne	2,897	171	38.8
Doubs : Besançon*	990	177	40.4
Drôme	2,036	271	39.2
Finistère: Brest	4,349	195	30.5
Gard: Nîmes	2,313	263	41.8
Garonne (Haute) Toulouse*	1,050	170	41.7
Gers	573	179	40.9
Hérault: Montpellier	2,876	263	38.6
Ille-et-Vilaine: Rennes*	1,275	209	40.2
Indre	912	122	37
Jura	2,204	205	35.5
Loire-inférieure: Nantes*	811	145	41.8
Maine-et-Loire: Angers	2,914	163	40.7
Manche: Cherbourg*	533	141	42.2
Marne: Reims*	215	224	44.3
Marne (Haute)	851	254	48.9
Mayenne	2,976	148	41
Meurthe: Nancy*	1,122	199	42.9
Morbihan: Lorient	2,637	208	33.8
Moselle: Metz	3,328	174	46.1
Nièvre	2,105	155	35.2
Nord: Cambrai, Douai, Dunkerque, Lille, Roubaix, Tourcoing, Valenciennes	8,568	206	39.4
Orne	352	213	51.8
Rhin (Bas): Strasbourg*	1,538	295	39.8
Rhin (Haut): Colmar, Mulhouse	3,714	244	40.6
Rhône: Lyon	3,310	209	33.1
Saône (Haute)	1,273	181	43.2
Sarthe: Le Mans	3,191	184	43.4
Seine: Paris	9,159	456	30.9

Table 3 continued

Department ^a	Stature. <i>N</i> of observations	Infant mortality ^b	Life expectancy ^c
Seine-et-Marne	2,632	208	45.3
Seine-Inférieure: Le Havre, Rouen	4,982	365	41.8
Somme: Amiens	2,192	217	43
Vienne: Poitiers	1,052	133	42.1
Vienne (Haute): Limoges	1,530	173	28.9
Vosges	2,203	222	40.5
Mean		210.55	40.01
SD		61.99	5.16

Sources Le Bras and Todd (1981), Bonneuil (1997); and see note 17

^a Equal to 1 if conscript resides in the department named. For each department, the names of large and medium-size cities are indicated after the colon. In this case, an asterisk indicates that the draft-lottery lists do not include height for the cities concerned (see note 19)

^b 1861 per 1.000

^c 1846–1850 at birth

246 expectancy at birth. The impact of infantile diseases on adult height is all the greater
 247 in that it becomes apparent during the first 3 years of life, when the natural growth
 248 rate is at its peak (Tanner 1994). Thus, for the birth cohort of a given year, infant
 249 mortality, life expectancy at birth, and adult height are linked (Komlos 1998;
 250 Horlings and Smits 1997; Weir 1997; Haines 1998).

251 For our analysis, the use of Bonneuil's data seems to be more accurate, since the
 252 infant mortality figures seem to constitute an underestimation of the urban mortality
 253 rate, whereas those for life expectancy do not.³⁰

254 3 An apparent paradox: big cities make for tall citizens—but at what price?

255 Comparison of the gross-average figures reveals that urban–rural height differences
 256 were insignificant. Parisians (165.57 cm) were almost exactly the same height as
 257 their rural counterparts (165.59 cm), and even the inhabitants of other large cities
 258 (Marseille, Lyon, Rouen, Lille), who were the worst off of the lot, were only 3 mm
 259 shorter (165.26 cm). Those who seem to have benefited from the highest level of net
 260 nutrition were the inhabitants of medium-size and small towns (165.66 and
 261 165.76 cm, respectively), very slightly above the height of the entire sample
 262 (165.61 cm).

263 These results may seem surprising in light of the fact that, as we have already
 264 mentioned, the urban environment has been shown to have had a negative impact on

30FL01 ³⁰ There is no correlation between the Bonneuil and the Lebras and Todd figures ($R^2 = 0.00$). Thanks go
 30FL02 to Jean-Pierre Bardet for his comments concerning these demographic figures. Paris was the only large
 30FL03 city burdened with an urban penalty, if one uses the infant-mortality rate as the indicator (Seine: 456),
 30FL04 whereas Lyon (Rhône: 209) boasted a mortality rate below the average of the sample (210.55).



