On The Road to Industrialization: Biological Standard of Living in Saxony, 18th and 19th Century.

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Possible remaining errors are those of the author.

1. Introduction

The process of industrialization in the Kingdom of Saxony started relatively early. In particular, the last quarter of the 18th century was a period of rapid industrial development especially for the textile sector. The Saxon government was oriented to foster economic growth, and it is exemplified by its interference in the army recruiting process: in fact, starting from around 1725, it discouraged the recruitment of industrial workers.[2] The Kingdom of Saxony experienced also a rapid demographic growth. In the period of fast industrialization (1775-1815) we find an annual growth rate of 0.5%.[3] Saxony has also been theatre of important conflicts which have certainly influenced its economic development and demographic dynamic: the Silesian wars (1741-1748)[4], the Seven Years' War (1756-1763), and the Napoleonic Wars. The Kingdom of Saxony then represents an interesting case study for both its Malthusian dynamic and its early industrial development which put it as one of the main engine of the German modern economic growth[5]. Furthermore, we aim to expand the literature on living standard in Germany which, especially for the 18th century, is relatively scarce[6].

In order to investigate standard of living in the pre-industrial and industrial Saxony we analyze the physical stature of a sizeable sample of individuals required to serve the army. It is known that height reflects the nutritional status of an individual during his early childhood net of workload and the disease environment (Tanner, 1990; Komlos, 1994). Given the consistent share of the familiar budget devoted to purchase food[7], human height has been used as a proxy for economic indicators as per-capita income, and in particular it also reflect the impact of relative prices and income inequality through the analysis of occupational height differentials.

In this paper, the anthropometric analysis is supported by the study of marriage rates which we believe reflect actual and expected economic conditions. In our knowledge, this is the first approach in this fashion.

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[2] Forberger (1958).
[3] The data on the demographic trend are drawn from Schirmer (1996).
[4] Also known as the Austrian-Succession War.
[5] Kuznets (1966).
[6] Bavaria is the only region investigated for this period. See Baten (2001).
[7] Vecchi and Coppola (2005).

The paper is structured in the following way: in the *data* section we describe the dataset and we address the main statistical issues related to our sample; in the *trend analysis* section we study separately the secular trends for the 18th and 19th century; in the successive section we introduce the estimates of the marriage rates and we match the results with the height trend previously estimated; finally, in the last section we discuss the main results and draw some ideas for future research.

2. Data

The Saxon army was the second in history[8] in collecting information about its soldiers. We collected the recruiting lists at the State Archive in Dresden, which provide detailed information about physical stature and socio-economic variables for soldiers born in 1647-1866 cohorts. In principle our dataset contains more than 70,000 observations, 62% regarding adults (23-49 years old), 36% youths (16-22), and 2% over-50.

The recruitment lists report names (first, second and family name), military rank, age, height in inches, origin, and previous occupation in 43% of the cases. Mainly, the birth year has been recovered through the date at which the individual was enlisted. Furthermore, for about 70% of the whole data set we collected information on the marital status of the soldiers.

Since the recruitment lists provide "stock" information, we encountered more than two thousand of duplicates.[9] With the support of the names and the provenance we have been able to delete the observations which showed up more than once, retaining the last in time perspective. This correction allowed us to verify also the accuracy with which the army measured the soldiers' height; in some cases we found that the soldiers were subject to repeated measurement as the height values presented slight positive differences. This result shows that the height reported in the lists was the actual one.

The literature in anthropometric history is plentiful of height distributions which suffer from a truncation point: our dataset is not an exception. According to the observed distributions, the Saxon army enforced different minimum height requirements

[8] France was the first. See Komlos 2003.
[9] Duplicates are soldiers present in more than one list.

(henceforth MHR) depending on the recruitment period and the military rank. For instance, in the 18th century the official MHR for infantry was at 72 inches[10] (circa 170 cm), whereas in war periods and in the successive century it was lowered up to 68 inches (circa 160 cm). In Figure 1 and 2 we report the height distributions of adult infantrymen recruited respectively before and after the Seven Years' War. Evidently the army did not strictly enforce the 72 inches MHR in the period immediately before the war, whereas it is more evident from Figure 2.

