

# ***Did the Railway Increase Inequality? A Micro-Regional Analysis of Heights in the Hinterland of the Booming Ruhr Area During the Late Nineteenth Century\****

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*This study uses anthropometric methods to investigate the combined effect of economic growth and the expansion of the railways on the biological standard of living in the rural hinterland of one of Germany's major industrial areas, the Ruhr district. Methodologically, we propose an interaction approach to accommodate the ambiguous effect which market integration might have had on the well-being of agricultural and industrial populations. A pilot study which used an interaction approach for a southern German area during an earlier phase of market integration demonstrated that railway construction had serious drawbacks for agricultural communities. However, our investigation of heights in north-western Germany shows that while in the early 1880s, agricultural places profited somewhat less from the newly-built transportation facilities than non-agricultural places did, this significant and negative interaction of railway access with proximity to high-quality protein production disappeared by the late 1890s. While, in the short run, market integration might have had unhealthy effects on some parts of the population, in the long run its advantages outweighed its drawbacks. Moreover, we provide the first trend estimates of heights in northern and western Germany for the late-nineteenth century. We find that overall height trends were positive, although social inequality increased and heights became increasingly determined by wages.*

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## **1. Introduction**

One of the most intensely debated issues in economic history is the evolution of living standards during phases of rapid economic development.<sup>1</sup> Many earlier studies focused on the purchasing power of the lower classes during the initial stages of the Industrial Revolution.<sup>2</sup> Later on, additional components of human welfare such as life expectancy and nutrition entered into the discussion: during some phases, even the real income of the lower social classes improved, while their "Biological Standard of Living" deteriorated.<sup>3</sup> Since average human stature turned out to be an indicator of the quality of nutrition during childhood (which in turn tended to be correlated with health and life expectancy), the biological standard of living became widely used for studying different aspects of human welfare. Following the seminal study of Margo and Steckel who found that the pre-war United States experienced declining heights in an era of rapid per capita GDP growth, much research has been done in this field, although most studies could only rely on macroeconomic evidence.<sup>4</sup> In two remarkable papers, however, Craig, Haines and Weiss were able to disaggregate regional factors in the U.S. to the county level.<sup>5</sup> High-quality proteins such as those contained in milk were consumed locally and not transported across counties before the railway network was extended to remote agricultural regions. Hence research must be carried out on even more disaggregated regional units. The present study extends the literature by collecting relevant information on villages and towns and connecting it with anthropometric data. We measure the distance between each location and the nearest railway

division of labour between the authors resulted in Joerg Baten being mainly responsible for the economic analysis, while Georg Fertig focused on statistical techniques. However, both authors are equally responsible for the text.

<sup>1</sup> For an overview, see Steckel (1995).

<sup>2</sup> Lindert and Williamson (1983); Feinstein (1998).

<sup>3</sup> Komlos (1989).

<sup>4</sup> Margo and Steckel (1983).

<sup>5</sup> See Craig and Weiss (1998); Haines, Craig, and Weiss (2003) for studies on the county level. See also Goodwin, Grennes and Craig (2002).

station, both before and after the railway began to interconnect remote rural communities in the late nineteenth century. Figures on cows and pigs are used to estimate further how closely these locations were situated to protein production. Komlos has summarised the discussion on the “early industrial growth puzzle” and provided a list of factors that might explain the bifurcation of heights and real income.<sup>6</sup> Among the most prominent explanatory variables were changes in income distribution, the relative prices of nutrients, and market integration.<sup>7</sup> We will argue that shifts in nutrient – and especially protein – consumption between urban and rural dwellers were a major driving force behind regional height differences: in spite of generally higher incomes in industrial areas, it could be beneficial for children’s health to live in the remote, protein-producing countryside. However, when the railway came to those regions, children in places specialising in agricultural production profited less from the improved infrastructure than did other children. Thus, the relative advantage of proximity to nutrient production was reduced. This might seem astonishing since there is no doubt that the railway generated additional income. Yet parents could spend this additional income on other goods. For instance, protein provision to children (or nursing mothers) might have been given low priority if the head of the household did not notice or care about the harmful effects of consuming high quantities of starches instead of milk, cheese or meat. The unhealthy treatment of children was a widespread phenomenon in the nineteenth century. Most of the era’s very high infant mortality rates can be attributed to uninformed or careless parental treatment.<sup>8</sup> On the other hand, rich urban dwellers (and to some extent all people in non-

<sup>6</sup> Komlos (1996); on the use of anthropometric methods, see also Steckel (1995). One of the earliest articles on European heights was Komlos, who forged the term “Biological Standard of Living” (1985). For another good overview of the early industrial growth puzzle, see Komlos (1998). The regional inequality of the Habsburg Empire was recently described in Komlos (2007), and on Japan see Bassino (2006).

<sup>7</sup> Several other factors are connected to these core elements: for instance, proximity to nutrient production – a prerequisite for higher nutrient consumption – was the driving force behind the changes caused by market integration.

<sup>8</sup> Lee (1977).

agricultural regions) benefited from the new infrastructure not only in terms of real income but also with regard to their diet. Fresh milk of sufficient quality was simply not available in the cities before the railway came. It can be presumed that nutritional inequality rose after this period of impressive market integration in favour of the rich.

We do not claim that average heights measure welfare in the same way that real wages do, or that they are influenced only by protein input. Clearly, they are also influenced by the disease environment, and in very specific situations perhaps by child labour. Alternative causal chains can be speculated about, but we decided to disregard them as long as those factors cannot be observed. For instance, it could be imagined that the railway transported unhealthy micro-organisms from the cities to the countryside (Haines 2004, p. 256). However, we cannot measure this effect empirically, whereas protein production is an observable variable.

It is important to study heights because they tend to be correlated with life expectancy and health. R. Fogel (1994) stressed in his lecture to the Nobel Prize committee that a height gap of 17.5 cm among Norwegian males in the 1960s and 1970s increased the probability of dying in the subsequent period by no less than 71 percent. He based his work on H. Waaler (1984), who measured several thousand Norwegians and followed their height development in a longitudinal study. Norway had one of the best-nourished populations in the late twentieth century. Baten and Komlos (1998) estimated that one centimetre in height equals about 1.2 years of life expectancy, with only negligible coefficient changes over time between the birth cohorts of 1860, 1900, and 1950 (the latter having been adults since the 1970s). Hence, one centimetre already makes a meaningful difference, since living 1.2 years longer is a substantial asset in one's 'quality of life-portfolio.' Moreover, height differences are not only important for proxying welfare levels, but are also intrinsically interesting, since height often influences self-confidence, for example. Based on this relationship, contemporary economists use height as an indicator of the willingness to take risks (Dohmen *et al.* 2006).