Table 4 Regressions at the individual level

	Model 1	SE	Model 2	Model 3	Model 4
Constant	166.27	0.04	165.30	164.93	160.12
Variables observed at the individual level					
Clothing manufacture	-0.89	0.11	-0.92	-1.09	-1.24
Industry	-0.58	0.19	-0.59	-0.98	-1.13
Textile	-0.32	0.09	-0.36	-0.80	-0.95
Mining	-0.32	0.18	-0.41	-0.50	-0.70
Building trade	-0.3	0.09	-0.33	-0.35	-0.43
Farm-worker	-0.23	0.06	-0.31	-0.63	-0.94
Artisan (misc.)	-0.15	0.10	-0.19	-0.43	-0.53
Farmer	Reference		Reference	Reference	Reference
Unknown	0.04	0.20	0.06	-0.07	-0.25
Transportation	0.07	0.13	0.02	-0.32	-0.41
Food-production trade	0.16	0.11	0.11	-0.06	-0.17
Metallurgy	0.23	0.09	0.20	-0.02	-0.17
Carpentry	0.23	0.09	0.20	0.04	-0.08
Misc.	0.51	0.11	0.48	0.29	0.21
Trader	0.64	0.12	0.61	0.38	0.26
Employee	1.64	0.15	1.58	1.37	1.25
Student	1.75	0.23	1.74	1.59	1.54
Public education/clergy/white collar	1.98	0.18	1.94	1.78	1.66
Literate	Reference		Reference	Reference	Reference
Illiterate	-2.44	0.05	-2.43	-2.23	-1.96
Semiliterate	-1.67	0.13	-1.64	-1.46	-1.31
Educational level unknown	-1.47	0.11	-1.39	-1.22	-0.67
Variables observed at the canton of residence level					
Paris	-0.91	0.08	-0.93	-2.60	-1.18
Large towns	-0.55	0.11	-0.41	-0.79	-0.51
Medium-size towns	-0.16	0.08	-0.09	-0.39	-0.29
Small towns	0.05	0.05	0.07	-0.01	0.06
Rural	Reference		Reference	Reference	Reference
Variables observed at the district of residence level					
Calories			0.00^a		
			(0.00/0.00)		
Animal protein				0.07	0.06
Variable observed at the department of residence level				(0.00/0.00)	(0.00/0.00)
Life expectancy					0.13
					(0.00/0.00)

Explanatory variables without dummies for departments

In bold font: significant at the 1 % level

^a Exact value: 0.0004

265 height during the first phase of industrialization in numerous countries and capital
 266 cities. Any lingering doubt regarding the sanitary conditions of nineteenth-century
 267 French cities is obliterated when one considers the grim female life-expectancy
 268 figures.³¹ It therefore seems paradoxical that the inhabitants of Paris and other
 269 French cities would be so tall relative to their rural compatriots.

270 In fact, as soon as one controls the influence of the conscripts' living milieu for
 271 occupations and educational levels, combined (Table 4) or separate (not reported
 272 here), one finds that an urban penalty existed in nineteenth-century France, just as it
 273 did in other countries. The larger the city, the higher was the penalty. If the raw data
 274 indicate that residents of Paris and other French large towns were as tall as their
 275 rural counterparts, this parity is in fact a function of their having attained a superior
 276 educational level and their having found jobs that paid better and were less
 277 physically taxing than agricultural labor, thus offsetting the urban penalty. On the
 278 other hand, the urban penalty was insignificant if not nonexistent in small- and
 279 medium-size towns, no doubt because these towns were too small for the negative
 280 effects of their expansion to translate into a decline in height of their inhabitants.

