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# Protein Supply and Nutritional Status in Nineteenth Century Bavaria, Prussia and France

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## Abstract

What determined regional height differences in the 19th century? We compare anthropometric evidence with production estimates of different food products and other economic variables. To this end, we concentrate on 179 rural regions and 29 towns in Bavaria (Southeast Germany). This regionally disaggregated level of analysis enables us to study the influence of the local supply of different food products on the nutritional status of the population, among which milk turned out particularly important. This result is tested and confirmed with regional data from Prussia and France.

**Keywords:** Heights; Protein Consumption; Bavaria; Prussia; France; Industrialization; Regional inequality; Germany; Physical Stature; Milk production

## 1. Introduction

Nearly all previous anthropometric studies have pointed to the importance of regional height differences. To give just a few recent examples of a large literature, Komlos (2007) studied the regional height differences in the 19th century Habsburg monarchy, finding that military recruits in Austria and today's Croatia were significantly taller than those in the Polish- and Romanian-speaking parts of the Empire.[1] Stegl and Baten (2008) and Moradi and Baten (2005) assessed recently heights in the Middle East and Africa, respectively, and found marked regional differences. The influence of protein production per capita was often causing differences in height in remote and sparsely populated areas (see also Cuff, 2005).

In this study, we assess regional differences in the Southeastern German kingdom of Bavaria in the 19th century at the level of 179 rural districts and 29 towns, whose population averaged 14,000 (in 1844). This regionally disaggregated level of analysis enables us to assess the influence of the local supply of different food products and other economic variables on the nutritional status of the population. We will assess whether the proximity to protein production, and milk production in particular, has a positive influence on regional heights. This core question will be called the "milk hypothesis" (see also Bogin 1999, and on Bavarian convicts Baten and Murray, 2000). In addition, we compare the main results of the analysis of Bavaria with two other states, Prussia and France.

Between 1803 and 1816 Bavaria consisted of many small territories with different economic structures. Upper Franconia in the northeast and parts of Swabia were regions with large proto-industrial sectors particularly in textile and metal manufacturing, as large on a per capita basis as that of Saxony or Bohemia. The rest of Bavaria was dominated by agriculture (Bosl, 1985). Nevertheless, different soils, transport facilities, and population densities

[1] See also Komlos (1985) on regional differences.

implied different production structures. Milk and beef production in the southern and eastern mountain regions contrasted with grain and pork production along the Danube and Main Rivers. In the lower Main region and in the Palatinate near the Rhine, quite a lot of potatoes were produced as well as pork, grain and wine, and this was also true of the proto-industrial region in the northeast. These regional differences make a study of the influence of regional production structures on nutritional status interesting. This analysis should also contribute to our general understanding of the relationship between nutritional status and economic development at the early phase of industrialization.

Similar differences existed in Prussia and France. Roughly speaking, Prussia had dominant cattle-farming areas in the Northwest, whereas its industrial cores were situated in the Rhineland, Silesia, and region around Berlin. French agriculture produced more protein in the Northeast, and the industrial centers were the North, Alsace-Lorraine, and Paris.

## 2. Data sources

Two types of anthropometric data sources are analysed in this study – individual records of conscripts and published conscription statistics.

**Individual conscript lists 1815-49.** Although there was a minimum height requirement, all 21-year-old males were first measured, except very few volunteer soldiers, emigrants and priests.[2] A large number of conscription lists are available for birth cohorts between 1815 and 1849. These lists report health, height, name, district of birth, district of conscription, birth year, and occupation of the conscript and that of his father (or mother, if she was unmarried or widowed).[3] There are some gaps in the archives for the proto-industrial

[2] The conscripts were chosen by lot from those eligible. Those who could afford it could buy substitutes to do the military service, and the sons of noblemen had the privilege of entering the cadet corps, however, they, too, were recorded and measured (see Regierungsblatt für das Königreich Bayern, München, 1830, pp. 441-607). For the sources, see Table 1.

[3] A few groups were recorded but not examined. Their share (between 0 and 3%) was too small to bias the result. The following groups were not measured: a) volunteer soldiers already serving in the army b) those who

weaving districts, the potato region, and the industrially developed towns, i.e., Augsburg and Nuremberg. The conscript lists are used in the entire study.

**Conscription statistics at the district level 1809-35.** Gaps in the archival lists can be bridged to a certain extent by the published conscription statistics, which are available for the birth cohorts 1809 to 1835 (Fig. 1).[4] These aggregate statistics report (a) the number of conscripts from a certain year and district, (b) the percentage rejected because of short stature, and (c) the percentage rejected because of illness. Average height is not recorded, but as we know that heights are normally distributed, we estimate average height as a function of the percentage of those subjects rejected because they were too short.[5] Similar sources will be analyzed for Prussia and France.

Using the individual conscription lists of 1815-49, we can actually estimate the relationship between average heights and the rejection rate by regressing the average height in a district on the share of conscripts rejected there, who were shorter than 155.6 cm, by district and five-year-birth period:

Average height (in cm) = -0.8 * rejection rate (in %) + 169.3 cm

(P-values are 0.00 for both coefficient and constant, adj. $R^2$=0.52; N=63)

Hence we estimated that a one percent change in the rejection rate meant a 0.8 cm change in average height.[6]

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disappeared illegally; c) priests who had taken orders. Percentages of the three groups were extremely low, and they belonged to different social strata. Military volunteers might have been a little bit taller than the average because of the minimum height requirement, although this minimum requirement was extremely low (155.6 cm). Priests were also probably taller, because their parents tended to belong to the middle and upper classes. By contrast, missing recruits were mostly born in the lower social classes, as the occupations of their parents recorded in the lists suggest.

4 But not for Lower Franconia up to 1819. They were published in a contemporary statistical journal, see Beiträge zur Statistik des Königreichs Bayern (1854) and (1859).

5 Certainly, there are disadvantages in the conscription statistics, compared with the individual archival lists. Occupations were not recorded, and the statistics did not go beyond the birth year 1835 on an annual basis. In addition, the counting method changed between the birth years 1830 and 1831 (see notes to Table 1)

5 If the rejection-rate was higher, the coefficient decreases. For the conscripts of the Grand Duchy of Baden born between 1820 and 1840, for example, a one percent change in rejection rate was brought about by only a 0.5 cm change in average heights (calculations on the data from Ammon, 1899.)

FIGURE 1 AROUND HERE

## 3. Characteristics of Bavaria

Before we test the milk hypothesis and other potential determinants of height, we examine the characteristics of Bavaria. Compared to other countries, Bavaria had a larger number of cattle per capita. In 1852/53, there were 0.57 cattle per capita in Bavaria, while in France (1852), Hungary (1857), and Germany as a whole (1857) there were only about 0.34 cattle per capita, and in Austria (1851) there were 0.42 (Hoffmann, 1965; Böhm, 1995; Mitchell, 1975; Sandgruber, 1987). Moreover, Bavaria's grain production was not much lower than in other European countries, while the industrial sector was less important, except in regions such as Swabia and Franconia (Nuremberg). Only 23% of the population of Bavaria was employed in industry, in contrast to 48% of the British population (Hoffmann, 1965).

Before the railway age, the possibilities for the transportation of bulky goods were more limited in Bavaria than in other parts of Europe. Water transport was the only cost-efficient way of moving bulky goods long distances, but the only navigable rivers in Bavaria were the Main and the Rhine in the North West and the Danube in the southern half of the country. However, the Danube flowed in the wrong direction from an economic perspective, i.e., from west to east. This was disadvantageous for trade in agricultural goods, because the countries downstream of the Danube were themselves agricultural surplus regions: the flow of trade in food traditionally was in an east-west direction (Böhm, 1995). Consequently, the grain and wine surpluses of the Palatinate and of Main-Franconia were sent to the districts along the Rhine, while there was little trade in bulky goods in the entire south and north east of the kingdom. The grain surplus of the South was mainly exported to Switzerland and Württemberg by road, but this was very expensive, hence of negligible magnitude (Böhm, 1995). All of Bavaria's net exports of agricultural products amounted to only about 2% of rye output, and about 10% of that of wheat.

The total commercialized share of grain output (i.e., including internal trade) is estimated to have been about 20% for the early 19th century; the remaining 80% was subsistence production (Böhm, 1995). The trade in cattle and butter fat was also very intensive within the country (Bavaria Vol. I, 1860, pp. 439-443). According to cross-border trade statistics for the late-18th century which are available only for upper and lower Bavaria, grain and salt were the main export items, each composing about a quarter of the total value of internationally traded goods (Schremmer, 1966). Grain exports represented about 60% of all Bavarian exports of the early 1820s.[7]

One can infer from the trade figures that, in the 18th century, the foreign trade of southern Bavaria was concentrated in the export of primary commodities, and not of protoindustrial goods. The relatively high proportion of people working in Bavarian agriculture was producing predominantly for the domestic market, and numerous human capital intensive luxury products were imported (Rudhart, 1825). In contrast, in the parts of Franconia that later became northern Bavaria, protoindustrial woven goods and the famous "Nuremberg goods" (predominantly metal products) were produced in very large quantities for export even in early modern times, as were textile products of Augsburg and in some of the smaller cities of Swabia and Franconia.[8] There were no major changes between the late-18th and early-19th centuries in the wine exports from the Palatinate and lower Franconia, or in the export of grain from the Würzburg area. Production of these goods was determined by the comparative advantages of these regions derived from climatic and geographic factors.[9]

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7 However, the data might also be interpreted so as to imply that exports of grain did not increase by much in the intervening period. E.g. Augsburg, one of the largest German cities of the early modern era (Böhm, 1995, pp. 331-2).

8 For weaving in Eastern Upper Franconia: Schmid (1923); for industrial activity in Nürnberg: Gömmel (1978); Wiest (1968).