-Insert Figure 1 and 2-

In presence of a truncated sample, it has been shown that the "best" estimator is the Restricted Maximum Likelihood estimator (A'Hearn, 2004; Heintel, 1996; Komlos, 2003). It allows to have a flexible truncation point which can vary according to the rank and the recruitment period. Furthermore, as the MHR is presumably close to the population mean, in order to have more accurate estimates we imposed the modern figure of 6.86 cm for the (adult) population standard deviation and 7.2 for the youths (aged 16-22)[11]. Figures 2 also put in evidence a rounding problem: the measures have been probably rounded to the nearest half inch. This issue has already been addressed in the literature and then will not be covered in this paper. Anyway, it is necessary to take into consideration the rounding when choosing the exact truncation point[12]. Whereas in the presence of heaping, in order to have a random sample we chose as truncation point the measure next to the heaped one.

As shown in Figure 1, the age composition of the Saxon army changed noticeably after the 1820 birth cohort. This shift to a younger army with a relative change in the MHR suggested us to analyze the 18th and 19th century separately.

Regarding the geographical coverage, Figure 4 shows that it is fairly homogenous, with a consistent number of observations for each part of Saxony. North and East are the most

[10] An inch ≈ 2.36cm. For a detailed description of the history of Saxon army in the 18th century, S. Kroll (2003).
[11] See Frisancho (1990).
[12] For more details see A'Hearn (2004) and Heintel (1998).

represented areas, and 11% of the analyzed sample reported as provenance one among the three biggest cities.[13]

We codified around 82% of the reported places and we reasonably assume that it indicates the soldier's birthplace. We then proceeded grouping the counties following the actual borders of Saxony, and we defined 4 macro areas: (*i*) the industrial region which includes the south-western area of Vogtland and the surrounding of Chemnitz, (*ii*) the agricultural region which embrace the northern part of Saxony with the city of Leipzig, (*iii*) the central-eastern part which comprise the city of Dresden, and finally (*iv*) the southern area of Saxony characterized by a mountainous landscape. This categorization aims to capture the effect of the urban/rural environment, and the effects that an agricultural or industrial area can have on the height potential of an individual.

About 49% of the studied sample reported a previous occupation. The economic activity of the individuals is expected to mirror the socio-economic background in which the individual was raised. Then, we created 7 occupational groups plus a category which embraces all the individuals who did not state any occupation (*unknown*). In particular, we defined a category which takes into account all the occupations that have a direct access to food (bakers, butchers, etc.); people employed in agricultural activities have been grouped in this category as well (*food*). We also distinguished between craftsmen and people employed in factories (respectively *crafts* and *industrial*), and we defined one separate category for the textile industry (*textile*) which was the most developed industrial sector in Saxony. Furthermore, we aimed to capture the effect of education grouping professions such as doctors and musicians (*professional*).

3. Trend Analysis

3.1 18th Century

For the 18th century we analyzed the physical stature of adults (23-49) belonging either to infantry or officers with a known provenance within the current Saxon borders. In the sake of estimates accuracy, we decided to disregard grenadiers and cavalry because of

[13] Dresden, Leipzig, and Chemnitz.

their upward biased physical stature and peculiar distributions which did not allow a precise definition of a MHR.

We provide a secular trend which starts from the 1680 birth-cohort and reaches the first decade of the 19th century. The trend is built regressing the height of individuals on a set of dummies indicating the birth decade[14], the military rank, and a further set of covariates in order to control for origin and occupation. We estimated the mean height using the Truncated Maximum Likelihood estimator. In particular, as suggested by A'Hearn (2004), we constrained the standard deviation to the modern value of 6.86 cm since our truncation points are likely to be close the population mean.

-Insert Figure 5 here-

Furthermore the standard errors are adjusted for clustering, i.e. we allow for dependence among individuals within counties (clusters).