**1.1 Studies on Regional Height and Market Integration.** Our research strategy is based on the literature on regional nutritional status during

the Industrial Revolution. Komlos developed a model of food consumption during the early market-integration process.<sup>9</sup> He compared five regions of the Habsburg Empire, as his data for the eighteenth century did not allow a regression approach on a more disaggregated level. Komlos found that the initially remote and non-integrated regions had the tallest military recruits, but also experienced the most drastic height decline during the early market-integration phase. The formerly isolated peasants had provided their children with good nutrition simply because they had had no alternative - transaction costs were too high to buy other foodstuffs. Yet when new means of transportation became available and demand in the rapidly urbanising centres grew considerably, the same peasants felt tempted to consume more luxury goods (like tobacco, sugar, clothing or clocks) and gave less protein-rich food to their children, because the exciting new goods necessitated higher expenses. This does not mean that the peasants let their children starve, but only that the quality of the latter's food decreased somewhat.<sup>10</sup>

Baten studied 179 Bavarian regions and found a positive impact of local milk production, notably before the railway arrived in early-nineteenth-century Bavaria.<sup>11</sup> Only the areas near towns displayed a distinctly negative market-integration effect, because they sold many nutrients on urban markets. Baten also found a positive impact of milk production for Württemberg around the mid-nineteenth century,<sup>12</sup> whereas Twarog produced a map of late-nineteenth-century heights in which recruits from dairy regions were no longer significantly taller.<sup>13</sup> Closest to our approach, but for an earlier time period and a resource-abundant country, is the study by Craig and Weiss who calculated food production estimates for the United States at the county level and introduced the variable of access to navigable waterways in the early nineteenth century.

<sup>9</sup> Komlos (1989); Komlos (1987). See also Haines (2004).

<sup>10</sup> A'Hearn (2003) found that in Italy textile workers were, in fact, among the shortest segments of the population, which implies that the famous Italian textile districts did not increase workers' biological standard of living.

<sup>11</sup> Baten (1999a).

<sup>12</sup> Baten (1999b).

<sup>13</sup> Twarog (1997).

When regressing the heights of Civil War recruits on these variables, they found an impressive negative impact of the transportation variable whereas nutrient surplus production was positive, both in terms of proteins and calories.<sup>14</sup> As mentioned in the introduction, we think that transport facilities should be additionally considered on the local level, because milk and other perishable goods could not be shipped over more than one to five kilometres, and German and U.S. counties often covered an area of 50-80 kilometres or more in diameter. Milk was transported by railway both unrefrigerated in the early period – which limited the distance for transports – as well as refrigerated on specialized railway cars. After early attempts in the U.S. (near Chicago) during the 1860s, a refrigerator railcar (“reefer”) was developed for practical use in 1876 (Dienel 1995, on the following). In Germany, the engineer Carl von Linde made an important distribution by developing in 1876 one of the first mechanical refrigeration systems, which was later used for railway cars. Refrigerator cars were in broad use during the 1890s in Germany and the U.S. (and also in milk producing countries such as Denmark and the Netherlands). In 1898, the first refrigerator railcars were exported to Russia, von Linde installed a new system there in 1901 (von Linde 1984). By 1913, there were already more than 100,000 temperature-isolated railway cars in the US alone, most of them ice-cooled. Moreover, our study extends earlier works by making the interaction between terms more explicit: possibly, railway access and proximity to agricultural production had a positive effect, but the interaction between the terms led to a lower provision of high-value nutrients to children, which is often hypothesised as the core explanation for the early industrial growth puzzle.

### *1.2 The Effect of Integration on the Social Distribution of Nutritional Resources.* Which effect of market integration and lower transport costs

<sup>14</sup> Craig and Weiss (1998); however, Craig and Weiss did not include interaction terms between railway access and food production to highlight the food-export process. See also Haines (1998), Drukker and Tassenaar (1997), and Haines, Craig, and Weiss (2003).

would we expect on the distribution of nutritional resources among different social strata? After distinguishing between protein-surplus regions versus protein-import regions, we grouped households by social strata, and by food-producing households versus households producing other goods.

For the surplus-production regions where milk protein had previously been available at very low prices, we would expect that market integration increased the relative price of protein substantially, and that much of the locally produced protein was now exported. Given the increasing relative price of protein poorer nutrient-producing households would probably have reduced their milk consumption by a larger extent than richer nutrient-producing households. The expected effect on non-agricultural households is less clear. In general, such households should have earned higher incomes and benefited more from the developing markets. Yet some households' income might not have increased because competition from other regions devaluated their human capital, which might have caused a decline in their nutritional status. In the protein-import regions, all households might have improved their nutrition, although the better-informed upper social strata might have been first movers in this respect.

The methodological advantage of introducing explicit interaction terms was demonstrated in an exploratory pre-study to this paper (*Table D*). We used published height and production data on Baden in south-west Germany. For this region, no data on individuals or their exact places of birth are available, but the birth regions are known. Thus, ecological regressions can inform us indirectly about the railway effect which might have had a negative impact on children's health. For 49 districts of Baden, height data on the conscript birth cohorts of 1840-64 were published.<sup>15</sup> Per capita cattle numbers served as a proxy for protein production and were significantly positive. The presence of a railway station in the district before 1864 also had a positive effect. However, the interaction between specialization in cattle farming and railway access had a negative effect on conscripts' heights. As usual in interaction

<sup>15</sup> We removed the very large town of Mannheim – with minimal cow rates – and the two outliers Wolfach and Pfullendorf (a border and a mining region, respectively).

analysis, the base effects must not be overinterpreted - they must simply be included in the regression to avoid a bias of the interaction coefficient. The high interaction coefficient implies that a high level of cattle production signified a considerable advantage which was completely eliminated where railways were built.<sup>16</sup> It is, of course, an open question whether the breaking-up of local subsistence farming by the railway had a comparably negative long-run impact in periods and regions where economic growth and market integration progressed much further.