9 For wine production in the Palatinate: Bassermann-Jordan (1923); for the grain in the Würzburg region: Angerpointner (1994).

## 4. A typology of regions

In this section we postulate a typology of economic regions based on nutritional flows and the degree to which the markets were integrated. Compared with today's standards, nutrition in Bavaria in the early 19th century was characterized by a shortage of protein and fat, even if meat and dairy products were available to some extent, but too expensive to be affordable by most of the population on a regular basis.[10] Basic food consisted of grain, milk, vegetables (e.g., cabbages), potatoes, clarified butter and meat.[11]

In addition to productive capacity, the degree of market integration and transport costs were very important for the nutritional differences between regions. The following nutritional typology at the regional level takes into account some special characteristics of Bavaria in the early 19th century.[12] Six types of regions can be distinguished:

**Towns:**[13] towns were those municipalities with a population of 5,000 and more inhabitants (in 1840). They can be subdivided into industrial and administrative towns, but their common feature with regard to nutrition is the large influx of meat and grain. Beef cattle sent to towns such as Munich made a large contribution to the protein supply of the urban population. In 1810, 8,000 beef cattle with a slaughter weight of about 650 kg per animal were driven to the markets of Munich annually. However, the absence of cooling systems meant that milk and dairy products were difficult to transport. Based on the assumption that the maximum distance sour milk could be transported was 40-55 km, the milk supply in Munich and Augsburg was about 60 liters per capita in 1840 and about 40 liters in

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9 Cheese played a minor role, except for soft cheese (Topfenkäse) produced in the milk regions which could not be transported. Data on hard cheese, which could be transported, was not found in any of the statistics.

10 Clarified butter was an important additional source of fat, especially in towns.

11 The definition of "region" is based on Sidney Pollard`s argument that economic regions have a center, but no clearly defined borders (Pollard, 1994, pp. 57-63).

12 Twenty nine towns with 5,000-92,000 inhabitants in 1840 were administered directly by the Bavarian gouvernment.

Nuremberg.[14] Given that one liter of sour milk contained about 30g of protein, and 1 kg of meat (average quality) about 170g, Munich's protein supply from meat was 5.5 times higher than from milk (Beck, 1986).

The unfavorable disease environment in the early 19th century was a major influence on net nutrition in the towns and their surroundings. Urban hygienic conditions were worse than rural ones, especially up to the last third of the century.

**The areas surrounding the larger towns** were well integrated with urban markets.[15] This had the first implication of a problematic disease environment, similar to the urban market. Another factor arises from the situation that the farmers were able to sell their milk, fruit and vegetables there, which generated income, but also meant higher work loads. Böhm (1995) calculated the work load in different agricultural activities. Growing fruit and vegetables was labor intensive; hence the work load of the agricultural laborers were probably high, most likely higher than in the regions where the markets were less integrated. Yet, their real wages were also higher because the value of their product was greater. Relative to their work load and the disease environment, however, the net nutrition of the people in these areas might be expected to have been generally poorer, and to contain less protein than in the towns. The non-agricultural goods available in the towns probably tempted the farmers to forego consuming some milk.[16] We defined the areas near towns as those districts directly adjacent to the town districts.

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13 Beiträge zur Statistik des Königreiches Bayern (1855). This seems to be a general feature of pre-industrial times, because refrigeration was not available and land was scarce close to towns. For example, only 54 liters of milk per capita were transported to Vienna in 1830 (Sandgruber, 1982, p. 161).

14 Defined as districts surrounding towns. See also definitions in Table 1.

15 For example, at the beginning of the century a senior official of the Bavarian government wrote about the district Wolfratshausen, close to Munich: *"They spend a lot on clothing: silver clocks and women in silk dresses can be seen everywhere."* (*"Dort wird viel auf die Kleider verwendet; man sieht überall silberne Uhren und die Weibsleute in seidenen Kleidern."*) (Hazzi, 1804, vol. 3.1, p. 194). Similar descriptions exist also for milk regions, but there "luxurious clothing" did not contrast with poor nutrition. In contrast, the biological standard of living as he describes it, sounds poor: *"Heights are low in this area, many persons become crippled due to heavy work loads at early ages (...) Bread is always of low quality, meat is consumed nowhere. In the upper part [with better nutrition, J.B.], noodles with clarified butter is a common food." ("Die Menschen sind hier klein, durch zu*

**Milk and beef cattle producing areas** (hereafter called milk regions). The high average per capita stock of cattle in Bavaria was the result of the large number of cows in the milk regions in the Alps and its foothills where the human population density was low (Fig. 2).[17]

FIGURE 2 AND TABLE 1 AROUND HERE

Milk production is highly correlated with beef production – the correlation coefficient is 0.85. The cattle were sold in urban markets but the milk was used to primarily produce clarified butter and sour milk. Consumed locally at an extremely low price, even the lower-bound estimate of milk consumption is as high as 400 liters per capita annually in the milk regions.[18] Since plenty of sour milk was available in these regions, even the lower classes could afford to consume it, and consequently we would expect them to have higher net nutritional standard than elsewhere.[19] "Milk regions" are defined in Table 1, Col. 4 and 5 as those regions with at least 400 liter production per capita and year, if they were not districts near a town. In the other regressions, the liter values are entered directly.

**Agricultural regions with significant potato production ("potato regions").** Potato growing spread slowly from the northwest and northeast of Bavaria southward. It did not

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*frühe Anstrengung verkrüppelt (...) Das Brot ist durchgängig schlecht; nirgends ißt man Fleisch, in der obern Gegend sind die Schmalznudeln eine gewöhnlich Speise."*) (Ibid., p. 193/4).

16 Estimates of milk production in 1840 are based on the number of cows multiplied by a lower-bound estimate of their annual milk yield of 800 liters, which takes into account some production losses.

17 In hereditary contracts, meat and clarified butter are always defined in exact measures, while - if sour milk is recorded at all - it was only mentioned in terms of "enough" (Beck, 1986, p. 147).

18 "Sour milk" has less fat than what we know today as butter milk. Clarified butter was an important item of commerce, sold to urban and even non-urban consumers. In contrast, hard cheese is never mentioned in contemporary accounts and statistics, with the exception of the Zollverein statistics. For 1841, the latter report 12 gram cheese export and 182 gram cheese import per capita annually between Bavaria and countries outside of the Zollverein (Austria, including Bohemia, and Switzerland). Even if these figures are doubled, because probably there was trade with western and northern neighbors as well, the amount of traded cheese must have been insignificant. G. Seuffert (1857), p. 428-9. After mid-century, hard cheese production began to spread from the western Alpine region toward east and north.

reach southern Bavaria until mid century, except in the areas near the towns.[20] Potato regions exported almost none of the potatoes grown there: instead they used them for their own consumption and to feed pigs (Bavaria, 1866, p. 209). Typically, these regions had a large increase in population, as did the weaving districts. "Potato regions" are defined in Table 1, Col. 4 and 5 as those regions with at least 400 kg production per capita and year, if they were not districts near a town.

The level of potato production was very low in the late 18th century. Hence, the size of potato production correlates with the speed of its diffusion. A rapid shift toward potatoes is also an indicator of a growing lower class, as only for this part of the population was the potato, a labor-intensive, but land-saving crop, very attractive to cultivate in gardens or small plots. Some of the districts which adapted the potato early and intensively were also specialized in wine growing (especially in Lower Franconia and Palatinate).

**Weaving and other Proto-industrial districts**. There was a substantial weaving region in the northeast made up of 11 districts (see notes to Table 1). They were situated in infertile, mountainous areas with a dense and still growing population.[21] Potatoes were also produced in the proto-industrial areas, but other agricultural production was limited. The main industrial product was cotton cloth, which provided most of the income of the population of this region. A few agricultural goods were imported, but contemporary sources describe the low level of real income. In contrast to English factory production, the Bavarian cottage weavers were backward. They could compete only by reducing labor costs to extremely low levels and by having women and children participate in production. Heavy work loads for

19 Contemporary sources frequently describe potatoes as being extremely unpopular in the southern part of the country. Even in 1860 many farmers from mountainous regions were proud of not having eaten a single potato in their lives. Bavaria 1865, p. 442.

20 Beiträge zur Statistik des Königreichs Bayern (1855).

children and pregnant women were another reason that we would expect a low biological standard of living in these regions.[22]

Apart from the Northeastern weaving region, there were some other industrial regions, such as the rural surroundings of Nuremberg and Augsburg (the latter was a district called Friedberg which specialized on clock-making), the salt mining district of Reichenhall, as well as the Palatinate districts of Kaiserslautern and Frankenthal. Our definition threshold for those districts is 30% non-agricultural employment.[23] While individual conscription records are not available for the weaving region, the height of men from there can be estimated using conscription statistics aggregated at the district level.

**Other rural regions.** Most of Bavaria produced rye, wheat and swine. Bavaria exported about 10% of the wheat it produced, and much less of rye over the borders (Böhm, 1995). The grain producing regions were on the plains of the Main, Inn and Danube and thus more favorably situated with regard to the availability of river transportation than the milk regions. Transport costs of grain and pork were, therefore, lower, and it is likely that the farmers in these regions sold a high percentage of their production. To the degree that those other agricultural districts were connected with the cities by exporting their food to them, they also shared the heavier disease load of cities.