The coefficients linked to the birth cohorts are, with the exception of the two decade 1720-1740, highly significative (see Table 2). The trend presents some cycles with a significative downturn in the second half of the 18th century[15]. In particular in the first 30 years of the century (1705-35), height increased at circa 1.15 cm per decade. The trend then shows a local minimum around 1745, which corresponds with the period of the Silesian wars (1741-1748). After that period, Saxony experienced a period of relative improvement in terms of biological standard of living reaching a remarkable measure of 168.6 cm. Finally, the last quarter of the 18th century is characterized by a strong decline in physical stature which points to a considerable impoverishment of the population living condition. For the same period, this is a common feature of many other European countries which experienced decreasing living standard due to a strong demographic growth and a generalized increment of relative prices of food (Komlos and Cinnirella, 2005; Schirmer, 1996). In Saxony such a decline was probably magnified by the consequences of the Seven Years' War (1758-1763), and the famine years (1771-1772)

[14] Or quinquennia when possible.
[15] For studies on height cycles you are referred to Woitek, 2003.

which determined a remarkable increase in food prices and mortality rates (Schirmer, 1996).

Even though only 38% of the regression sample reports a previous occupation, it is possible to draw some results: there is a height premium for individuals who had direct access to food or previously worked in the textile sector (respectively 0.76 and 0.83 cm). But also the (presumably) miscellaneous category of *unknown* and *unskilled* shows a height advantage in comparison with the base category of craftsmen.

The geographical dummies show a clearer story: living in relative big cities was detrimental for the biological living standard. In particular Dresden, the biggest city in Saxony,[16] had the shortest people: circa 1.64 cm shorter than individuals from the industrial area; individuals in Leipzig were 0.73 cm shorter[17]. As expected, officers and non-commissioned were on average 4.4 cm taller than infantrymen.

Given the size of the sample, we ran separate regressions in order to construct regional trends. We distinguished four main areas: (*i*) Leipzig and surrounding (*Agric.area*), (*ii*) the city of Dresden and the central-eastern part of Saxony (*Dresden area*), (*iii*) the industrial area of Vogtland with the city of Chemnitz (*Ind.Area*), and (*iv*) the remaining Southern area (*South*).

-Insert Figure 6 here-

The four trends have a clear common pattern. In particular, the northern agricultural area presents a flatter trend until 1770. The other regions experienced a common increase from 1740 until 1765, and a successive decrease for the following two decades.

[16] Dresden had 21 000 inhabitants in 1699, 46 000 in 1727. During the Seven Years War Dresden had around 63 000 inhabitants; after the war 44 000. In 1852 it had 100 000 inhabitants. Leipzig had 14 000 in 1648, 32 000 in 1753, and 26 000 after the Seven Years War. Chemnitz had 21 000 inhabitants in 1834.

[17] The differential between Dresden and Leipzig is statistically significative.

3.2 19th Century

In order to analyze the 19th century, we focused on the soldiers aged 16-22. The model specification is similar to the previous one, the only difference regarding the introduction of age dummies to control for the physical growing process (see Table 2).
The trend is built on decennial birth cohorts starting from 1800 until 1850 and is standardized for an infantryman aged 22.

-Insert Figure 7 here-

The trend is clearly decreasing, and the statures decline at about 2.3 cm per decade. Previous finding about the urban effect is confirmed: in the 19th century the height penalty for living in Dresden was 2.35 cm, referring always to the same base group. Chemnitz has a disadvantage of 1.44 cm. These differentials are statistically different from the values estimated for the 18th century suggesting a worsening of living conditions in those two cities.
In terms of sub-regions, the central and eastern part of Saxony presents the shortest physical stature, even after controlling for the effect of Dresden.
In this second regression sample, 79% of the soldiers reported a previous occupation. The estimated occupational disparities are consistent with the results of 18th century, though *unskilled* and *unknown* are not statistically significant. Propinquity to food has a similar magnitude, though the p-value is slightly larger than 0.10. The textile and service sector show a significant height advantage (respectively 1.15 and 1.73cm), but the coefficient linked to textile is not statistically different from the previous regression. The coefficient linked to professional is very high (ca.5.8 cm), but the very small number of observations for this category induces to take this estimate with extreme caution.
Also for the 19th century we ran separate regressions for each relevant geographical area, and again we can observe the existence of a common trend among the four areas.

-Insert Figure 8 here-

4. Marriage Rates

For a sub-sample representing the 70% of the entire dataset we collected information on the marital status of the soldiers. Unfortunately we do not know the age at which they got married, but the data allow us to obtain the probability of getting married through the estimation of a standard *probit* model.