281 The coefficients associated with various job groups bear the sign that one would
 282 expect: the most advantaged were white-collar workers, whereas urban manual
 283 workers, paid a pittance, were at the bottom of the anthropometrical hierarchy.³²
 284 The beginning of the modern era, fundamentally industrial and urban, was thus
 285 accompanied by a widening of several anthropometric gaps, in conformity with
 286 Kuznets's hypothesis that economic inequality increases during the period of early
 287 industrialization. The height gap between craftsmen and farm-workers, employed as
 288 they were in traditional and rural sectors, was not as wide. Proximity to food sources
 289 helps to account for a relatively high nutritional level among farmers. On the other
 290 hand, those who prepared foods ("food-production trade": butchers, pastry cooks,
 291 bakers, et al.) did not enjoy a significant advantage, largely because this category
 292 was not exclusively one of independent artisans but included a considerable number
 293 of workers and apprentices as well.³³

294 The results obtained concerning the influence of profession and educational level
 295 on anthropometric inequalities provide a nuanced clarification of the issue of the
 296 role played by income inequalities on the height decline that occurred during
 297 industrialization. On the national scale, it is notably thanks to a favorable income
 298 structure and to a superior cultural capital—in other words, to an increase in the

31FL01 ³¹ Female residents of Paris (Seine) and Lyon (Rhône) had a life expectancy at birth of 30.9 and
 31FL02 33.1 years, whereas during the period 1846–1850, the average for the departments in our sample was
 31FL03 40.1 years (Bonneuil 1997). Over the long run, height is closely correlated with both life expectancy and
 31FL04 mortality, which in turn are very closely correlated with infant mortality (Komlos 1998; see also the
 31FL05 following studies for evidence of this correlation in particular countries: Hurlings and Smits (1997) (the
 31FL06 Netherlands), Weir (1997) (France), and Haines (1998) (US).

32FL01 ³² Moreover, this job gap widens when one controls these correlations for the "department of residence"
 32FL02 variables (Table 5). Among the 4 groups for which there is more than 1 cm of height loss in Table 5
 32FL03 relative to Table 4, 3 are found in those associated with the Industrial Revolution (industry, mining, and
 32FL04 textile)—a finding in line with the fact that these job groups (along with the fourth group, farm-workers)
 32FL05 were found in the northern and most prosperous region of France.

33FL01 ³³ The draft-lottery lists provide information concerning a given job sector but rarely any information
 33FL02 concerning the status.



Table 5 Regressions at the individual level and explanatory variables with dummies for departments

	Model 1	SE	Model 2
Constant	168.39	0.16	170.55
Variables observed at the individual level			
Industry	-1.65	0.19	-1.65
Textile	-1.58	0.10	-1.58
Mining	-1.38	0.18	-1.38
Clothing manufacture	-1.36	0.11	-1.36
Farm-worker	-1.28	0.07	-1.28
Artisan (misc.)	-0.79	0.10	-0.79
Building trade	-0.56	0.09	-0.56
Unknown	-0.52	0.19	-0.52
Metallurgy	-0.42	0.09	-0.42
Transportation	-0.34	0.13	-0.34
Food-production trade	-0.28	0.11	-0.28
Carpentry	-0.17	0.08	-0.17
Farmer	Reference		Reference
Misc.	0.08	0.11	0.08
Trader	0.15	0.12	0.15
Employee	1.05	0.15	1.05
Student	1.57	0.23	1.57
Public education/clergy/white collar	1.62	0.18	1.62
Literate	Reference		Reference
Illiterate	-1.51	0.05	-1.51
Semiliterate	-0.83	0.13	-0.83
Educational level unknown	-0.55	0.12	-0.55
Variables observed at the canton of residence level			
Paris	-0.65	0.24	-0.65
Large towns	-1.41	0.13	-1.41
Medium-size towns	-0.62	0.08	-0.62
Small towns	0.00	0.05	0.00
Rural	Reference		Reference
Variables observed at the district of residence level			
Animal protein	0.00 ^a	0.00	0.00 ^a
Variable observed at the department of residence level			
Life expectancy		-0.05 (0.03/0.05)	
Alpes Hautes	-5.67	0.29	-6.12
Aube: Troyes*	0.35	0.24	0.7
Aude: Carcassonne	-3.69	0.18	-3.56
Aveyron	-2.13	0.17	-1.91
Bouches-du-Rhône: Aix, Arles, Marseille	-1.13	0.15	-1.19
Calvados: Caen*	-0.99	0.19	-0.57
Corrèze	-5.25	0.24	-5.88
Côte-d'Or: Dijon*	-0.3	0.19	0.03