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21 *"Their wage is inexplicably low and their lot sometimes miserable"*, wrote the economist and government official Ignatz Rudhart in 1827 *"Ihr Arbeitslohn ist unbegreiflich niedrig und ihr Loos bisweilen kümmerlich."* (Rudhart, 1827, Bd. II, p. 62). The primary reason was poor nutrition. A government physician described one typical example, the district of Naila, in 1860: "Concerning the architecture of their bodies, the weavers, who form an important part of the population, are somewhat special. In most cases their thorax is narrow and flat, their muscles underdeveloped. (...) Nutrition [in the whole district, J.B.] is characterised by large quantities [of potatoes, J.B.], while proteins are lacking". German original: *"In Beziehung auf die Architektur des Körpers zeichnen sich besonders die Weber aus, welche ein bedeutendes Kontingent der Einwohnerschaft ausmachen. Sie haben in der Regel einen engen, flachen Brustbau, die Bildung der Muskeln ist in ihrer körperlichen Formation zurückgetreten. (...) In Beziehung auf die Kost wird [im gesamten Distrikt] durch die Masse ersetzt, was durch den Mangel an proteinreichen Nahrungsmitteln abgeht"* (Physikatsbericht des Landgerichts Naila, Bavarian State Library, sign. cgm 6874).

22 In contrast, for the weaving districts we did not apply a definition by the share of non-agricultural occupations, as the region was clearly defined in different sources. Even in one district which had a lower share of non-agricultural occupations (Baireuth rural), weaving was dominant, but people only weaved part-time. Reducing the "weaving districts" in Table 1 to the ones with 30 percent and more non-agricultural population does not change the results much.

## 5. Cross-sectional analysis of regional differences in Bavaria

**Determinants of the rejection rate (for being too short) in rural districts.** In order to investigate spatial patterns of net nutritional status, three cross-sectional regressions are run, for the birth periods 1809-19, 1820-29 and 1831-35. The towns are analyzed separately in the following. The dependent variable of the regressions is the rate of rejection of recruits on account of being shorter than the minimum height requirement of 155.6 cm. The spatial pattern is shown in Fig. 1. We assume that regional genetic height differences were unimportant within Bavaria. This seems reasonable, as there are almost no regional height differences today.[24] Possible influences of regional differences on nutritional status are entered as independent variables in the regression (Table 1). Because agricultural data are available for all 179 rural Bavarian districts, production estimates for milk, grain and potatoes are used as continuous variables in the regression (Col. 1 to 3). Other independent variables include such dummy variables as "area near town" or "weaving district".[25]

The regression equations look very similar for all three time periods – the milk production variable always has a highly significant negative effect on rejection rates and average height is thus positively influenced. In weaving districts the rejection rates were above average, confirming the scattered references to the low biological standard of living of people engaged in proto-industrial activity. Rye production, in contrast, increased the rejection rates very little; it was significant only for the birth cohorts between 1809 and 1819.

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[23] The Institute for Military Medical Statistics and Reports reported today's heights by regions. The differences between regions were lower than 0.3 cm for the conscription period of 1990-94, if we aggregate them in a similar way to the historical evidence: 'milk regions' 179.1 cm, 'weaving regions' 179.2 cm, 'potato regions' 179.2 cm, 'other rural regions' 178.9 cm.
To compare historical heights with the data of our time, we have to assume that immigration after WW II affected all regions similarly. This is a reasonable assumption, since this was the policy of the government of the Federal Republic of Germany at that time. The emigration of the mid-19th century did not change regional height patterns, as can be see from the maps of Ranke (1881).

[24] The weaver dummy variable had to be introduced into the regression because statistics on the number of weavers are unavailable at the district level. This dummy variable pertains to the 11 narrowly defined regions in the Northeast.

This was the case, because the protein yield of grains was too low compared to the work loads in their production, and partly because a high share of nutrients was "exported" to towns. In addition, regions which specialized in grain production obviously did so at the expense of livestock products. In contrast, potato production invariably had a negative influence on heights as it is always associated with increased rejection rates.[26] The estimated height disadvantage for the birth group 1831-35 is 0.5 cm. As mentioned in section one, potato growing areas were poorer ones where rapid population growth created a Malthusian situation. The variable "area near town" had an increasing effect on rejection rates in the third period. We included a rough proxy for the disease environment, the 'share of those rejected for disease reasons'. This variable represents the share of all recruits with a severe disease which was considered as preventing them from military service, for example, hernias or missing limbs. The share of those rejected because of sickness is significant for the 1810s and 1820s, but insignificant for the early 1830s, perhaps because of modest multicollinearity effects. In contrast, the variable "rye wages of day-laborers" had almost no influence on heights; it only lowered the adjusted R-square values.

Because of the changes in statistical procedures between periods 2 and 3, no inter-temporal comparison between these periods is warranted. Between the 1810s and the 1820s, the influence of both milk production and the weaving variable became larger.

A typical strategy to evaluate the economic significance of a variable is to consider a one standard deviation change in the explanatory variable and multiply it with the coefficient of this variable. One standard deviation difference amounted to about 206 liter per capita per annum, and the coefficient is 0.59 for 1831-35, hence 0.59*2.06=1.21 percent. Can we transform this into an effect measured in centimeters of height? As we estimated above that a one percent change in the rejection rate was associated with 0.8 cm decline in average height,

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[25] The coefficients for the early period remain nearly the same regardless if potato production figures for 1810 or 1853 are entered in the regression.

conscripts from regions where milk production was one standard deviation above the average were 1.21*0.8= 0.97 cm taller than conscripts from regions with average milk production. Almost one centimeter difference is an economically significant amount. For example, Baten and Komlos (1998) estimated that one additional centimeter of height difference corresponds with 1.2 year additional life expectancy, which is an important amount.

We also tested whether explicitly defined milk and potato regions showed the observed effects, relative to the "other rural" region represented by the constant.[27] The milk effect is also evident in this specification (Table 1, Col. 4). Finally, we tested an interaction term (Col. 5: Area near town * Milk region). This would measure how, in terms of anthropometric outcomes, milk available for local consumption in rural areas was depleted as a consequence of proximity to an urban market. However, this variable turned out to be insignificant and the coefficient small. This might indicate that the area-near-town effect was not caused by the interaction with milk production.

The use of the production statistics as explanatory variables is based on two assumptions: (1) that in regions where an agricultural good was produced, the local population was better supplied with this good than were other areas. This is especially true if the transport costs of this good were high in relation to its value per weight.[28] (2) that the regional structure of production changed little during the period considered. Typical 1810 milk and cattle regions produced predominantly the same goods in 1840, even if output increased (correlation between milk production in 1810 and 1840 is +0.87 at the district level). In rye and weaving districts and areas near towns the structure of output also remained much the same. The only fundamental change in the production structure was the spread of

[27] For this, we defined milk regions as having more than 400 liters of milk production per capita and year, and potato regions as having more than 400 kilograms of potato production per capita and year.

[27] Examples are milk (no transport over more than 50 km) and potatoes (low price per weight). This local-supply effect was less valid for beef cattle, bacon or grain because their value per transportation cost was higher than that for potatoes. The local supply effect was also measured by Craig and Weiss (1998) and Haines et al. (2003). However, we do not have data on the allotments to animals, and that due to our concentration on animal protein the results are not directly comparable. See also Haines and Kintner (2008).

potato growing, which started in the northwest and northeast and moved slowly southward. Data on potato output are available for 1810 and 1853. To minimize the regional variation in potato output, the average production over the two years was calculated for each region.[29]

FIGURE 3 AROUND HERE

In sum, the regional analysis indicates the following for recruits from rural areas (Fig. 3): (1) Milk production had a positive and significant influence on physical stature. (2) In proto-industrial weaving districts, nutritional status was generally lowest. (3) Nutritional status declined in weaving districts between 1809-19 and 1820-29 (Table 1). (4) The nutritional status of the birth cohorts 1831-35 (measured in 1852-56) was low in areas near towns, either because the link to the urban disease pool or because of the high share of food sold on urban markets. (5) Rye production and the wages of day-laborers had no significant effect on heights. (6) The rejection rate on account of illness was associated negatively with heights in the first two regressions.

TABLE 2 AROUND HERE

**Determinants of the rejection rates (for being too short) in towns.** We repeat the above exercise for conscripts born in towns (Table 2). Milk production around towns had a positive influence on heights again, though significantly so only for periods 1 and 3. The estimated difference of a standard deviation is 1.6 cm for 1831-35. It is possible that when food prices were low in the 1820s, more meat could be purchased so that towns were less dependent on

[28] Even before potato growing was introduced, there was one common characteristic of those regions that later grew potatoes – population was dense in relation to agricultural acreage. This provided incentives for producing potatoes despite their unpopular taste, because if labor was cheap the land productivity for this crop was high. For this reason, more inhabitants per acre could get basic sustenance.

buying milk from the areas immediately surrounding them (Seuffert, 1857). The percentage of officials and professionals, and of people living in their households, is a proxy for the administrative towns. The percentage of officials always influenced rejection rates negatively and significantly (estimated difference in heights: 1.9 cm for 1831-35). Differences in our proxy for disease environment are never significant, a finding which could be caused by the small number of observations. It might also be that the differences in disease environment were too small, after controlling for the milk supply in the cities' surroundings, and the occupational structure of the city.

**The determinants of height of individual conscripts.** These findings on the influence of regional differences are explored further using a sample of individual level data on military conscripts. The military lists from weaving and potato districts, and from industrial towns are not extant. However, five types of region can be examined. Munich was a typical urban administrative center, and data from the alpine areas are representative of men living in the milk region. Data on "areas near towns" come from districts around Munich and Augsburg. The "other rural" regions are represented by a number of districts, and the industrial regions can also be captured.

TABLE 3 AROUND HERE

The rural districts are sorted by height (Table 3). Recruits from milk regions such as Tölz were fully 5.7 cm taller than those from other rural regions such as Bergzabern or Moosburg. The districts from the Alpine milk region are at the top of the table, the large amounts of protein produced were to a large extent consumed within this region (whereas some of Moosburg's protein – a meat producing district close to the Danube river – might have been "exported" to the towns). The areas near town (indicated by names in italics) are

among the districts with lower average height. In contrast, urban men were relatively tall in Bavaria on account of the presence of the court and the bureaucratic elite.