It is a reasonable to assume that the decision to constitute a family and then to became (economically) independent is closely related to the current economic situation and the future perspectives. In this fashion, a correlation between "secular swings in real wages and the crude marriage rate" has been shown for England, 1541-1871 (Wrigley and Schofield, 1993). Following this approach, we studied the probability of getting married estimating a standard *probit* model. The covariates used are height, age, military grade, dummies for birth cohort, and the usual set of occupational and regional dummies. In the sake of interpretation, in Table 3 we report the marginal effect (i.e. the change in probability of getting married). They have been computed at the mean height of 168.5cm and age of 26. From the table we can see that the highest marginal effect is linked to the 1740-44 birth-cohorts. Then we plotted in the same graph the height trend for the 18th century and the marginal effects shifted for the mean age value (Figure 9). It is quite evident that the marginal effects follow the same trend as the physical stature. In particular both curves reach their respective peak in 1765-70. It implies that individuals born in that period were the tallest and, for the same years, people aged 26 had circa 17% more probabilities of getting married.

The study of the marriage rates then supports the previous findings related to the height trend, in particular confirming the peak reached right after the end of the Seven Years' War (1756-1763) and the strong decline experienced in the last decades of the 18th century.

5. Discussion

It is difficult to explain the height peak reached in the years immediately after to end of the Seven Years' War. Such conflict surely altered the demographic dynamic. According to Schirmer (1996), in wartime Saxony lost about 6% of its population, more than 100 thousands individuals.[18] These figures are indicative of the impact of the war and might suggest a Malthusian interpretation: an abrupt diminution of the pressure on natural resources favored the condition of the population not directly involved in the conflict. This seems to be reflected also by the estimates of the marriage rates, according to which people during that quinquennium (1765-70) had the highest change in probability of getting married.

Regarding the decline at the end of the 18th and the first half of the 19th century, possible explanations can be ascribed to causes such as an increase in income inequality, worsening of the epidemiological environment, an increase in the workload, and a rise of relative price of food.

Occupational differentials are expected to mirror changes in income distribution. In the previous sections we could not find a clear pattern in occupational differentials; only the textile sectors kept its own (constant) height premium during the period analyzed. Furthermore, people employed in the service sector showed a consistent height premium for the first half of the 19th century.

The regional trends did not show large differences among each other, suggesting to disregard the epidemiological environment explanation. It does not seem plausible to infer that all the areas contemporaneously experienced a worsening of the environmental conditions, giving then rise to the observed trends. But as shown in other studies, the urban environment was detrimental to the biological living standard, and it probably worsened in the 19th century as reflected by the Dresden estimates.

Surely in the last 30 years of the 18th century the industrial development accelerated. Forberger (1958) reports that 170 new big factories were founded in the whole 18th century; 101 had been founded just between 1771 and 1800. But as we have seen, the decrease in biological standard of living was not confined to a particular area, and then

[18] According to Blaschke (1967), in comparison with the peace-time Saxony had 120,000 more deceased and 20,000 less birth.

there must have been a common cause. The rise in the relative price of food, and market integration might have played a conclusive role. During and after the famine years (1771-72) food prices raised and, presumably, also the supply of other goods saw an increase[19]. This might have induced people in the cities to substitute expensive food for other goods. On the other side, increased market integration might have pushed previously self-sufficient households to sell a bigger share of their food production, given that home-consumption became more expensive.

From the regional trends is also evident a temporary recovery in terms of biological standard of living during the Napoleonic period. For this period, the industrial area around Chemnitz and especially the cotton sector deserve special attention. The Continental Blockade implemented by Napoleon from 1806 until 1813 practically saved the Saxon hand-spinning industry which was suffering from British competition. In February 1806 yarns' import were prohibited and the contemporaneous restrictions on British and Indian cotton goods increased the demand for internally produced goods. This had the effect of expanding the textile industry, and it is mirrored by the increment of spinning machines which number increased from 13,000 in 1806 to 256,000 in 1813 (Crouzet, 1964). To which extent the Continental System affected the biological standard of living of the Saxonian population, and in particular of the ones employed in the textile sector is an interesting question which will deserve further research. For the time being we can assess that the positive height differential observed for the industrial area is statistically significant. Next step will be the estimation of the impact of protectionism on what we could consider a "treatment group", namely the individuals belonging to the textile group.