Table 5 continued

	Model 1	SE	Model 2
Côtes-du-Nord	-4.02	0.13	-4.19
Creuse	-3.17	0.18	-3.27
Dordogne	-4.04	0.17	-4.07
Doubs: Besançon*	0.88	0.21	0.94
Drôme	-2.59	0.18	-2.6
Finistère: Brest	-4.84	0.14	-5.33
Gard: Nîmes	-2.98	0.17	-2.85
Garonne Haute: Toulouse*	-3.12	0.23	-3
Gers	-3.2	0.28	-3.11
Hérault: Montpellier	-2.68	0.15	-2.73
Ille-et-Vilaine: Rennes*	-3.61	0.20	-3.57
Indre	-1.27	0.24	-1.41
Jura	-0.69	0.16	-0.9
Loire-Inférieure: Nantes*	-1.02	0.24	-0.88
Maine-et-Loire: Angers	-1.55	0.14	-1.47
Manche: Cherbourg*	-2.93	0.28	-2.78
Marne: Reims*	-2.72	0.43	-2.45
Marne Haute	-1.35	0.23	-0.83
Mayenne	-2.47	0.16	-2.38
Meurthe: Nancy*	-0.55	0.21	-0.36
Morbihan: Lorient	-2.48	0.15	-2.79
Moselle: Metz	-0.25	0.14	0.12
Nièvre	-2.08	0.18	-2.31
Nord: Cambrai, Douai, Dunkerque, Lille, Roubaix, Tourcoing, Valenciennes	Reference		Reference
Orne	-0.68	0.34	Dropped
Rhin Bas: Strasbourg*	-0.41	0.18	-0.38
Rhin Haut: Colmar, Mulhouse	-0.8	0.13	-0.73
Rhône: Lyon	-1.47	0.15	-1.82
Saône Haute	-0.68	0.20	-0.47
Sarthe: Le Mans	-2.93	0.15	-2.71
Seine: Paris	-2.14	0.23	-2.61
Seine-et-Marne	-0.56	0.14	-0.24
Seine-Inférieure: Le Havre, Rouen	-2.17	0.11	-2.04
Somme: Amiens	-0.78	0.16	-0.58
Vienne: Poitiers	-1.62	0.22	-1.47
Vienne Haute: Limoges	-3.58	0.20	-4.16
Vosges	-1.81	0.16	-1.74

In bold font: significant at the 1 % level

For each department, the names of large and medium-size cities are indicated after the colon. In this case, an asterisk indicates that the draft-lottery lists do not include height for the cities concerned (see note 19)

^a Exact value: 0.005

Table 6 Regressions at the district level and explanatory variables at the district and departmental levels; explained variable: mean height

	Model 1	SE	P	Model 2	SE	P	Model 3	SE	P
Constant	160.59	0.44	0.00	160.47	0.42	0.00	158.16	0.85	0.00
Variables observed at the district of residence level									
Literacy rate (%)	0.07	0.01	0.00	0.06	0.01	0.00	0.05	0.01	0.00
Animal protein (g)			0.04	0.01	0.00	0.04	0.01	0.00	
Variable observed at the department of residence level									
Life expectancy (females)						0.08	0.02	0.00	
R^2	0.51			0.57			0.59		
N	134			134			134		

299 extent of inequalities—that the height of the residents of large cities, paradoxically,
 300 does not decline relative to average height in small towns and the countryside. This
 301 compensatory mechanism of anthropometric inequalities among various types of
 302 living areas coexists, nevertheless, with an income spread that is greater in major
 303 cities than in the countryside.

304 As for the nutritional variables as explanatory ones (the endogenous variable
 305 being individual height), the coefficients associated with nutritional availabilities
 306 are significant, if not equally important (Table 4, models 2 and 3). For instance, to
 307 observe an individual height increase of 1 cm, an additional 2,500 cal or 14 g of
 308 animal protein, on average, is needed; nearly the equivalent of an entire day's
 309 availability. This may seem like a large amount but in fact is in line with results
 310 obtained by a different method for US individuals (Haines et al. 2003). On the other
 311 hand, the same growth can be observed by increasing the Crude Nutrition Index (see
 312 Table 1 for definition) of 16.7 % or by adding a mere 40 cl of raw milk or 33 g of
 313 protein.³⁴