Protein availability in the district had a large positive and economically significant influence also at the individual height level (Table 4, Column 1). Caloric production by itself was insufficient and had a negative impact: Bavaria's main grain production areas exported a high share of their output. Moreover, with trade integration, the disease environment sometimes also becomes more problematic, which might have happened in the regions that produced many calories near rivers. On the other hand, real wages were also comparatively high in grain areas close to the Danube and Main Rivers. In order to control for the time trend, we use two sets of variables, five birth period dummies and real wages during the year before enlistment (Baten, 2000): Because recruits were still growing at age 21, real wages could still affect their growth during the year prior to recruitment. Hence we added the real wage level of the year before measurement of the conscript (i.e., a one year lag) (Gömmel 1978). The birth period dummies have insignificant coefficients. The real wage variable probably picks up the effect, and it has a statistically and economically meaningful impact on heights. In column 2 and 3 we considered the robustness of the coefficients by changing the model slightly. The results are quite robust: only the industrial district loses its detrimental impact on height if the local food production is not controlled for.[30]

TABLE 4 AROUND HERE

## 5. Comparison: Prussia

[29] In addition, we are using the Schneeweiss method in column 2 to deal with multicollineariy between the two nutrient production variables, sweeping out the impact of calorie production on all the other variables. We find that the protein variable remains robust, see Schneeweiss (1990, p. 141-3).

In order to compare the main result found above for Bavaria that milk production influenced local heights substantially, we next analyze Prussian military rejection statistics. For the Kingdom of Prussia, the military conscription records of the measurement year 1854 have been processed, with an underlying sample of 441,236 individuals (Dieterici, 1855). Unfortunately, most of the original individual military records of the Prussian army were destroyed during WWII. In the above publication, the share of those with a height below 162.4 cm is reported by region, for the age range between 20 and 24 (Fig. 4). We have seen above that a low rate of rejection implies tall heights and vice versa. Prussia had general conscription; hence almost all persons were measured and aggregated by contemporary statisticians. A caveat about these records is that those aged 21-24 were measured again, if they were unfit for service during the first measurement. About 175,000 of the underlying cases were age 20, 143,000 age 21, 112,000 age 22, and 32,000 age 23 and 24. However, we assume that the share of repeated measurement was similar across regions.

FIGURE 4 AND 5, TABLE 5 AND 6 AROUND HERE

The amount of milk production per capita in 1861 has been estimated at the district level (Fig. 5, Table 5) (von Viebahn, 1868). Von Viebahn reports the highest level of average milk production per capita for the district of Muenster, followed by Trier, Koblenz, and Stralsund, whereas Danzig, Posen, Bromberg, and Duesseldorf had very low values. Duesseldorf had the highest level of industrialization and population density, whereas the other districts with low milk production per capita were in the Eastern grain belt. The regional differences of milk production did not change as much over time, as an analysis of cattle number demonstrated (Baten, 1996). If we regress the rejection rate on regional milk production, we obtain a statistically negative relationship (Table 6, Col. 4), as in Bavaria. Each additional hundred liters of milk per capita and year reduced the rejection rate for being

too short by 7.6 percent. The R-Square of this single variable is 0.27, hence a bit less than a third of rejection rate differences can be explained in Prussia by milk production alone. The largest deviations are Duesseldorf and Arnsberg, the two most industrialized district of the Rhineland, which had sufficient income to import protein from other districts. Hence it seems clear that the Prussian case supports the "milk hypothesis": i.e., the importance of milk production for the physical growth of the population.

## 6. Comparison: France

A second test can be made with French regional data. France was the first European country that introduced general conscription; hence we again have a representative sample (Bassino and Dormois, 2009). For France, the share of the tallest conscripts is published in the Statistical Yearbook (Annuaire Statistique, 1878).[31] Fig. 6 shows the share of conscripts taller than the threshold of 167 cm, which is also correlated with average height. Toutain (1992/1993) has estimated French milk production for 1840. Hence we can compare the milk production with the share of tall conscripts (Fig. 7). Another potentially interesting variable is the average of agricultural and industrial real wages (Toutain, 1992/1993). With those two variables, the variation in French heights can be explained relatively well, the R-Square of both variables is almost 0.40 (Table 6, Col. 3). The effects are not only statistically, but also economically significant: for example, one standard deviation of increase in milk production increases the share of tall conscripts by 5.3 %, compared to the mean. We have also graphed the residuals, i.e. the share of tall recruits after removing the effects of milk production and real wages (Fig. 8). It is interesting that the districts with largest and smallest residual share of tall recruits are now more or less randomly scattered over France. This contradicts an earlier

[31] Bassino and Dormois (2009) reported doubts about the share of those who were not included, mostly poor emigrants and other parts of the poorer social strata. But this affects the share of the tallest conscripts only to a minor extent (via the denominator, which represents all conscripts), which is the only statistic available for the analysis here.

suggestion by anthropologists that there is a higher genetic height potential of "Germanic" people in the North, and a lower genetic height potential of "Romanic" people in the South (Koepke and Baten, 2008). Tall recruits were primarily a function of milk protein and of real wages.

FIGURE 6, 7, AND 8, TABLE 6 AROUND HERE

## 7. Conclusion

This case study of the Kingdom of Bavaria, and the comparisons with Prussia and France, have shown that local agricultural production mattered a lot for heights in a given region. An analysis of the regional structure of production in 179 Bavarian rural districts revealed important geographic differences that varied systematically with milk and potato production, as well as industrialization and urbanisation.

Areas near towns had a relatively low nutritional status, because a large percentage of the protein-rich food produced in these regions was sold in urban markets. Nutrition was also poor in the weaving and potato regions in Bavaria, both of which were densely populated in the early 19th century.[32] Cattle transport permitted a relatively high nutritional status in Bavarian towns, especially in administrative centers. Inhabitants of Munich, for example, did not suffer from the nutritional disadvantages experienced by the inhabitants of rural non-milk regions.[33] This was caused by the proximity of Munich to the Alps so that it could be supplied with dairy products. In addition, the presence of the court meant that a relatively large middle class lived in the town. Few other contemporary towns were so luckily situated. This differs from evidence from American, English, Swedish and Japanese towns of the same period,

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[31] Evidence about these last two regions is based on a single source only, the conscript statistics, while several sources were used to investigate differences between the other regions mentioned in this study.

[33] Similarly, the rejection rates in administrative cities such as Bamberg or Bayreuth were relatively low, but those facts were not analyzed systematically in this study.

where "urban penalty" was not only evident in higher disease rates and lower life expectancy, but also in lower heights.[34]

The most important result of this study is the measurable influence of milk production on nutritional status in the 19th century. All anthropometric evidence points to the fact that inhabitants of regions that specialized in cattle farming achieved higher nutritional status than their contemporaries in grain producing or other areas. "Milk production per capita" explains a lot of the variation in rejection rates among Bavarian regions. This finding was tested also with regional data for Prussia and France. In both countries, there was a significant influence of local milk production on average height (or the share of short or tall conscripts, which tend to correlate with average height). The main reason for this is the lack of refrigeration which prohibited the transportation of milk over great distances until the late 19th century.[35] Hence, farmers produced (besides meat) clarified butter and sour milk, only the first of which could be transported easily over long distances. Even when real income was low in some of the "milk regions", the low relative price of milk and sour milk made a protein-rich diet possible for the regional population in the early modern period.

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33 Many anthropometric historians have observed height disadvantages for urban inhabitants: Komlos (1992); Margo and Steckel (1983, p. 169); Shay (1994, pp. 41-43); Sandberg and Steckel (1987, pp. 101-110).

34 In addition, hard cheese production was unknown in these "milk regions".

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**Table 1**

**Regressions: Determinants of Rejection Rates in Bavarian Rural Districts**

| Dependent variable: Rejection rate (in %) | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| a) Reason: | Too Short and Weak | Too Short and Weak | Too Short | Too Short | Too Short |
| b) Birth years: | 1809-19 | 1820-29 | 1831-35 | 1831-35 | 1831-35 |
| Explanatory variables: | | | | | |
| Milk production | -0.46** | -0.53** | -0.59** | | |
| | (0.00) | (0.00) | (0.00) | | |
| Rye production | 0.26** | 0.00 | 0.01 | | |
| | (0.01) | (0.98) | (0.97) | | |
| Potato production | 0.13** | 0.11** | 0.12* | | |
| | (0.09) | (0.02) | (0.14) | | |
| Rejection because of disease | 0.05** | 0.03** | -0.00 | 0.01 | 0.01 |
| | (0.00) | (0.00) | (0.99) | (0.66) | (0.43) |
| Rye wages of day laborers | 0.09 | 0.10 | -0.05 | -0.25* | -0.25* |
| | (0.40) | (0.24) | (0.73) | (0.07) | (0.07) |
| Weaving district | 0.97** | 2.01** | 2.90** | 3.08** | 3.07** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Area near town | 0.31 | 0.27 | 0.89** | 0.63* | 0.79 |
| | (0.13) | (0.22) | (0.01) | (0.06) | (0.27) |
| Milk region | | | | -1.95** | -1.92** |
| | | | | (0.00) | (0.00) |
| Potato region | | | | 0.39 | 0.39 |
| | | | | (0.17) | (0.17) |
| Milk prod. * area near town | | | | | -0.08 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | (0.26) |
| Constant | 0.91 | 1.89** | 5.84** | 5.62** | 5.66** |
| | (0.16) | (0.00) | (0.00) | (0.00) | (0.00) |
| Adj. $R^2$ | 0.46 | 0.48 | 0.29 | 0.27 | 0.27 |
| N | 150 | 179 | 179 | 179 | 179 |