[19] For a series of rye prices see Schirmer (1996), p.43.

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Table 1. Descriptive statistics of the analyzed sample

	Whole Sample	Adults (23-49)	Youths (16-22)
Mean height	71.2	71.6	70.7
Mean age	25.6	28.3	20.8
Infantry	0.93	0.90	0.97
Officers/Non-comm.	0.07	0.10	0.03
Regional Distribution			
Agricultural	0.28	0.28	0.29
Industrial	0.14	0.13	0.15
Centre-east	0.18	0.19	0.16
Mountain	0.28	0.28	0.28
Cities			
Dresden	0.04	0.04	0.04
Leipzig	0.04	0.04	0.05
Chemnitz	0.03	0.03	0.03
Occupation			
Professional	0.007	0.006	0.008
Textile	0.14	0.13	0.17
Food	0.06	0.05	0.07
Crafts	0.17	0.16	0.19
Industrial	0.01	0.01	0.02
Service	0.02	0.01	0.02
Unskilled	0.06	0.04	0.11
Unknown	0.51	0.59	0.39
Sample size	37,775	23,138	14,396

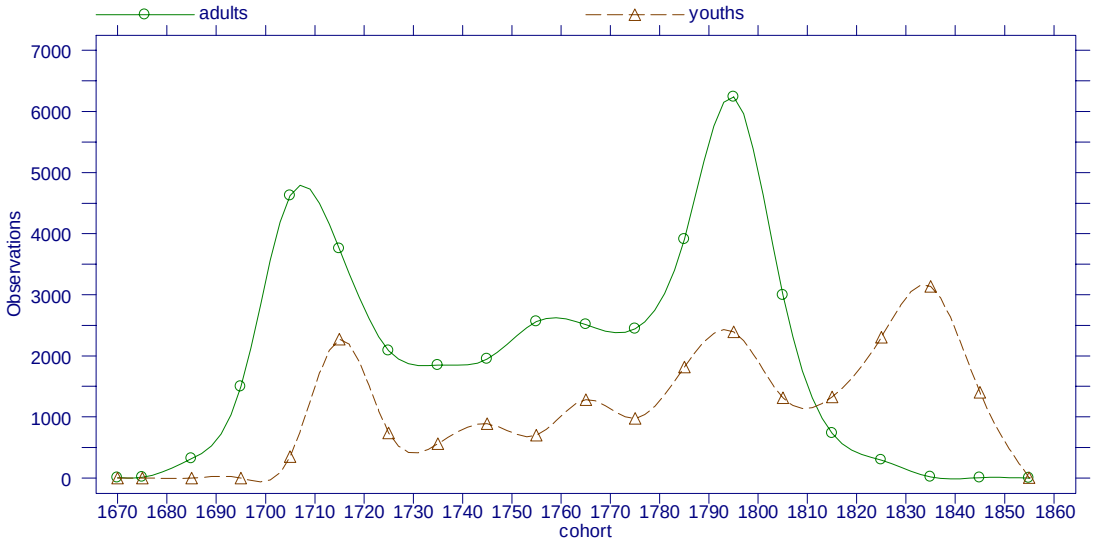

Figure 1. Distribution of birth cohorts by age-group

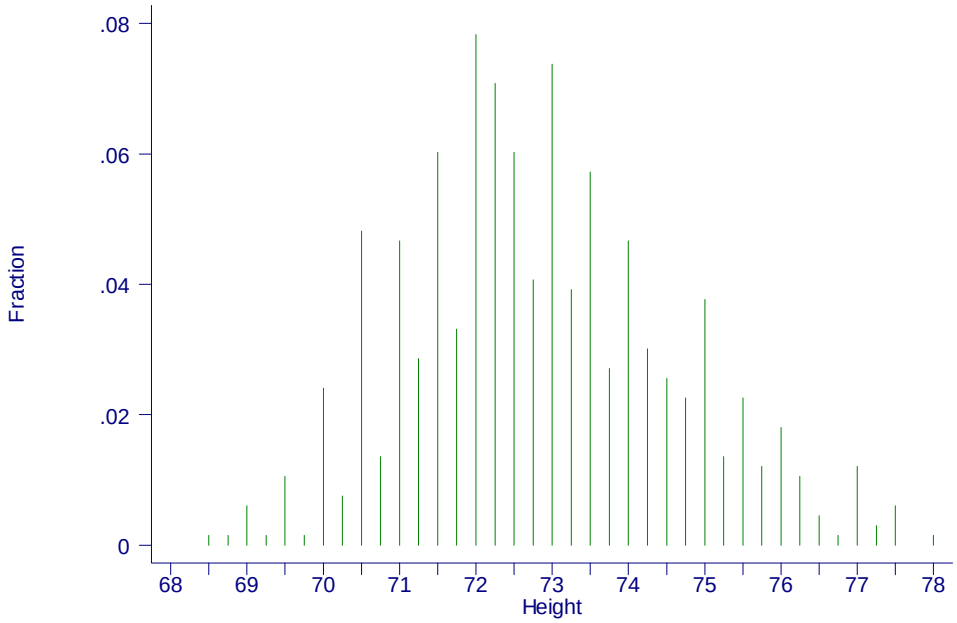

Figure 2. Height distribution of adult infantrymen recruited before the Seven Years' War, 1754-56. (n=664)

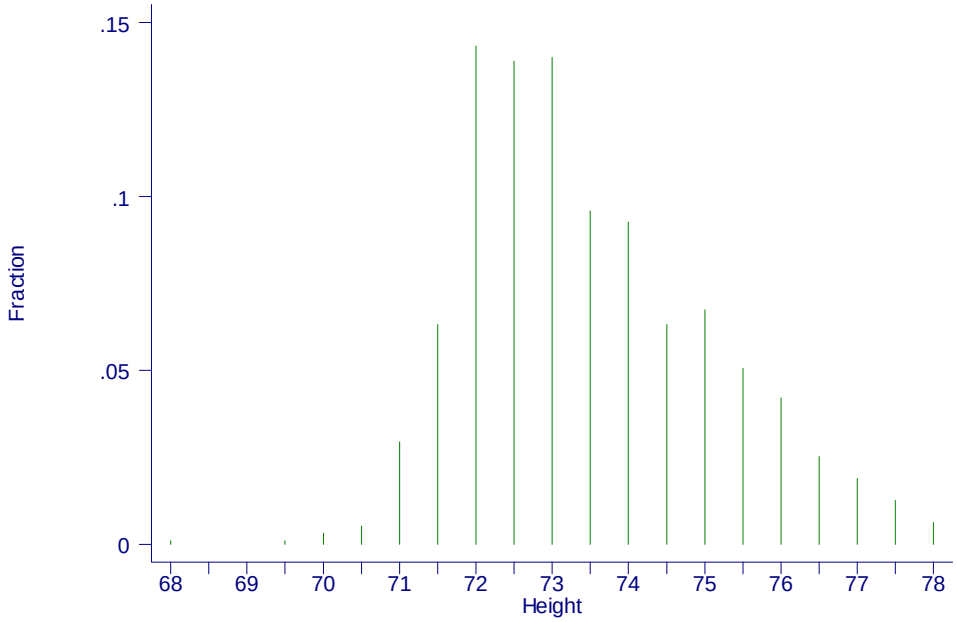

Figure 3. Height distribution of adult infantrymen recruited in 1795-96 (n=950)