314 Comparison of the values for animal protein and milk could lead one to wonder
 315 whether, when it comes to accounting for a height increase, milk may be less
 316 important than meat, since a portion of <90 g of edible meat contains 14 g of
 317 animal protein, whereas one would have to drink 400 g of raw milk to absorb the
 318 equivalent amount, which would cost at least as much.³⁵

319 We are not in a position to resolve the milk-versus-meat debate from a nutritional
 320 point of view; nevertheless, it seems safe to say that animal protein is an important
 321 factor in the net-nutrition discrepancies among individuals from different districts.
 322 The introduction of nutritional variables as explanatory ones does not significantly
 323 modify the coefficients associated with the living milieu (urban vs. rural), in the
 324 case of calories, proteins, or calcium (Table 4, models 1 and 2, and models not
 325 reported here). On the other hand, the introduction of the animal-protein variable

34FL01 ³⁴ Regressions are not reported in Table 4. All of the respective coefficients are significant (0.1 %): 0.06,
 34FL02 0.002, and 0.03. All of the other coefficients of the regression remained practically unchanged.

35FL01 ³⁵ 0.06–0.11 francs (price of transport) for 400 g of milk, as opposed to 0.07 francs for 90 g of beef.

326 (Table 4, model 3) reveals the importance of a high-protein diet in maintaining
 327 urbanites' height.³⁶

328 Introducing into the regression the variables for the department of residence
 329 results in such a sharp decrease in the value of the animal-protein coefficient that it
 330 is no longer significant (Table 5). This result is not, in fact, surprising, since the
 331 Saint-Malo-Geneva line is defined not only by anthropometric factors but also by a
 332 higher rate of animal-protein consumption in the north than in the south, that is, the
 333 anthropometric geography and the dietary geography are identical.

334 The negative coefficient for Paris also decreases significantly, but this is due to
 335 the fact that the department of Seine is nearly identical to the city of Paris. This
 336 coefficient indicates only that the vast majority of Parisians ($N = 8,347$) were
 337 somewhat shorter than their suburban counterparts ($N = 812$) and that most of the
 338 urban penalty of Paris is captured by the "Seine" variable. More important is the
 339 fact that the negative coefficients associated with the large and medium-size towns
 340 almost double: not surprising, either, since they were located to the north of the
 341 Saint-Malo-Geneva line and thus in the region of France with the tallest inhabitants.
 342 Controlling for department of residence thus clarifies the phenomenon of the urban
 343 penalty.

344 If one controls model 3 of Table 4 for the presence of a railway line in 1853 or
 345 1868, the negative value of the cities coefficient increases slightly—models not
 346 reported here.³⁷ Although, as we have observed, the geographical layouts of the
 347 railway network in 1853 and 1868 were vastly different, the positive coefficients
 348 associated with its presence in these 2 years are virtually identical, on the order of
 349 4 mm.

350 Nevertheless, this "positive" impact of the railway seems to be a statistical
 351 artifact. If one controls these models for the departments of residence—models not
 352 reported here—the coefficient associated with the railway lines diminishes almost to
 353 nothing, be the network that of 1868 (+2 mm) or that of 1853 (−0,1 mm). In other
 354 words, most of the railways were built in the most prosperous region; what was
 355 captured by the railway variable before introducing departments into the regression
 356 was partly a general socio-economic feature.

357 To test the hypothesis that energy expenditure, especially when disease is the
 358 cause, has a significant impact on health and therefore on height, we introduce the
 359 variables of female life expectancy and infant mortality, which can be observed only
 360 at the departmental level (Table 4, model 4, and a model not reported here). These
 361 variables turn out as expected: *ceteris paribus*, an increase of 7.7 years (life
 362 expectancy) or a decrease of 333 ‰ (infant mortality) is correlated with a height

36FL01 ³⁶ Our results were similar when we used the reduced sample of 81,605 individual observations (without
 36FL02 Paris, see Heyberger 2009). In this regard, the hypothesis that a heavy penalty was imposed on Paris
 36FL03 seems all the more plausible, even if the food-availability estimates for Paris derive from Husson and not
 36FL04 from the agricultural survey. Moreover, while the estimates of animal-protein availability for the big
 36FL05 cities are based on the latter, the urban penalty also increases here.