## 2. Data and evaluation

*2.1 Construction of the Data Set.* It is likely that the impact of market integration is most evident for regions where the integration of commodity markets proceeded rapidly. In the case of Baden, where early railroad construction implied considerable welfare costs for some children whereas it otherwise benefited the population, it is questionable whether these negative effects persisted in the long run or were much rather overcome by the benefits of markets and interregional economic growth. In the late nineteenth century, it became profitable to transport cheap milk-protein over more than just one to five kilometres.<sup>17</sup> Rural regions that were directly adjacent to an urban or industrial area were extremely affected by this process. One of the most rapidly growing industrial centres of late-nineteenth-century Europe was the Ruhr area. The Westfalian *Regierungsbezirk* (county) of Arnsberg, located east of the river Ruhr, provides a good test case for the effect of market integration on nutritional status. In the state archives in Munster we therefore located lists of recruits

<sup>16</sup> Given a mean of 0.497 cows per capita and a standard deviation of 0.17 (Baten 1999, p. 108), the coefficients add up to the following predicted heights before railway construction: 161.7 cm in areas with a cattle density of one standard deviation below average, 163.1 cm in average areas, 164.4 in areas with a cattle density of one standard deviation above average. This considerable advantage enjoyed by the milk-producing regions was completely eliminated when the railway was built and average heights converged at 163.5 cm. In other words, the railway cost cattle producers a full centimetre in height, whereas it gave 1.8 cm to people in areas without much cattle.

<sup>17</sup> The distance over which shipment was already profitable depended on the local relative prices.

who were born in that region in the late nineteenth century.<sup>18</sup> We collected two cross-sectional samples, an earlier sample of soldiers born in 1882 ( $N=678$ ) and a later sample comprising the birth cohort of 1897 ( $N=705$ , both measured when they were 20 years old, migrants excluded). We grouped conscripts' heights by birth cohort because the years immediately after birth have the most important impact on final adult stature.<sup>19</sup> The comparison of these two snapshots of a region in the direct neighbourhood of Europe's most rapidly-growing industrial heartland yields important insights into the indirect welfare effects of infrastructure improvement.

We measured the market integration process in the following way: we calculated the distance of each place to the nearest railway station. If a community was close to a railway station, it certainly had more possibilities to import or export nutrients, i.e. it was more market-integrated than remote areas. As to the classification of the regional units, our study focuses on the Prussian *Regierungsbezirk* (county) of Arnsberg which consisted of 11 *Kreise* (districts), each of which had a number of *Gemeinden* (villages or towns; we will also call them "places", "communities" or "localities").

A second major contribution of this study are the first trend-estimates of heights of the population in north-western Germany. Thus, we complemented our two cross-sections with data from other birth cohorts, going back as far as 1868. We used 1,859 cases for measuring time trends in this region, hence the total sample size is 3,242.

The recruits were sampled from lists of conscripts born in the late nineteenth century.<sup>20</sup> For the *Regierungsbezirk* Arnsberg, the heights of recruits with birth years from 1868 to 1900 are documented in the medical examination (*Musterungslisten*) lists, organised by *Kreis*, *Amt*, place of residence, year of birth, and last names in alphabetical order (StAMS

<sup>18</sup> Unfortunately, lists from the Ruhr region itself have been lost.

<sup>19</sup> With a high degree of certainty, we can assume that by the end of the nineteenth century, most conscripts in this relatively well-nourished region of Germany had almost attained their final height. We will therefore group heights by birth cohort; see Baten (2000).

<sup>20</sup> Sources: State Archive Munster, Register Arnsberg 12. *Musterungslisten*. Findbuch-Signatur B 425.

Regierung Arnsberg Findbuch B 425, 591 volumes). Among other information, the lists give the place of residence, name, date and place of birth, names of the parents, occupation and class (*Stand*) of the father, height, and chest measurement. Recruits underwent medical examination between one and three times in successive years, beginning at age 20. The number of recruits per year and place was most often between 5 and 20 persons for the rural places. We constructed the sample in such a way that it includes 25 recruits from towns and 25 recruits from rural places for each district and birth year. However, the pattern of the surviving volumes is quite irregular; there are no complete cross-sections or time series. We therefore decided to construct two cross-sections. Those are centred around the birth years 1882 and 1897, with data from the preceding or following year having been included in some cases. *Figure 1* presents the geographical distribution of the two cross-sections as well as the locations of railways and major cities. The size of the symbols indicates how many heights are sampled. Our data set contains information on 11 of the 14 districts of the county of Arnsberg. Unfortunately, data regarding the three heavily industrialised western districts of Arnsberg (Bochum, Dortmund, Hagen) were not obtainable from the archival records.

Data selection was based on the place of residence. In an earlier project, one rural place from each *Kreis* was selected at random. Recruits from that parish were included to the extent possible, the 25 cases being filled up by recruits from the nearest rural places if necessary. Also, 25 recruits from the largest town in the district were sampled, supplemented by recruits from the next-largest town if necessary. Data were entered according to the sequence in the sources, using only measurements at age 20. From the lists of recruits, we recorded the birth year, place of residence, recruit number, height, occupation of the father, and place of birth. In a later round of data collection, the occupation of the father was recoded to class and sector, using Peter Lundgreen's (1988, pp. 319-364) German occupation code. Also, place-level and district-level variables referring to the relevant place of residence were added to the entries. Since this record linkage refers to the place of residence, place-level information on migrants is less informative than on non-migrants. The share of migrants in both cross-sections is around 21 %, leaving us with

678 recruits in the first and 705 recruits in the second cross-section as well as 1,859 cases which were used for the time series. For the study of other birth cohorts, we selected four regional units and followed them over time: the city of Hamm (1881-90, 1892-97) and the districts of Altena (1869, 1876-95, 1897-98), Siegen (1875-82, 1897), and Soest (1868-71, 1880-83, 1885-86, 1888-92, 1895, 1897-98). Initially, we had 4,100 cases (including migrants).

Definitions, sources, means, and standard deviations are given in *Table 2*. For linking recruit data to local or regional-level variables, we collected economic data on years that were as close as possible to the two height cross-sections. Distance to the nearest railway station was determined for the years 1882 and 1897. We established the local per capita number of cows and pigs for 1871 (for the recruits born in 1882) and 1900 (for those born in 1897). Other variables were available for one point in time only. For the year 1889, the local number of factories and mills (per capita) and the local per capita tax rates for buildings and land were computed. On the level of the district, we calculated the average per capita number of cows in 1837-60 (reported in 1864), and included the industrial wage level of 1892.

*Railway distance* is the distance to the nearest railway station, calculated for each place. While data collection for this purpose was tedious, we can – for the first time – reliably judge the export possibilities of each place. The minimum was zero kilometres, the maximum was 21 kilometres for the early cross-section (railway distance of 1882). The maximum for the second cross-section was eight kilometres (railway distance of 1898). Navigable waterways did not play a large role in this region; only Hamm had an important harbour (and one of the earliest railway stations).