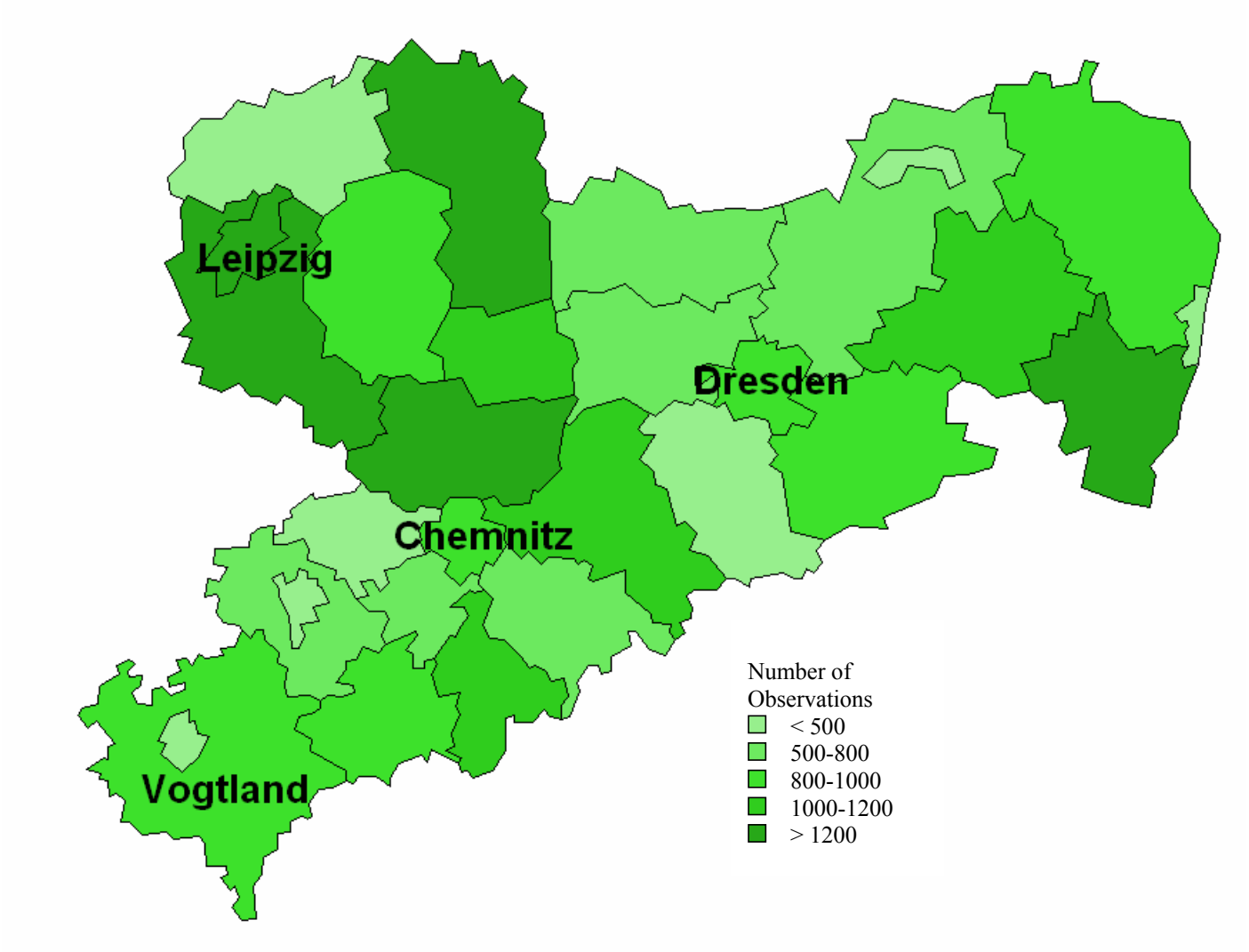

Figure 4. Geographic distribution of the sample

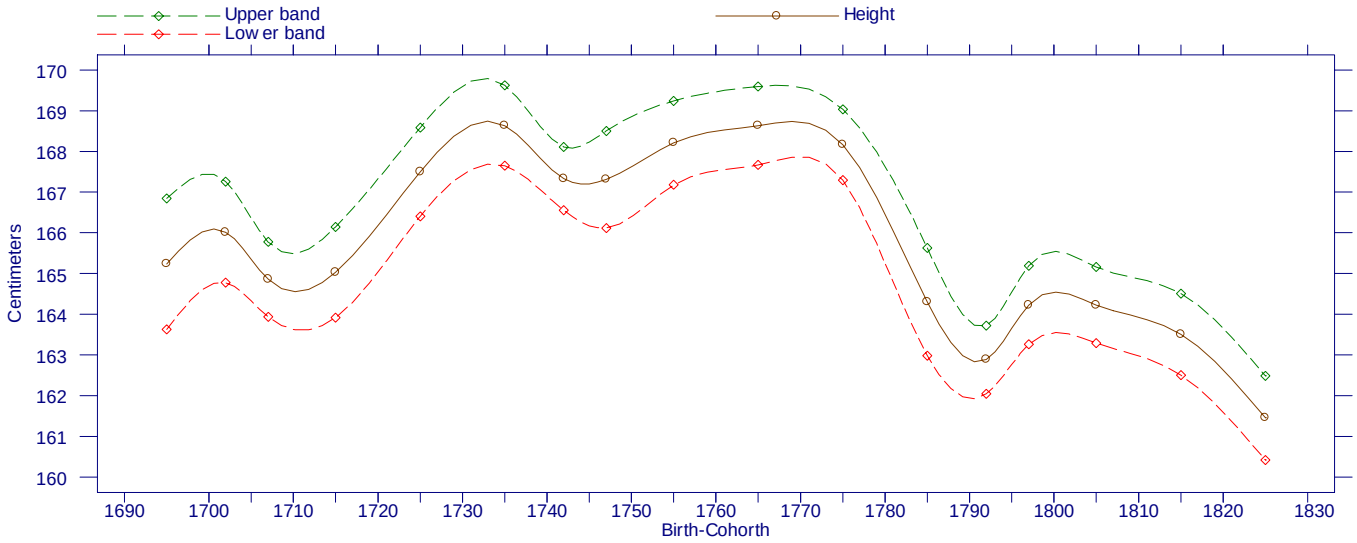

Figure 5. Height trend of adults (aged 23-49).