37FL01 ³⁷ Once again, small towns are the exception. The urban penalty reaches 0.6 cm for medium-size cities
 37FL02 and more than 1 cm for large ones—with the exception of Paris, where it reaches nearly 3 cm.



363 increase of 1 cm.³⁸ What is more, the absolute value of the negative coefficient
 364 associated with cities diminishes when one controls the regression for life
 365 expectancy (Table 4, models 3 and 4): a certain percentage of the shortest
 366 inhabitants in a given city can be accounted for by the low overall life-expectancy
 367 rate there. Nevertheless, the coefficients associated with the cities in the fourth
 368 model (Table 4) remain negative even after one has controlled for life expectancy,
 369 especially in the case of Paris; one can therefore attribute the value of these
 370 coefficients to non-fatal illnesses.

371 Our analysis thus encourages reconsideration of the importance of those factors
 372 associated with energy expenses in determining height at a critical moment in
 373 French urban history. It lends equal support to the idea that the deterioration in
 374 epidemiological and hygienic conditions constituted the primary factor in the
 375 decline in the mean height of Parisians during the first half of the century.

376 The fact that the coefficients associated with the cities in Table 4, model 4,
 377 remain negative even after one has controlled for life expectancy could also be
 378 explained by the migration of poor (and short) rural workers, as migration was not
 379 included in the analysis. An analysis in which conscripts living in Belfort and
 380 Mulhouse (medium-size towns undergoing high levels of migration coupled with
 381 rapid industrial growth) were individually sorted into “city-born” and “country-
 382 born” revealed no significant height difference between the two categories
 383 (Heyberger 2005, 2008, see also note 12). It therefore seems unlikely that the
 384 urban penalty observed in Table 4 is due to phenomenon of migration on the part of
 385 the poorest sector of society. Furthermore, there is evidence that in nineteenth-
 386 century France, migrants were, as a rule, taller than non-migrants (Boëtsch et al.
 387 2008, see also Humphries and Leunig 2009 for England).

388 Controlling the influence of life expectancy (Table 4, model 4) for departments
 389 of residence causes a change in the sign of the life-expectancy coefficient, which
 390 remains significant at the 10 % level (Table 5, model 2): when life expectancy
 391 increases, height decreases. This phenomenon could be explained by the fact that
 392 non-fatal illnesses may be more important than fatal illnesses when it comes to
 393 determining height discrepancies between departments and districts.

394 The regressions in Tables 4 and 5, calculated as they are on the basis of
 395 observations at the individual level, serve as a fine filter for our analysis of the
 396 influence of one or another explanatory factor. However, when one takes into
 397 account the vast quantity of individual observations, the total variance in height is
 398 more a matter of genetics than of socio-economic factors. The adjusted R^2 s are
 399 therefore very weak, even if the coefficients of each variable considered
 400 individually are of great interest.

38FL01 ³⁸ This figure seems quite large; Baten and Komlos—no doubt on the basis of other, unspecified
 38FL02 hypotheses—claim that the life-expectancy increase correlated with a 1-cm height increase is only
 38FL03 1.2 years in length (Baten and Komlos 1998). In contrast, extrapolating from our results, one would
 38FL04 conclude that over the course of the Industrial Revolution, life expectancy increased by more than one
 38FL05 hundred years! Nevertheless, diachronic data lend plausibility to our calculation, at least in the case of
 38FL06 nineteenth-century France: an increase in conscripts’ mean height of 0.75 cm between the 1790–1799 and
 38FL07 the 1820–1829 birth cohorts is paralleled by a 7.2-year increase in female life expectancy.

Analyses at the aggregated level (Table 6), on the contrary, reveal what roles, more or less important, socio-economic factors play to the extent that mean height, as opposed to individual height, constitutes an index that is far more a function of socio-economic than of genetic factors.³⁹ To use a chronological analogy, in a school, the observed difference in individual height among students in year X is important in that it accords more importance to the genetic potential of each person's growth than to inequalities in living conditions. On the other hand, if one compares the average height for year X in a given school to that for year $X + 30$ in the same school, the observed height difference between year X and year $X + 30$ will be much smaller than the observed difference between the shortest and the tallest students in year X , but it is explained by socio-economic factors alone.