As final adult height is mostly determined by nutrition and health during the first years of life, we were pleased to find parents' occupation in the conscription lists. This allowed us to classify the social stratum to which the respective individual belonged (which is in turn a relatively good proxy for the family's income during this period, as skill levels can be distinguished by occupation). In the following regressions, we initially entered nine occupational and social class groups, using a classification

that is widely accepted as a standard for grouping occupations in Germany (see, for example, Baten 1999).<sup>21</sup>

**2.2 Minimum Height Requirements and Selectivity Problems.** Before tests of market integration and nutrition are possible, we need to evaluate the data set with regard to the following questions: firstly, was there a minimum height requirement that could have biased the mean height upwards? Did other institutional arrangements of the Prussian military impact on the selection process of the soldiers? Secondly, did the two base years of our cross-section have different characteristics? For example, were they less comparable because the base years represent different phases of a potential height cycle?

There was general military conscription in Prussia during this period. Hence, soldiers were not volunteers who opted to join the military due to labour market characteristics or similar criteria. Instead, everybody had to be measured. After everybody liable for military service was medically examined (and measured), the health status (and lot) decided who had to join the army. The institution of *Einjaehrig-Freiwillige* (the sons of middle and upper-class families were allowed to serve for just one year) posed no problem, because the conscription law required that everybody should be put on the lists without exception.

Further evidence about the measurement of our conscripts before military selection can be gained from comparing the empirical height distribution with the expected normal Gaussian distribution. The result is an almost perfectly normal distribution (*Figure 2*).

**2.3 Were the Two Cross-Sections Taken from Similar Phases of Height Cycles?** It would be an advantage for our cross-sectional study if neither

<sup>21</sup> 1.1, 1.2, 1.3 upper class (1.1 agricultural, 1.2 industrial, 1.3 services, such as large landowners, large entrepreneurs, and priests); 2.1 middle class, agricultural sector (mainly farmers); 2.2 middle class, industrial sector (e.g. master craftsmen); 2.3 middle class, service sector (e.g. middle-class officials); 3.1 lower class, agricultural, unskilled labour (e.g. farm labourers); 3.2 lower class, industrial unskilled labour (e.g. factory workers or unskilled building traders); 3.3 lower class, service sector (e.g. servants). The numbers refer to the code of Lundgreen, Kraul and Ditt (1988).

the year 1882 nor the year 1897 were untypical years in terms of heights, because then we could be reasonably sure that those years were representative of the two periods of the early 1880s and late 1890s. We also report these height trends because this is the first study on heights in northern and western Germany. Until now, only the south of Germany has been studied, although regional differences were large (in *Figure 4* only the area between Freiburg, Niederbayern and Unterfranken plus Saxony had been studied previously).<sup>22</sup> In addition to our cross-sectional samples of 1882 and 1897, we collected 1,859 height measurements to construct time series for four districts (*Figure 3, Table 3*). Although we collected data on all Arnsberg's 11 districts, we can only follow height developments over time for those four districts.

During the late 1860s, recruits from Arnsberg were not very tall.<sup>23</sup> Conscripts from Soest were about 167.5 centimetres tall (on the characteristics of those regions, see below).<sup>24</sup> We find a relatively impressive increase in height between the late 1860s and the early 1880s. Afterwards, the increase became slower in poorly-nourished Altena, while it almost stopped and became non-linear in Hamm and Soest. Outliers seem to bias the series for Siegen for the year 1883. Especially during the mid-1880s, a considerable downturn occurred above all in Hamm, and (to a slight but observable degree) in Altena. Twarog found a similar temporary downturn in heights for Württemberg (southern Germany) during the mid-1880s.<sup>25</sup> She related this to the non-agricultural parts of

<sup>22</sup> On Saxony, see Cinnirella (2007); Evert (2006).

<sup>23</sup> How tall were people in northwestern Germany in the nineteenth century? While we have sufficient information on southern Germany (for Bavaria, see Baten (1999a) and for Baden and Württemberg, see Baten (1999b) and Twarog (1993)), we know little about the north and west, except that there was an important east-west gradient (Baten 1996). Figures from 1906 inform us that north-westerners were the tallest in Germany (Baten 2003). Although, on average, southern Germans were probably already shorter around the middle of the nineteenth century, there are many examples of taller southerners: in the district of Toelz in southern Bavaria (with very high per capita milk production), conscripts were about 170 centimetres tall in the early nineteenth century. For comparison: French conscripts were 165.5 centimetres tall in 1882 and 166.8 centimetres in 1897, see Weir (1997).

<sup>24</sup> In general, conscripts from the city of Hamm were tallest, followed by Soest and Altena (*Figure 2*). The difference between Hamm and Altena was more than one centimetre, which is considerable.

<sup>25</sup> Twarog (1993), p. 299.

society, while agricultural heights increased during this period. This view corresponds with our observation that the downturn was most visible in the city of Hamm, which is the only large city on which we have data.

While there is some irregularity in the series, no regularity of business cycles is discernible. By inspecting developments over time, we came to the conclusion that drawing cross-sections from 1882 and 1897 was methodologically unproblematic because the two years were not untypical years. We also concluded that this region in north-western Germany experienced a substantial increase in heights between the 1860s and 1890s. At the end of this period, heights of about 168-169 cm were recorded, which is consistent with the values in *Figure 3*.

### **3. The nutritional status of regions and social groups**

*3.1 Proximity to Nutrient Production, Remoteness and Other Regional Characteristics.* Our eleven districts are situated east of the booming Ruhr area. In the north lies the county (*Regierungsbezirk*) of Munster that was specialised in dairy farming (see *Figures 1* and *4*). In the west, we find the rapidly industrialising counties of Cologne and Düsseldorf (the latter containing the western part of the Ruhr area). Arnsberg had less economic exchange with its eastern and southern neighbours because they were not very industrial (hence, there were less advantages from trade).<sup>26</sup>

In *Figure 1*, we firstly report proximity to protein production by using cows per capita-values (darker areas had more cows per capita around the mid-century), and secondly remoteness by displaying the "old" and newly-built railway lines (the latter are represented by solid lines). We also show symbols of various sizes that represent the location and number of height measurements of the places we recorded. Among our eleven districts, we can distinguish the Southern Highlands of Meschede, Olpe and Wittgenstein from the northern districts on the one hand, and on the other

<sup>26</sup> On regional demographic variation in the area under study, see Fertig (1999) and Fertig (2001); on market integration, see Kopsidis (2002); on intraregional division of labour (which followed Thucenen's model) see Kopsidis (2004); on relations between parents and children among agricultural producers see C. Fertig, G. Fertig, and Luennemann (2005).