Notes: P-values in brackets. * coefficient significant on the 10%-level. ** coefficient significant on the 1%-level. The difference between “too short and weak” and “too short” refers to change of definition in the conscription statistics. From 1809 to 1830 only those conscripts were counted in the category "unfit for being too short" who were shorter than 155.6 cm and also so weak (but not pathologically ill) that the recruitment physicians would not expect an increase of their heights up to the minimum requirement until the following year. Recruits with these two characteristics are called "definitely unfit for being too short". Their percentage ranged between about 1 and 3 percent in upper Bavaria. From 1831 to 1835, all recruits shorter than 155.6 cm were counted as "unfit" in the statistics, about 3 to 6 percent in Upper Bavaria. Although we can assume a correlation between the recruits "unfit because too short and weak" and those "unfit because too short", the development between the birth years 1830 and 1831 is not interpretable. The constant refers to a district that is neither near a town, nor a weaving district, and where all continuous independent variables are zero. Weaving districts are the district of Eastern Franconia, for which intensive weaving activity was reported in Rudhart (1825), namely Baireuth, Berneck, Culmbach, Hof, Kirchlamitz, Muenchberg, Naila, Rehau, Selb, Stadtsteinach, Wunsiedel. Standard deviations are for colum 1-3: milk prod. (1.03), rye prod. (0.87), prod. potato (1.85), Rejection because of disease (12.20), Rye wages (0.97). Sources on milk, rye, potato production, population, wages, rejection rates: Beiträge zur Statistik des Königreichs Bayern (1854, 1855, 1857, 1859). Montgelasstatistik (Bayer. Staatsbibliothek cgm 6844-55, on mortality [not used ] cgm 6847,4).

**Table 2**

**Regressions: Determinants of Conscript Rejection Rates in 29 Bavarian Towns**

| Dependent variable: rejection rate (in %) | (1) | (2) | (3) |
|---|---|---|---|
| a) reason: | too short and weak | too short and weak | too short |
| b) birth years: | 1809-19 | 1820-29 | 1831-35 |
| Explanatory variables: | | | |
| Civil servants'/professionals ' households in % | -0.08** | -0.07* | -0.15* |
| | (0.00) | (0.02) | (0.00) |
| Milk production in the area near town | -0.54* | -0.27 | -1.17* |
| | (0.06) | (0.28) | (0.03) |
| Rejection rate because of disease | 0.03 | 0.02 | 0.01 |
| | (0.25) | (0.33) | (0.94) |
| Constant | 3.28* | 3.31** | 9.19** |
| | (0.01) | (0.00) | (0.00) |
| Adj. $R^2$ | 0.28 | 0.20 | 0.23 |
| F | 4.68** | 3.27* | 3.86* |
| N | 29 | 29 | 29 |

Note: Constant refers to a hypothesized town where all explanatory variables are zero. P-values in brackets.

*, **: significance levels see table 1.

"Milk production": See table 1; "area near town": see table 1.

" Civil servants'/professionals ' households ": Number of persons living in the households of civil servants and professionals in % of total population (in 1852).

Sources: Milk production, rejection rate, population structure, calculated according to: Beiträge zur Statistik (see notes to Table 1).

**Table 3**

**Occupational Structure and Local Food Production of those Districts for which Individual Data on 21-Year-Old Conscripts are Available**

| District | District type | Height in cm | Share of non-agricultural population | Daily production of... | | |
|---|---|---|---|---|---|---|
| | | | | Protein | kcal (total) | kcal (potatoes) |
| Tölz | Milk | 170.2 | 7.0 | 43.5 | 294 | 13 |
| Miesbach | Milk | 168.3 | 19.2 | 39.6 | 1715 | 92 |
| Wasserburg | Other rural | 167.5 | 14.3 | 34.0 | 3038 | 338 |
| Reichenhall | Industrial | 166.8 | *42.1* | 26.0 | 1030 | 27 |
| Frankental | Industrial | 166.2 | *32.8* | 14.3 | 1251 | 96 |
| Bruck | Near town | 166.0 | 8.4 | 40.5 | 3283 | 467 |
| Hemau | Other rural | 165.7 | 19.8 | 19.7 | 1981 | 211 |
| Brückenau | Other rural | 165.6 | 20.4 | 18.7 | 2009 | 778 |
| Kaiserslautern | Industrial | 165.5 | *30.2* | 11.8 | 972 | 468 |
| Speyer (rural) | Near town | 165.3 | 25.7 | 14.6 | 1809 | 829 |
| Nuremberg (rural) | Industrial, Near town | 165.0 | *38.4* | 3.8 | 966 | 265 |
| Neustadt | Other rural | 164.7 | 25.6 | 13.8 | 1077 | 566 |
| Friedberg | Industrial, Near town | 164.7 | *30.1* | 27.4 | 2137 | 190 |
| Moosburg | Other rural | 164.5 | 10.9 | 33.9 | 3914 | 591 |
| Altdorf | Near town | 164.4 | 24.5 | 13.2 | 2486 | 969 |
| Bergzabern | Other rural | 164.3 | 12.9 | 14.7 | 2044 | 944 |
| *Administration towns:* | | | | *Daily consumption (approx.)* | | |
| München | Town | 167.1 | 99.0 | 30.0 | 2000 | 500 |
| Ingolstadt | Town | 166.1 | 83.8 | 30.0 | 2000 | 500 |
| Average Bavaria | | 166.0 | 30.3 | 23.9 | 1889 | 436 |

Notes: Towns are reported in a separate section at the bottom of the table, because agricultural production estimates are not informative about local consumption amounts. Instead, we report estimates for consumption in cities. München includes the district of Au.

Column (3): share of non-agricultural population (December 1852). Source: Beiträge (1853); Angerpointner (1994).

(4): Estimated production of animal protein (for the towns: estimated consumption) based on the estimated daily milk production in liters p.c. Algorithm: [Number of cows p.c. in 1840 x 650 l (annual output of a cow) : 365 (days)] x 30g (protein)/l (milk) + 25% of meat production (beef, pork) of the respective district (200 g of protein per kg of meat, see Beck (1986, p. 248), because most of the meat was exported to the towns. Source: Beiträge (1855).

(5): Estimated nutritional value (in kcal.) of grain and potatoes produced.) Grain and potato production of an average year per capita x 370 kcal/100g of grain, minus 25% because of wastage during grinding, therefore approx. 280 kcal/100g, + 70 kcal/ 100g of potatoes. The additional calories from milk products, meat and vegetables (approx. 30%) are not taken into account. Source: Beiträge (1857); Beck (1986, p 248).

**Table 4**

**Regressions: Determinants of Heights of 21-Year-Old Conscripts in South Eastern Bavaria, Born Between 1815-44**

| | Included nutrient estimates | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Middle and upper class | 1.25*** | 1.29*** | 1.37*** |
| | (0.19) | (0.19) | (0.21) |
| Born 1815-19 | -0.21 | -0.23 | 0.01 |
| | (0.17) | (0.16) | (0.19) |
| Born 1825-29 | -0.13 | -0.06 | -0.11 |
| | (0.13) | (0.12) | (0.13) |
| Born 1830-34 | -0.18 | -0.173 | -0.16 |
| | (0.17) | (0.17) | (0.20) |
| Born 1835-39 | -0.13 | -0.09 | -0.12 |
| | (0.12) | (0.12) | (0.10) |
| Born 1840-44 | -0.06 | 0.10 | 0.17 |
| | (0.23) | (0.25) | (0.25) |
| Real wage (over time) | 0.03*** | 0.03*** | 0.02*** |
| | (0.01) | (0.01) | (0.01) |
| Area near town | -0.31 | -0.79* | -0.69 |
| | (0.32) | (0.44) | (0.44) |
| Town | 0.06 | 0.32 | 0.72 |
| | (0.34) | (0.58) | (0.60) |
| Early industrial | -0.40 | 0.42 | 0.01 |
| | (0.36) | (0.40) | (0.46) |
| Protein | 1.08*** | 0.80** | |

| | | | |
|---|---|---|---|
| | (0.12) | (0.29) | |
| Calories | -1.00*** | | |
| | (0.20) | | |
| Constant | 163.50*** | 162.10*** | 164.10*** |
| | (0.72) | (0.75) | (0.58) |
| Observations | 21064 | 21064 | 21064 |
| Adj. R-squared | 0.04 | 0.03 | 0.02 |

Notes: Included nutrient estimates: (1) protein and calories, (2) protein, (3) neither protein nor calories. The p-values (in parentheses) are based on standard errors adjusted for clustering (regions). The constant refers to a conscript whose father had a lower class profession, and who was born in a other rural district between 1820 und 1824. Sources: State Archive Amberg, Records BA Hemau 761-786, LG Hemau 1207-1226M; State Archive Augsburg Records JVA Kaisheim; State Archive München - Records RA 27231-28366; Records JVA Wasserburg; State Archive Nürnberg -Records BA Nürnberg; State Archive Speyer - Records G 7 Militaria 1. The occupational coding scheme is based on Lundgreen and Kraul and Ditt (1988, pp. 321-350). Definitions: "animal protein": daily production (in towns: consumption) in units of 10g; "calories": nutritional value of daily grain and potato production in units of 1000 kcal; "real wage": real wage index (1913=100) of the two years before conscription; "town", "area near town", "early industrial district": see text and Table 3. **, * significance level 1% and 10% respectively.