Certain explanatory variables that produced satisfactory results at the individual level did not produce noticeable and significant results for mean height at the district level,⁴⁰ again on account of these problems of scale. This holds true not only for the job structure but also for the impact of the milieu (city or country)⁴¹; we therefore omit from our table the regressions that include these variables. At the same time, the regressions calculated with mean height at the district level as endogenous variable and a single explanatory factor indicate that calorie levels do not explain the anthropometric disparities found to exist between one district and another. On the other hand, the other explanatory factors, which we consider separately, offer a partial explanation of the observed inequalities; the literacy rate provides the closest correlation.⁴²

This analysis is confirmed in Table 6:⁴³ socio-economic factors account for the majority of the anthropometric inter-district disparities. The fact that there is a particularly close correlation between the conscripts' literacy level and the anthropometric indexes prompts one to reconsider—as did Postel-Vinay and Sahn recently, on the departmental scale—the importance of human-capital formation in the determination of net-nutrition levels (Postel-Vinay and Sahn 2010). A 1-cm increase in the conscripts' average height requires a 14.3 % literacy rate increase: a relatively small figure, to the extent that the standard deviation for the latter variable is 18.9.

³⁹ For more on this methodological problem in anthropometrics, see Baten and Murray (2000) and Brown and Guinnane 2007—which considers fertility—on the same kind of methodological considerations regarding aggregation.

⁴⁰ See footnote 12.

⁴¹ It is here that the “ecological fallacy” comes into play: the district constitutes an ecological unit far too large to permit one to identify with any precision the impact of noticeable, significant factors that play a role at the cantonal level.

⁴² All of the regressions are statistically significant at the 1 % level. The R^2 of the regressions between mean height and, respectively, protein, animal-protein, and calcium consumption, CNI, and life expectancy is, respectively, 0.10, 0.26, 0.26, 0.20, and 0.28. Respective values for the regressions with the proportion of stunted individuals as the endogenous variable are 0.10, 0.23, 0.22, 0.18, and 0.31. Moreover, the correlation between the mean height and the stunted proportion is very strong ($R^2 = 0.96$).

⁴³ Regressions with stunted proportion of conscripts as endogenous variable are not reported here since the results are very close to those obtained with mean height (R^2 of models 1–3 of Table 6 with stunted proportion as endogenous variable: 0.52; 0.56; 0.60, all significant at the 0.1 % level). This phenomenon is due to the very strong correlation between these two endogenous variables (see previous note).



432 Literacy is not just a proxy for per capita income, although, for one thing, it
 433 certainly helps to reduce the number of unwanted pregnancies and thus improves
 434 children's gross nutrition (Weir 1993, 1997). For another, in certain cases, the
 435 positive influence of instruction is observed even after one has controlled for income
 436 (Meyer and Selmer 1999; Steckel 1998): the positive influence of educational level
 437 would thus reflect not only the children's but also their parents' improved grasp of
 438 nutrition issues, enabling them to fight more successfully against diseases by means
 439 of health practices and paramedical care that were better adapted than were those of
 440 the illiterate conscripts. Last but not least, as a rule children learn to read at school:
 441 their being thus spared grueling physical labor during their growth years may help
 442 them to reach a greater maximum adult height, although this issue is the focus of
 443 intense debate (Ambadekar et al. 1999; Baten 1999a, p. 105; Bogin 1999; Kirby
 444 1995; Komlos 1998, p. 791; Steckel 1998, pp. 6 and 9).

445 In addition, both gross nutrition (availability of animal protein) and net nutrition
 446 (female life expectancy) play a role in observed inequalities.⁴⁴ At the district level,
 447 an increase of 1 cm in average height requires a daily increase of 25 gms of animal-
 448 protein availability or an increase in life expectancy of 12.5 years. In both cases, it
 449 is a matter of higher values than in the case of individual regressions, but these
 450 values remain within plausible orders of magnitude.

451 4 Conclusion

452 The analyses undertaken at the individual level show that the absence of an urban
 453 penalty, in anthropometric terms, in nineteenth-century France constitutes a
 454 statistical artifact. The height of city dwellers, and especially of Parisians, attains
 455 the overall national average only thanks to their consumption of a considerable
 456 amount of animal protein, which counterbalances the negative impact of the urban
 457 milieu, when it comes to the issues of epidemiology and hygiene.