hand from the proto-industrial district around the city of Siegen at the southern tip (see *Figure 1*). Those Southern Highlands had a high number of cows per capita over the whole period (see *Table 4*). Until 1882, railway lines only passed through the Olpe district, connecting especially the Ruhr area and Siegen. In Olpe, there were only a few stops. Meschede was only touched by railways along its northern borders, and Wittgenstein was completely unaffected by this important means of transportation. Between 1882 and 1897, a number of additional railways were built in the Southern Highlands, reducing the distance to the nearest station to one twentieth (Wittgenstein), one fifth, and one third (Meschede and Olpe, respectively). In contrast, distance to the railway was reduced only very slightly in most northern and the Siegen districts. We would expect that the relative price of protein and other high-quality food be highest in the most western districts of Iserlohn and Altena (especially in the transportation-integrated northern area of Altena). The north-western district of Hamm, in contrast, might have benefited from the protein exports of its northern neighbours (the districts of Luedinghausen and Beckum in the county of Munster). The other northern districts of Arnsberg, Soest, Lippstadt and Brilon were slightly more remote from the booming Ruhr area. With their good soil and early railway access, they concentrated on pork and grain production. Soest and Lippstadt had the highest number of pigs and (along with Brilon) very high land tax values, indicating a good soil quality (which was frequently used for pasture and grain production, whereas the poorer soil of the other districts was used for other crops, and less intensively). Interestingly, heights in those early-integrated agricultural districts were not above average compared to the other districts in the early cross-section (for example, 166.9 cm in Brilon), while the tallest heights could be found in the Southern Highland district of Olpe (as well as in Hamm).

Please note that distinguishing between eleven districts only yields a broad picture, whereas in the regression analysis, we use much more disaggregated data. The large number of locations and their respective distances from old and newly-built railway lines indicates a high variability beyond this classification in the Southern Highlands, the north and Siegen. This additional variability cannot be presented in descriptive tables and maps but was incorporated into the regression analyses below.

**3.2 Height Evolution by Social Group.** Similarly to our description of sub-regions within Arnsberg, we will consider height differentials between social groups in the earlier and later cross-section separately. As the upper class was very small (only 18 individuals), we aggregated it with the much larger middle class (about one quarter of the sample).<sup>27</sup> Upper-class heights were indeed impressive: 172.6 centimetres and 171.6 centimetres in 1882 and 1897, respectively.

In 1882 (white bars in *Figure 5*), the sons of the agricultural middle and upper classes were tallest, but their height advantages vis-à-vis rural, lower-class workers was only 0.2 centimetres. In contrast, the industrial middle class, craftsmen, and industrial workers were considerably shorter (the latter two categories by more than one centimetre). Note that many of these workers did not live in large industrial cities. There were also many industrial and craftsmen-type workers in small villages who worked for smiths and in the clothing industry. The change between 1882 and 1897 was dramatic. The agricultural middle and upper classes were the winners in Arnsberg, with a height increase of more than one centimetre that improved their already highest rank, reaching nearly 170 centimetres. The industrial middle and upper classes, including skilled artisans and service sector employees, also improved their positions, whereas craftsmen and the agricultural lower class were the losers during the last two decades of the nineteenth century. They lost more than one centimeter in height, a surprisingly large figure for a period which was otherwise characterised by height increases. Also, the industrial lower class was not able to improve its nutritional status – its heights remained at a low level. The fact that the height decline of the agricultural lower class exceeded that of the industrial lower class fits in well with our knowledge about wages. Walter G. Hoffmann estimated that between the early 1880s and the early 1890s, industrial wages improved considerably, whereas agricultural wages stagnated.<sup>28</sup>

<sup>27</sup> In accordance with census data of the time; see Baten (1999b); and Baten and Murray (2000).

<sup>28</sup> Hoffmann (1965). After this period, agricultural wages also increased somewhat, but less so than industrial wages. The ratio between the two changed from 1:1.5 to 1:1.75, i.e. an industrial worker earned 75 percent more than his agricultural colleague (although we have to keep in mind that he also faced somewhat higher costs of living).

#### **4. Regression results: the joint influence of market integration and social stratification**

We analyse the interaction between proximity to local food production, remoteness (or export possibilities), and individual resources (proxied by parental occupation). Some of the independent variables refer to the individuals, others to location. Among the variables that indicate local production, we found considerable multicollinearity. Hence, we performed a principal components-analysis in order to identify common factors among those variables (*Table 5*). Two factors could be extracted, one referring to agricultural production (agricultural land quality, cows, pigs) and the other referring to industrial activity and (to a lesser extent) to the value of buildings in the place. In the following, the first factor will be termed "agricultural factor" and the second factor "industrial factor." Given that milk could not only be traded over long-distances via the railway network, but also over shorter distances to neighbouring locations of the same district, we included the separate district-level variable "cows per capita" in the subsequent regressions, although some multicollinearity with the "agricultural factor" variable might remain. However, we used a lagged value (cows per capita in 1837-60) to reduce multicollinearity.

The regression analysis for the early cross-section of 1882 reveals a social inequality level that was still relatively modest by German standards (*Table 6*).<sup>29</sup> Middle-class recruits were not significantly taller than those from lower-income groups who are represented by the constant. In contrast, upper-class recruits were 4.9 cm taller, which is of course considerable (although based on a small group sample size).

Our results regarding the influence of agriculture require detailed consideration, because although we reduced the number of local-level variables through principal component analysis, agriculture is still involved on four levels: as parental occupation, as an opportunity for the trading of milk within the district (cows before 1860), as an "agricultural factor" on

<sup>29</sup> Earlier in the century, inequality had been higher in Bavaria, see Baten (1999a).

the level of the location, and as part of the interaction term. Taken together, the coefficients estimated for these agricultural variables do not corroborate an idyllic view of pre-market-integration subsistence agriculture. Lower-class recruits living in locations with average distance from the railway and an average "industrial factor" were on average 167.66 cm tall if their father had an agricultural occupation, if their district had many cows (one standard deviation above average) and if their location was one standard deviation above the average level of the agricultural factor. If the father had a non-agricultural occupation, if the district had a cow density of one standard deviation below average, and if the place was one standard deviation below average regarding the agricultural factor, the resulting average height was practically the same: 167.68 cm. Thus, agriculture had no impact on heights, in sharp contrast to the pattern we observed for Baden for an earlier period. In late nineteenth-century Arnsberg, there was a balance between the higher income generated from industry and the more abundant protein provided by local farming (this calculation is based on the coefficients given in *Table 6* and the means and standard deviations of the independent variables documented in *Tables 2* and *5*).