**Table 5**

**Rejection rate for being too short in Prussia (birth cohort 1854) and milk production per capita (1861)**

| District | Rejected (in %) | Milk p.c. (in 100 Liter) |
|---|---|---|
| Posen | 37.3 | 2.09 |
| Gumbinnen | 35.1 | 2.60 |
| Bromberg | 34.6 | 1.98 |
| Marienwerder | 32.5 | 2.34 |
| Oppeln | 32.3 | 2.60 |
| Breslau | 31.0 | 2.47 |
| Koeln | 26.3 | 3.06 |
| Koenigsberg | 25.9 | 2.34 |
| Aachen | 25.0 | 3.42 |
| Frankfurt | 23.6 | 3.04 |
| Danzig | 23.0 | 1.82 |
| Liegnitz | 22.5 | 2.99 |
| Koblenz | 21.8 | 3.60 |
| Merseburg | 20.7 | 3.23 |
| Potsdam | 19.5 | 3.20 |
| Koeslin | 19.5 | 2.94 |
| Magdeburg | 19.0 | 2.72 |
| Trier | 17.8 | 3.78 |
| Erfurt | 15.8 | 2.38 |
| Minden | 15.3 | 3.00 |
| Stettin | 14.6 | 2.66 |
| Duesseldorf | 14.3 | 2.16 |
| Arnsberg | 10.9 | 2.85 |
| Muenster | 07.6 | 4.35 |

| | | |
|---|---|---|
| Stralsund | 04.5 | 3.50 |

Sources: Rejection rates: Dieterici, C.F.W., 1855. Statistische Übersicht des Ersatz-Aushebungs-Geschäfts im Preußischen Staate für die Jahre 1837, 1840, 1843, 1846, 1849, 1852, 1853 und 1854. In: Mitt. d. Stat. Bureau's in Berlin, 8. Jg., 325-364; Milk: v. Viebahn, G. (Ed.), 1868. Statistik des zollvereinten und nördlichen Deutschlands, Bd. III, Berlin, 119.

**Table 6**

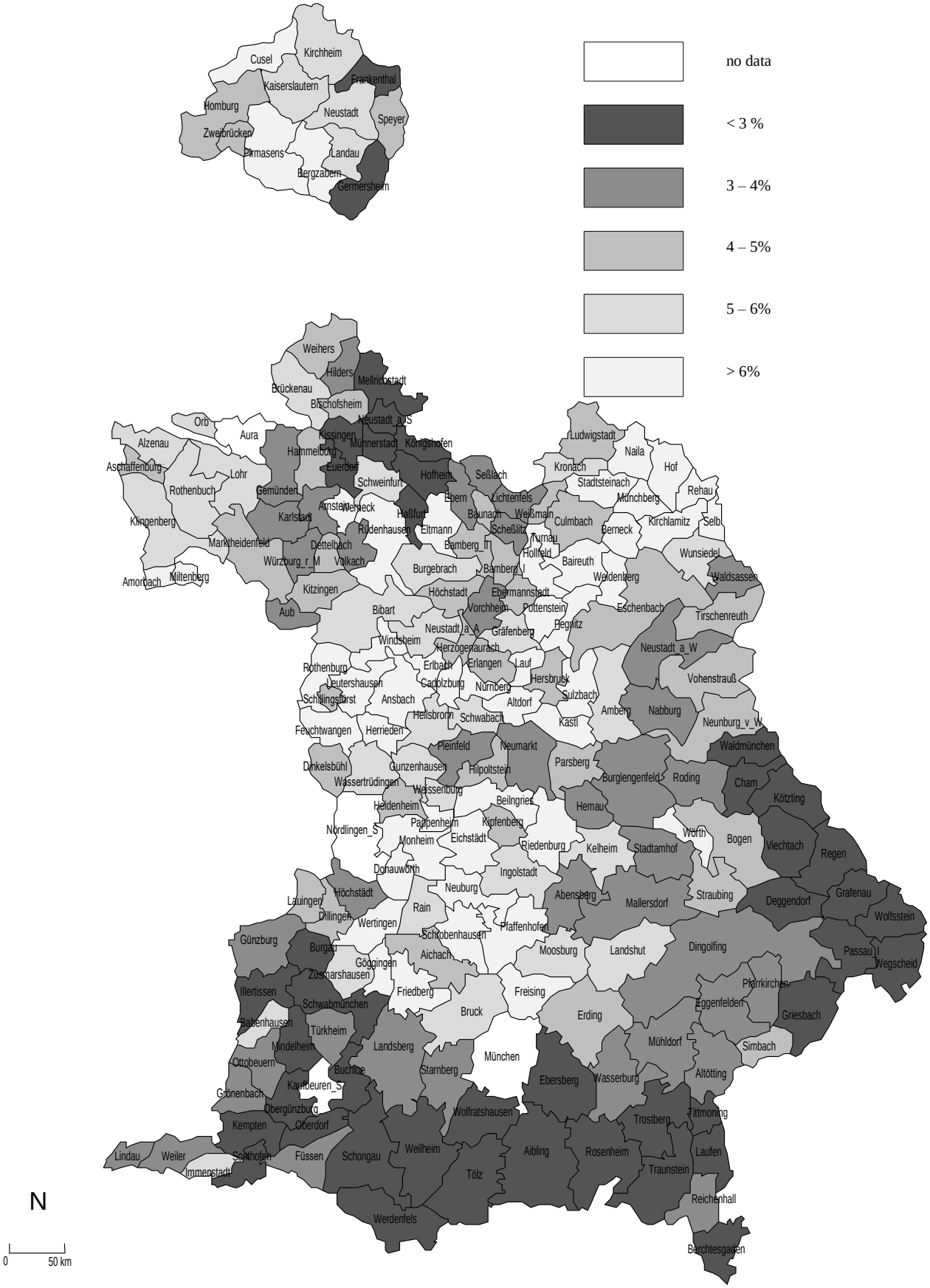
**Regressions of the share of tall conscripts in France, birth year 1854, and the share of rejected conscripts in Prussia, measurement year 1854**

| Regression no. | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| State | France | France | France | Prussia |
| Milk production | 0.80 | | 0.54 | -7.6 |
| per capita | (0.00) | | (0.00) | (0.01) |
| Real wage | | 1.15 | 0.87 | |
| | | (0.00) | (0.00) | |
| Constant | 30.4 | 7.8 | 10.7 | 0.00[a] |
| | (0.00) | (0.12) | (0.03) | |
| R-Square | 0.25 | 0.28 | 0.38 | 0.27 |

Notes: p-value in parentheses. Two outliers (Calvadados and Manche) who were further than 3 standard deviations from the mean have been excluded, in order to estimate the coefficient efficiently. If those two are included, the R-square declines to 0.27 in Col. 3, but still both coefficients remain significant at the 1 percent level. The units for milk production are 100 liter per capita and year in Prussia, and Franc price per capita (in 10 FF units) and year in France.

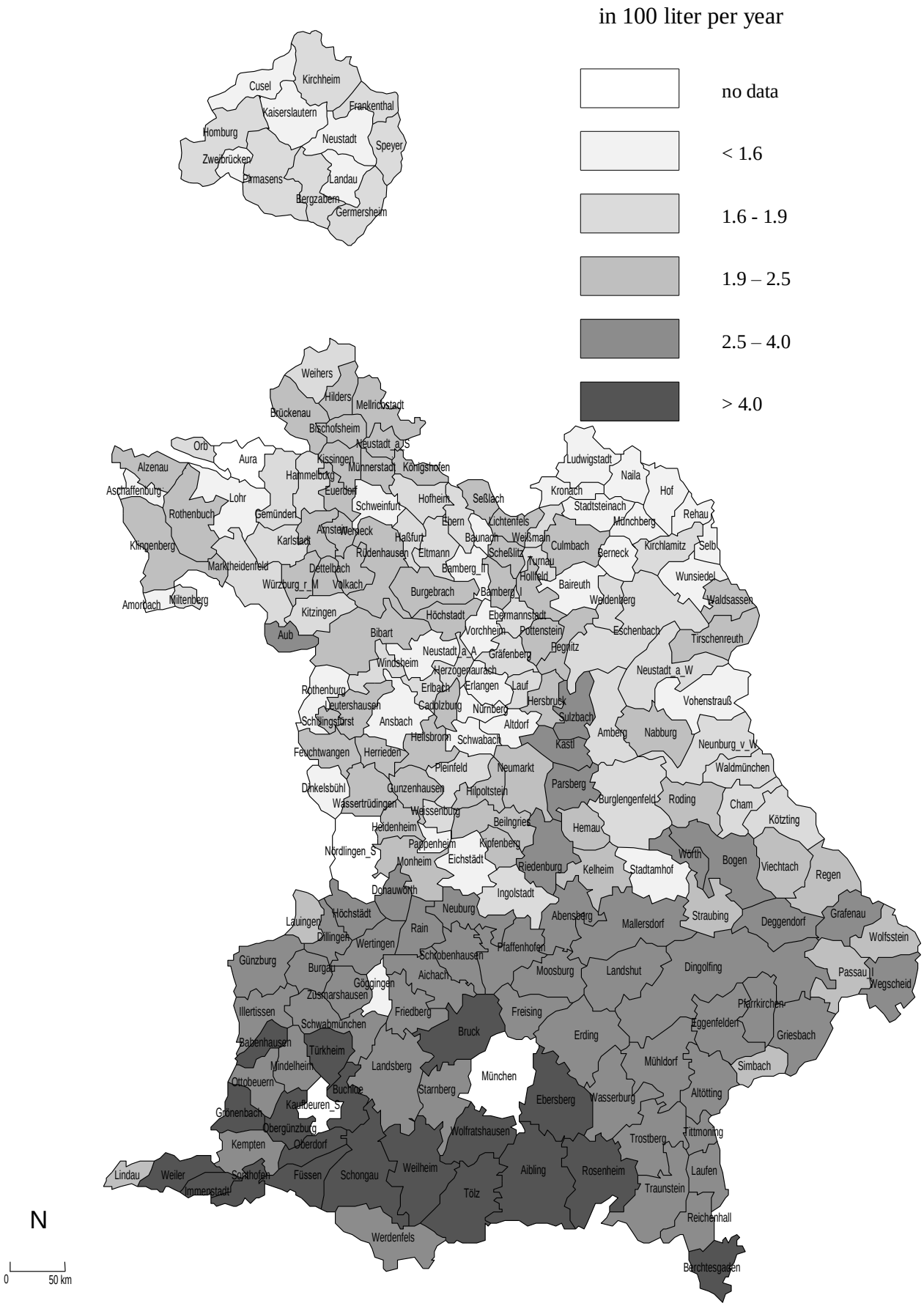
[a] in the regression of the rejection rate in Prussia, the constant was set to zero.