458 Other socio-economic factors, including the superior literacy rate and the
 459 professional structure found only in cities, help to explain the fact that the height of
 460 city dwellers did not slip below the average for urban and rural areas combined.
 461 Overall, a trade-off between the "heightening" factors, which are nutritional (gross
 462 nutrition), and the "shortening" ones, which are epidemiological (net nutrition), is
 463 achieved not only in Paris but also in other large French cities and in medium-size
 464 ones as well; this equilibrium prevents us from siding with either the nutrition or the
 465 epidemiology camp in the debate over the primary cause of this height pattern.

466 To the extent that prior analyses of the French "exception" have emphasized the
 467 importance of the role played by nutritional factors (Steckel and Floud 1997;
 468 Komlos 2003), our results lean in the direction of an upward reevaluation of the

44FL01 ⁴⁴ In Table 6, the nutritional variable that we chose to use is the availability of animal protein rather than
 44FL02 of calcium, even though the R^2 's of the regressions calculated with a single explanatory factor are similar
 44FL03 for the two (see footnote 42). In fact, the value of the coefficients associated with animal-protein
 44FL04 availability is greater in the case of mean height as well as that of the proportion of stunted individuals,
 44FL05 and we have already seen that at the individual level, animal protein (meat and milk) seems to possess a
 44FL06 greater explanatory capacity than does milk alone.

469 epidemiological ones. Insofar as Parisians' height declines over the course of the
 470 first half of the century among the working classes as well as among the
 471 bourgeoisie, the importance of the epidemiological factor, which affects all classes
 472 to virtually the same extent, is confirmed—see note 7—especially since this height
 473 decrease coincides with an increase in Parisians' food consumption (Husson 1856).
 474 Moreover, the fact that no urban penalty is paid by small towns, which are
 475 particularly numerous in France, prompts us to question the definition of “urban
 476 areas” used in anthropometric studies.

477 At the local—canton—level, the positive and modest impact of the railway
 478 proves to be a statistical artifact as soon as one controls for departments of
 479 residence. In this respect, our study diverges from anthropometric studies of the
 480 history of the railway in the US, in which a different methodology was used to
 481 describe a negative (Haines 1998; Haines et al. 2003) or positive (Solakoglu 2007)
 482 impact.

483 If one considers mean height at the district (as opposed to the individual) level,
 484 the literacy rate is the factor that explains the observed anthropometric disparities
 485 far better than do any of the nutritional or epidemiological ones: a finding that
 486 suggests that the importance of educational factors as a predictor of net nutrition
 487 may have been underestimated. It seems quite plausible that literacy, especially in
 488 the case of women, constituted an essential factor not only in the classic
 489 demographic transition but also in the corollary physical-growth transition that
 490 accompanied the Industrial Revolution.

491 When it comes to issues of methodology, we have seen that the most accurate
 492 estimates of the impact of gross nutrition on height are calculated on the basis of
 493 animal-protein availability (meat and fish as well as milk). As for the entirety of our
 494 analyses—the endogenous variable at the individual and district levels—animal-
 495 protein availability produces better results than does either total nutritional
 496 availability (calories or protein) or nutritional availability from a single product
 497 (milk), even if both approaches generate satisfactory ones. Our results thus indicate
 498 that the most economic and efficient analytical method is to evaluate the effect of
 499 nutritional availability from a range of foodstuffs high in animal protein consumed
 500 on a regular basis (meat and milk), rather than from a single product (milk). On the
 501 other hand, calculating total caloric availability, far more time-consuming and
 502 unreliable because of the deficiency of source material, is not the best option.

503 Finally, it seems that one could compensate for the lack of mean-height data by
 504 substituting an estimate of the stunted proportion of the population in question,
 505 since at the district level, the results derived from this statistic are virtually identical
 506 to those derived from mean-height data. Our results thus do not undermine the
 507 hypothesis of distribution normality currently being debated in anthropometric-
 508 history circles: the stunted proportion of a given population seems to be a statistic
 509 no more sensitive to socio-economic factors than is mean height.

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