More similarly to Baden, the changes that were brought about by railway construction were not the same in places that were specialised in agriculture and places that were not. Of course, in the regression analysis of the interactions, the base effects (distance to railway and agricultural factor) should, again, not be interpreted. When keeping occupations and the district-level numbers of cows constant, to bring the railway to a non-agricultural place (one standard deviation below average) would add 0.91 cm to the heights of the local recruits, while building a railway close to an agricultural place (one standard deviation above average) would add only 0.64 cm. A difference of three millimetres is certainly not large. However, at this comparably advanced stage of economic development, the negative impact of increased trade opportunities on the children of agricultural producers still accounted for almost one third of the advantages railway construction offered the local population. In contrast, the wage and industrial factors did not play a role in the early cross-section.

In the second cross-section for the birth cohort of 1897, we see an even more commercialised and unequal society. As indicators of

commercialisation, we firstly interpret the fact that wages now played a significant role in determining height. They are significant at the 10% level, and one standard deviation of additional wage equals 0.49 additional centimetres in height. This effect may not be large, but is certainly more noticeable than in the earlier cross-section. A second indicator of commercialisation is the fact that remoteness, in interaction with agricultural specialisation, did not play a positive role anymore: the coefficient switches to insignificance.

Apart from commercialisation, inequality also rose. An indicator of higher inequality is the significance of the middle-class dummy for this later period, whereas it was insignificant and small for the earlier birth cohort. Recruits from this class were 2.2 cm taller than lower-class ones. The coefficient for the upper class has grown to an enormous 7.5 cm, again based on a quite small group sample size. We conclude from this part of the analysis that between 1882 and 1897, important tendencies towards social inequality and commercialisation existed.

In the pre-study on Baden, we clearly perceived a positive impact of proximity to agricultural production without railway access. For Arnsberg, it can be demonstrated that a certain left-over of this effect lasted until 1882, while it finally disappeared towards the end of the nineteenth century. This suggests that in the long run, the hinterlands of the industrial core were not the losers or victims of the market-building process. From the height trends reported here, we can infer that as far as any losers of market integration can be identified at all, they would be the agricultural lower classes, mostly day labourers. However, as is suggested by the reduced frequencies of these occupations in 1897 (10 % of the second cross-section versus 20 % in 1882), day labourers suffered not only from reduced incomes, but also turned to other occupations. In the long run and across social strata, market integration was more beneficial than costly.

Our results can also be interpreted in terms of Amartya Sen's entitlement theory.<sup>30</sup> Sen hypothesised that the lower classes of non-commercialised societies have non-market-related advantages ("entitlements"). He further

<sup>30</sup> Sen (1977).

argued that health, nutritional quality and longevity depend not only on purchasing power. Especially in less commercialised economies, the allocation of resources which are essential for the biological components of the standard of living depends on "entitlements," a broader concept of property rights that includes purchasing power as well as the customary rights of subsistence farmers. Labourers even consume a certain quantity of foodstuffs without payment (as do, of course, the children of farm owners). Perishable foods and by-products such as offal and skimmed milk are particularly important for non-purchasing power entitlements. Our results suggest that this kind of behaviour was severely cut back in the process of commercialisation and economic development.

## **5. Conclusion**

In summary, we find an interesting development in the region near the booming Ruhr industries: between the early 1880s and the late 1890s, the advantages of the interaction between remoteness and proximity to nutrient production became insignificant. This can be interpreted as a strong commercialisation tendency: health-related resources were traded on markets to a much larger extent. This also meant more stratification and inequality, as shown by our anthropometric indicator: the middle and upper classes could now literally look down on the lower income and status groups, and regions with higher wages had taller recruits than low-wage areas.

Moreover, we provided the first height trend estimates for northwestern Germany. All previous studies on German anthropometric history before 1906 examined only the south and east (Bavaria, Württemberg, Saxony). The situation in the northwest was in fact quite different, with human stature being substantially higher on average than in the south and east. We find a quite positive trend for north-west Germany between the late 1860s and late 1890s. Yet this study has also shown that positive average trends sometimes disguise the difficult situation of certain social strata. In the case of the hinterland of the booming Ruhr area there were both winners and losers in this transformation and integration process.

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## *Appendix*

Did the Railway Increase Inequality? A Micro-Regional  
Analysis of Heights in the Hinterland of the Booming  
Ruhr Area During the Late Nineteenth Century

## ABBREVIATIONS OF OTHER SOURCES

C = Census: Koenigliches Statistisches Bureau: Der Viehstand der Gemeinden und Gutsbezirke im Preussischen Staate. Nach den Urmaterialien der allgemeinen Viehzaehlung vom 10. Januar 1873, vol. 3. (Berlin, Verlag des Koeniglichen Statistischen Bureaus, 1874) (cross-section 1882), and Koenigliches Statistisches Bureau, Viehstands- und Obstbaumlexikon vom Jahre 1900 fuer den preuBischen Staat, vol. 10 (Berlin, Verlag des Koeniglichen Statistischen Bureaus, 1903) (cross-section 1897).

O = Ortschafts-Verzeichnis nebst Entfernungs-Tabelle des Regierungs-Bezirks Arnberg: im Auftrag der Regierungs-Praesidenten nach amtlichen Material bearbeitet und hrsg. von den Regierungs-Supernumeraren Berkermann und Flamm (Arnberg, F. W. Becker, 1889).

M = Meitzen, A., 1869, Der Boden und die landwirtschaftlichen Verhaeltnisse des Preussischen Staates, vol. 4 (Berlin, Parey), pp. 248-251. (reprinted 1988)

I = Insurance wages (the wage that the insurance would pay to workers who were unfit to work after a job-related accident) as published in: Anhang zu Nr. 52 des Central-Blatts fuer das Deutsche Reich, (Berlin 31 Dec., 1897) (data from 1892).

Maps = Geographical information derived from:

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**TABLE 1. The impact of early railway connections on recruits' health in Baden's 49 districts (Amtsbezirke)**

	Coef.	t-Stat
(Constant)	159.1**	183.5
Cattle per capita	8.0**	5.7
Railway before 1864	4.4**	3.9
Cattle*Railway	-8.1**	-3.6

Source: See text.  
\*\*, \*: Significant at the 1 and 10 percent level of significance.  
Note: Dependent Variable: Height of Baden recruits measured in 1840-64. adj. Rsq 0.41. N=49. Mannheim, Wolfach and Pfullendorf excluded. Source: Baten (1999b).