**Fig. 1. Rejection rate (for being too short, in %) in Bavaria, birth cohorts 1831-35**



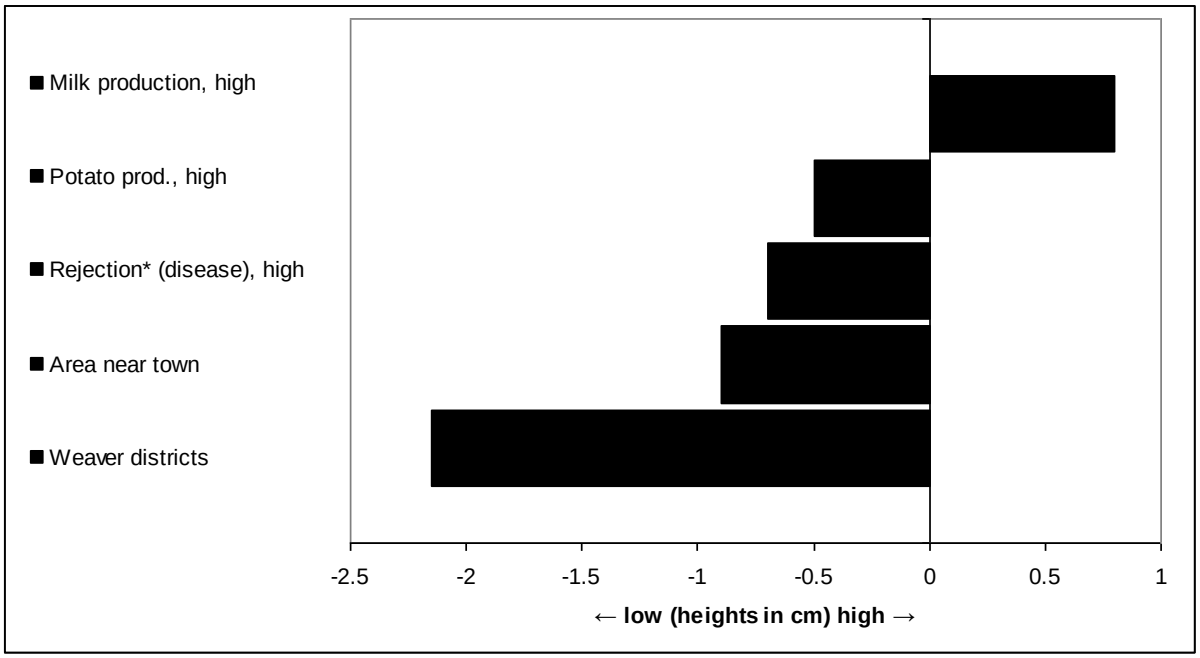

Note: no data on München, Kaufbeuren, Aura, Nördlingen.

**Fig. 2. Milk production per capita in Bavaria, 1840**




Note: no data on München, Kaufbeuren, Aura, Nördlingen.

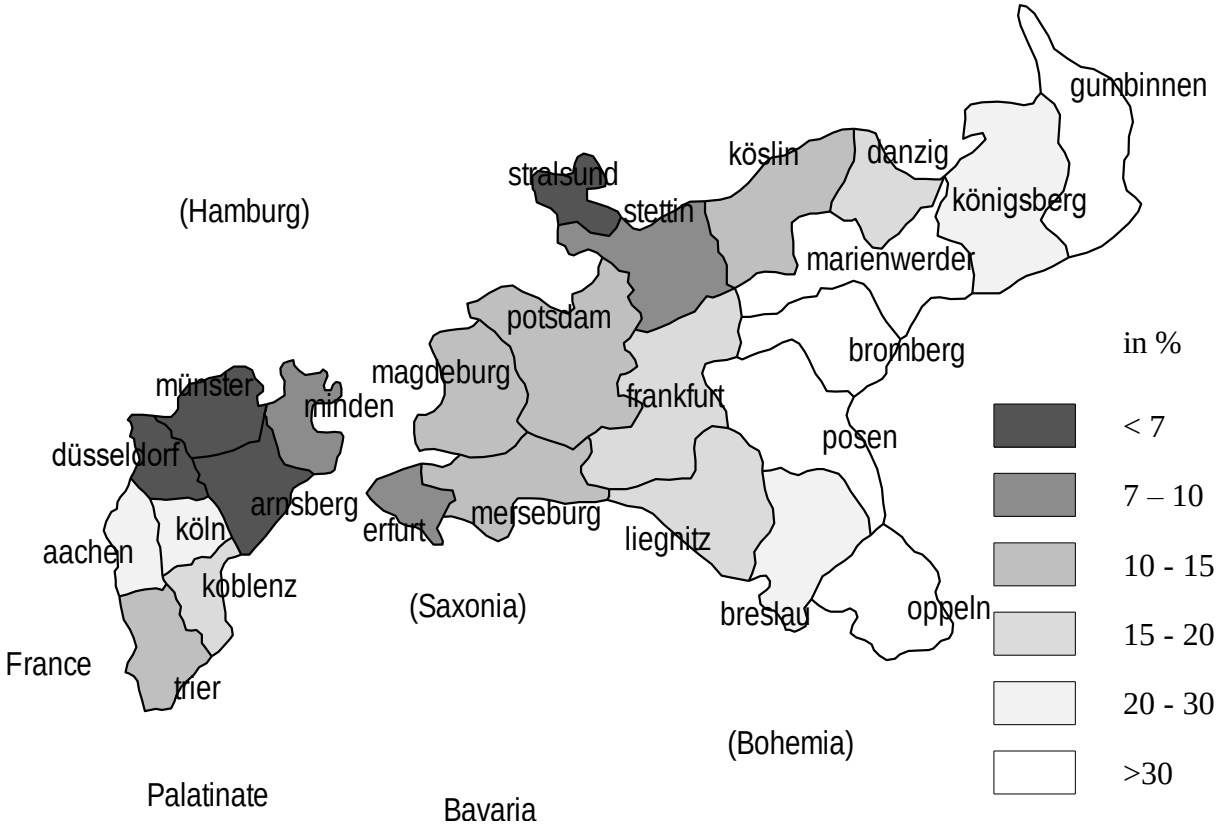
**Fig. 3. Estimated Influence of determinants from Table 1 on heights, birth years 1831-35 (Average height: 165.4 cm)**




High: Distance between two standard deviations of the exogenous variables; *1809-19.

Source: Table 1.

**Fig. 4. Rejection rate (for being too short, in %) in Prussia, measurement year 1854**




Note: conscripts aged 20-24. The minimum height requirement in Prussia was 162.4 cm, but conscripts at ages 21-24 were measured again, if they failed the minimum height requirement at age 20. Hence the rates were not directly comparable in level to those in Bavaria. Neighboring regions with brackets are not analyzed, while neighboring regions without brackets are studied in the other parts of this article.