**TABLE 2. Variable names, definitions, sources and descriptive statistics of place-level and district-level variables by cross-section**

Variable	Definition	Source	Mean 1882	Std.dev. 1882	Mean 1897	Std.dev. 1898
Rail distance	distance to next railway station in km	Maps	4.553	4.435	2.283	2.277
Cows (place level)	local number of cows divided by number of inhabitants (1871 for cross-section of 1882, 1900 for cross-section of 1897)	C	0.256	0.126	0.243	0.150
Cows (district level)	district-level number of cows (average 1837-1860), divided by number of inhabitants in 1864	M	0.237	0.033	0.236	0.043
Factories	local number of factories and mills in 1889, per capita (inhabitants in 1889)	O	0.003	0.004	0.004	0.005
Pigs	Pigs 1871/inhabitants 1871 or Pigs 1900/inh. 1900	C	0.167	0.134	0.435	0.395
Building quality (tax)	Tax for buildings per capita	O	0.751	0.461	0.704	0.471
Land quality (tax)	Tax for land per capita	O	2.195	1.982	2.105	2.271
Wage	Unskilled male wages 1892	I	176.053	28.704	178.868	24.851

Note: N=38 for Cross-Section 1882, N=53 for Cross-Section 1897. All variable definitions refer to the current place of residence of the recruits.  
Source of recruit heights: Landesarchiv Nordrhein-Westfalen – Staatsarchiv Munster, Regierung Arnberg, Musterungslisten, Findbuch B 425.

**TABLE 3. Height by district and birth decade (migrants excluded)**

	1860s	N	1870s	N	1880s	N	1890s	N
Altena	164.0	43	166.4	106	167.3	509	168.0	347
Hamm					169.1	323	168.8	354
Siegen			166.4	133	166.8	144	168.7	38
Soest	166.9	84	167.9	75	168.5	275	168.7	238

Note: non-migrants only. Source: see Table 2.

**TABLE 4. Descriptive statistics for heights and independent variables, by district and cross-section**

	Cows	Cows	Cows	Distance	Distance	Pigs	Pigs	Mills	Buildings	Land	Height	Cases	Height	Cases
	1837-60	1871	1900	1882	1897	1871	1900	1882		quality	1882	1882	1897	1897
Altena	0.23	0.11	0.14	2.95	2.08	0.09	0.00	11.75	1.09	0.41	167.1	166	168.5	77
Arnsberg	0.25	0.09	0.10	2.65	2.03	0.14	0.20	2.89	1.71	0.60	168.4	48	166.3	44
Brilon	0.24	0.21	0.18	5.30	5.30	0.37	0.42	2.50	0.68	1.92	166.9	39	167.3	53
Hamm	0.21	0.14	0.18	1.36	1.36	0.34	0.38	1.75	1.05	1.54	168.6	115	168.3	143
Iserlohn	0.12	0.05	0.08	0.48	0.48	0.08	0.09	6.91	1.25	0.74	n.a.	n.a.	168.3	88
Lippstadt	0.22	0.22	0.22	5.05	1.28	0.58	0.47	3.40	0.99	2.70	168.3	39	167.3	36
Meschede	0.31	0.23	0.27	9.71	1.95	0.31	0.32	4.72	0.60	1.03	168.1	43	169.7	49
Olpe	0.32	0.20	0.27	2.61	0.77	0.21	0.20	5.38	0.57	1.22	168.6	41	168.8	42
Siegen	0.21	0.11	0.15	3.09	1.82	0.08	0.08	2.90	1.15	0.55	166.7	98	168.7	38
Soest	0.25	0.18	0.15	2.05	0.95	0.54	0.52	1.40	1.18	2.56	168.3	89	168.5	84
Wittgenstein	0.27	0.30	0.26	20.16	0.90	0.20	0.20	2.45	0.29	0.61	n.a.	n.a.	167.7	51

Notes: The three maximum values for each parameter are highlighted.

"Cows" 1837-60 are cows per capita on the district level; Cows 1871 and 1900 are cows per capita on the place level.

"Distance" is the average of the distances to the nearest railway stop from the place where height was measured.

"Mills" means factories and mills per 1.000 inhabitants and includes saw mills (important especially for Meschede and Olpe).

"Buildings" and "land quality" are based on tax values in Marks per capita. "Height" refers to non-migrants only.

Source: see Table 2.

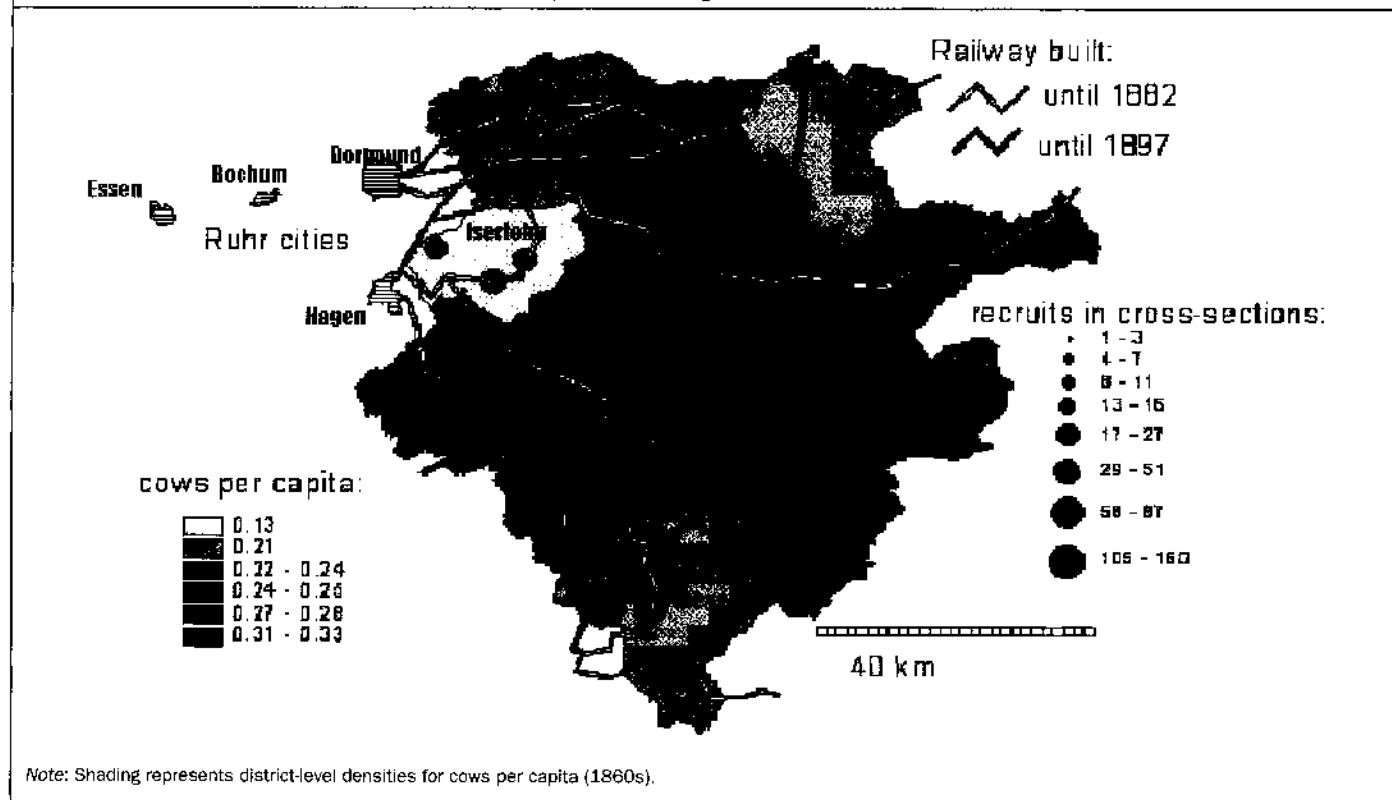
**TABLE 5. Principal components analysis for place-level variables:  
Standardized scoring coefficients and descriptive statistics for factors**

Variable	Factor 1 (Agrarian)	Factor 2 (Industrial)
Cows 1871/1900	0.35	-0.13
Pigs	0.32	0.18
Land quality (tax)	0.32	0.26
Buildings (tax)	-0.23	0.49
Factories	0.02	0.63
Eigenvalue	2.64	1.32
Cumulative co-variation explained	0.53	0.79
Mean 1882	-0.67	0.33
Mean 1897	-0.55	0.40
Standard deviation 1882	0.81	0.95
Standard deviation 1897	0.98	1.00

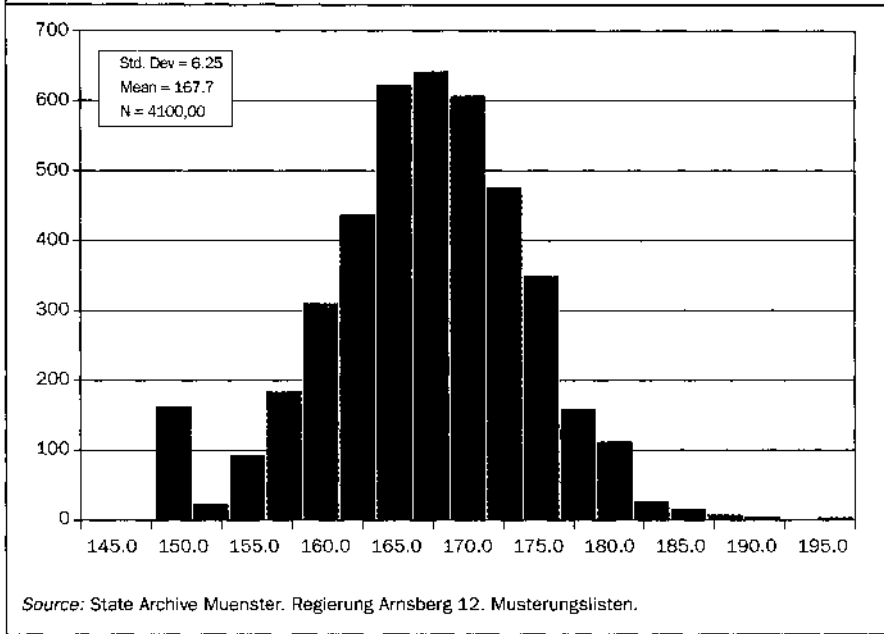
Note: all variables refer to recruit's place of birth and residence, and are calculated as *per capita* rates.

<b>TABLE 6. Regression results: determinants of height</b>		
	<b>1882</b>	<b>1897</b>
Intercept	163.16** (72.47)	162.04** (64.52)
Upper class	4.85* (2.31)	7.51** (3.29)
Middle class	0.64 (1.05)	2.21** (2.93)
Agricultural occupation	0.63 (0.95)	1.06 (1.11)
Occupation unknown	0.24 (0.30)	0.46 (0.79)
Cows before 1860	12.56 (1.62)	8.19 (1.50)
Wage	0.51 (0.65)	1.72* (1.72)
Agric. factor	-1.05* (-1.73)	-1.03* (-2.00)
Rail distance	-0.07 (-1.05)	-0.02 (-0.16)
Agricultural factor * Rail distance	0.46** (2.76)	0.27 (1.32)
Industrial factor	-0.14 (-0.34)	-0.55 (-1.47)
N	678	705
Adj. R-Square	0.0181	0.0239
<p>** , *significant at the 1%, and 10% levels of significance, respectively. The constant represents non-agricultural, lower-class occupations. The coefficients for wage are multiplied by 100 for presentation purposes.</p>		

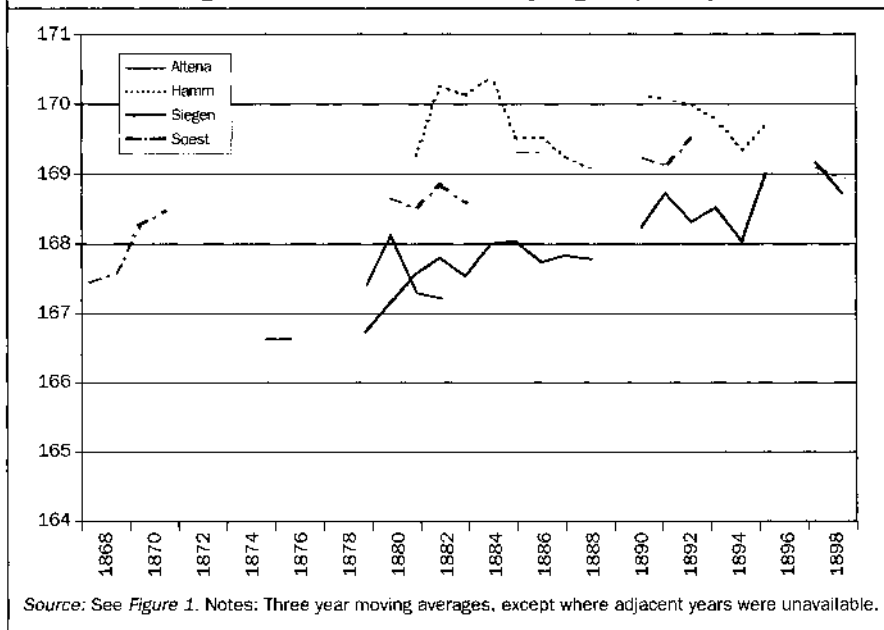
**FIGURE 1. Map of Arnsberg's eleven eastern districts**



**FIGURE 2. Height distribution of the entire sample**



**FIGURE 3. Height evolution in Westfalia by region (In cm). 1868-1898**



**FIGURE 4. Heights in Germany by county, 1906**