**Fig. 5. Milk production in Prussia 1861**

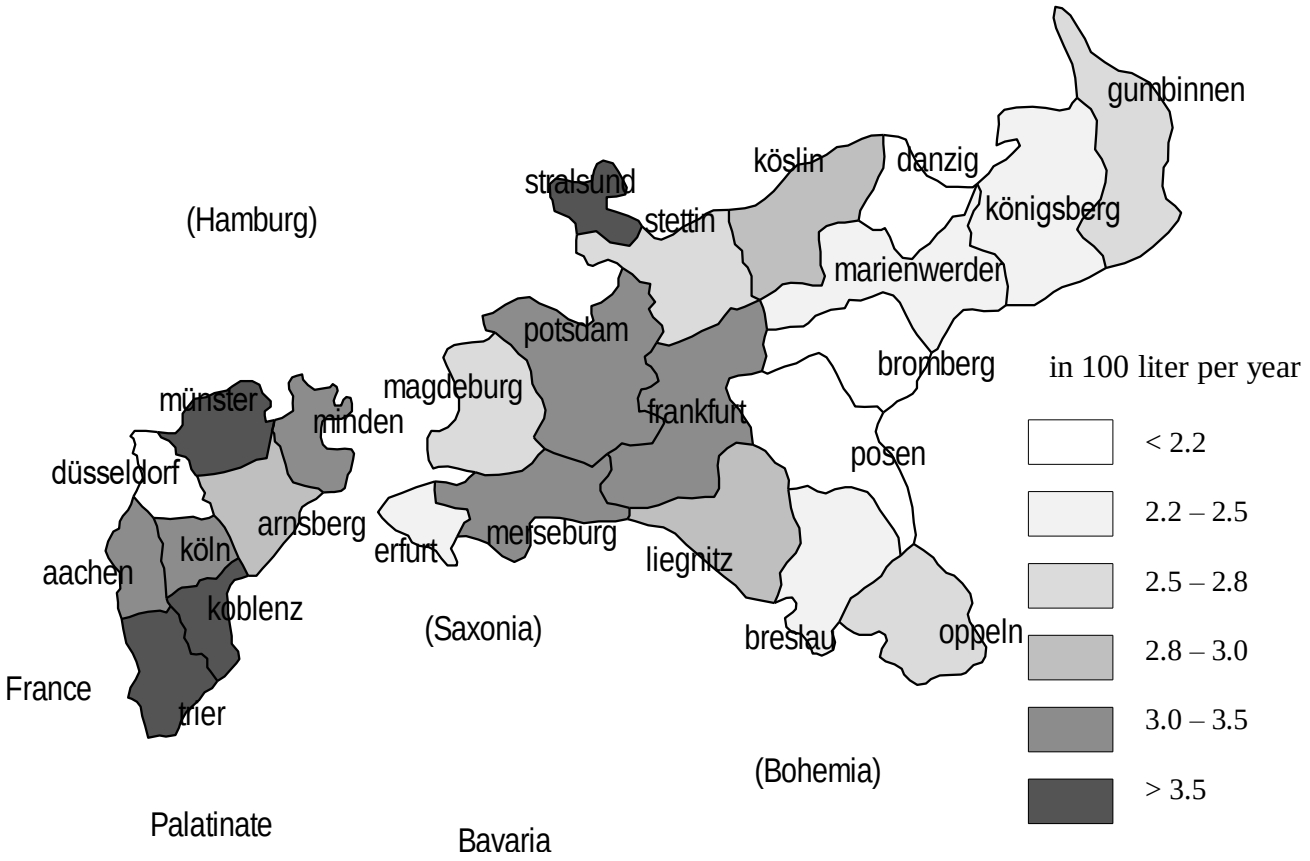
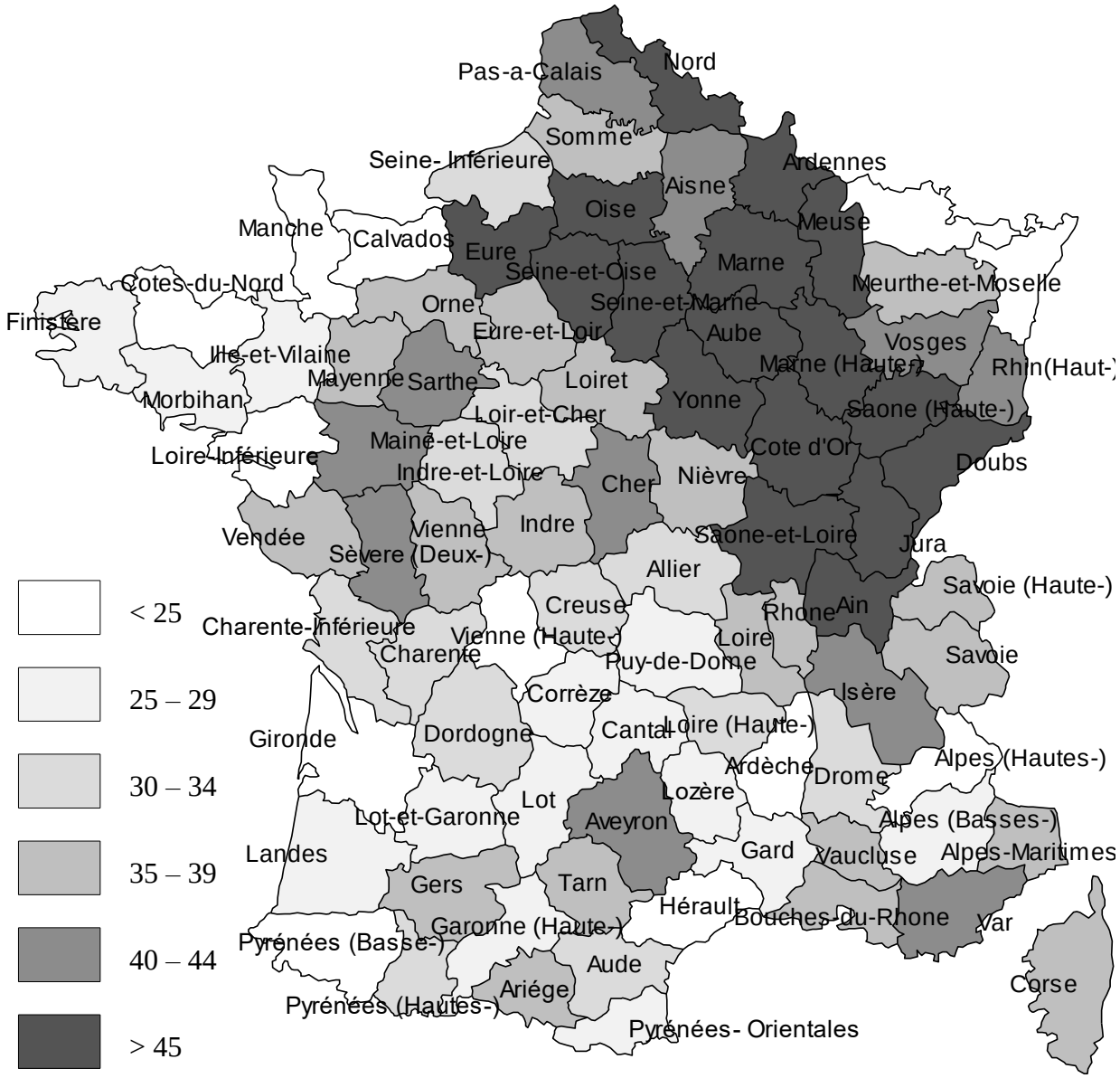
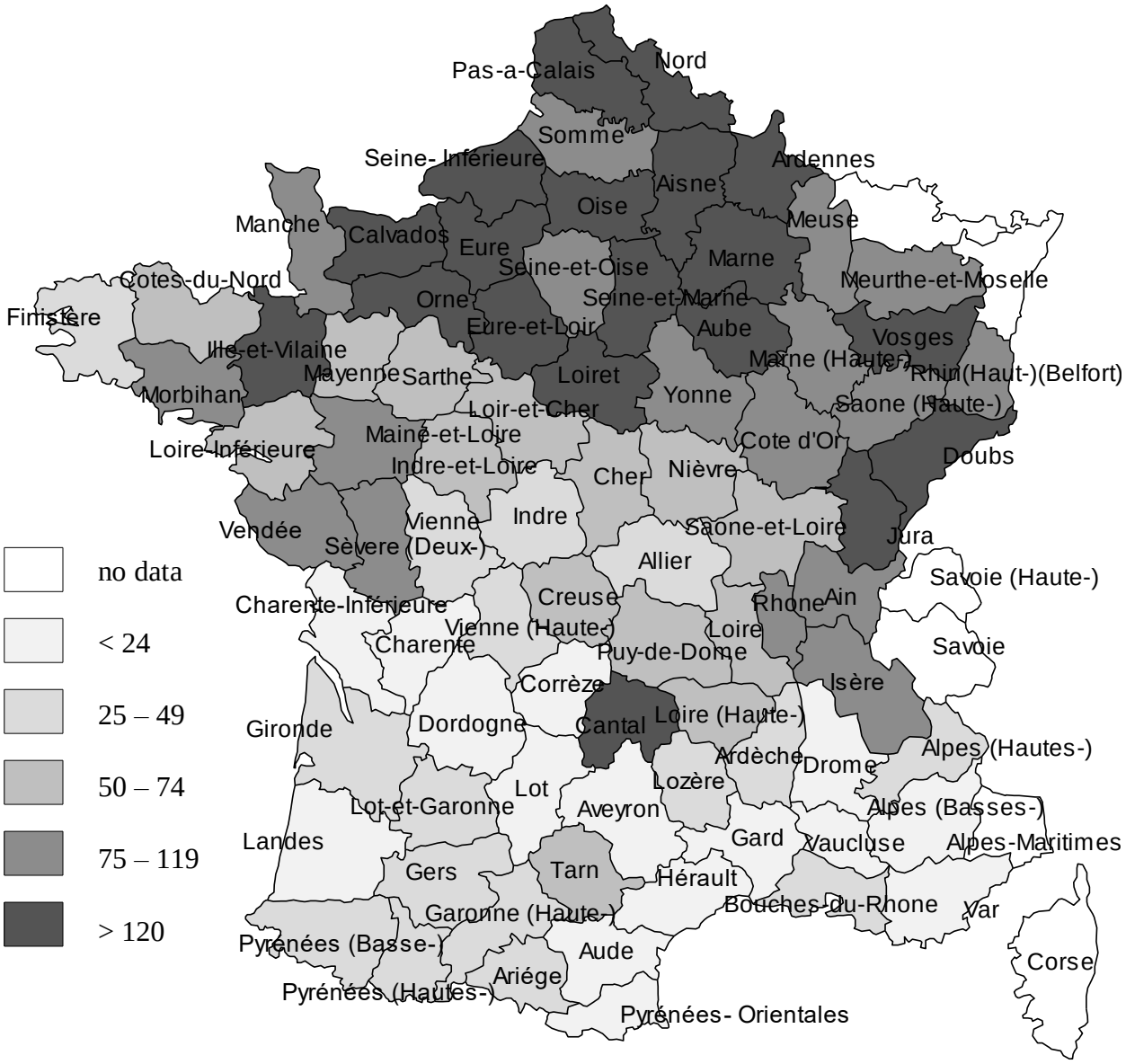


**Fig. 6. Share of tall conscripts in France (in %)**




Source: Annuaire Statistique, 1878.

**Fig. 7. Milk production in France (in Franc values)**




Note: no data are available for on Corse, Savoie, Savoie (Haute), Alsace, Lorraine

**Fig. 8. Residual share of tall conscripts in France (after removing the influence of milk production and real wages, in %)**