Note: the bands indicate two standard errors. The standard errors are adjusted for clustering.

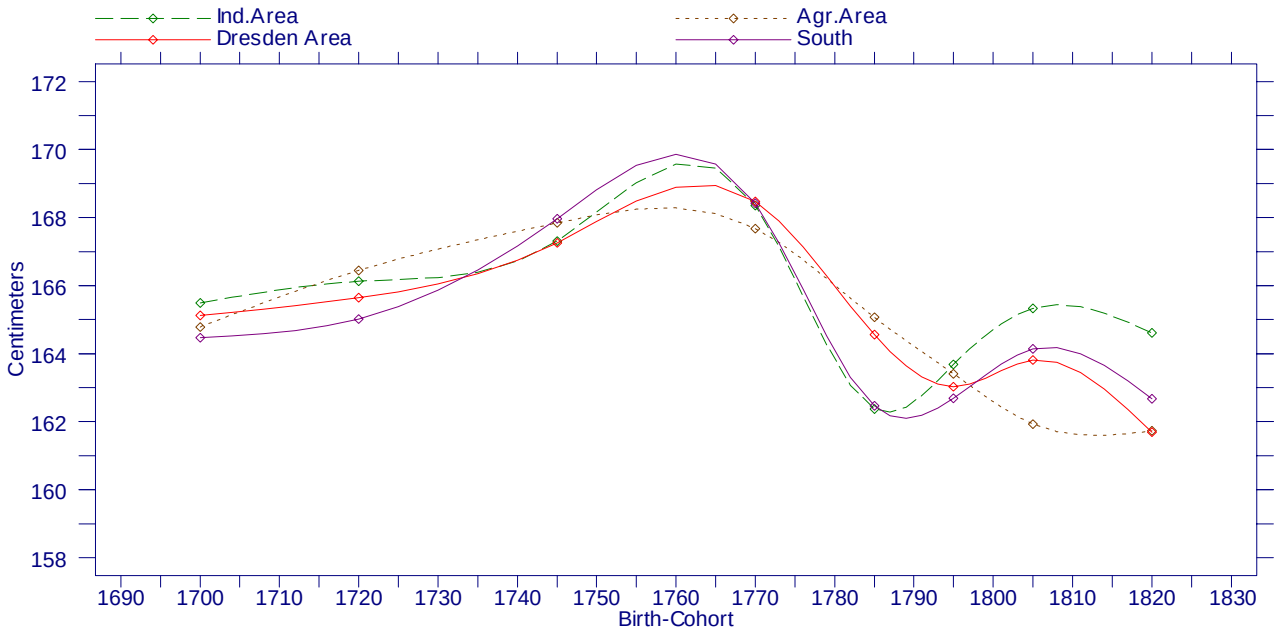

Figure 6. Height trend of adults by area

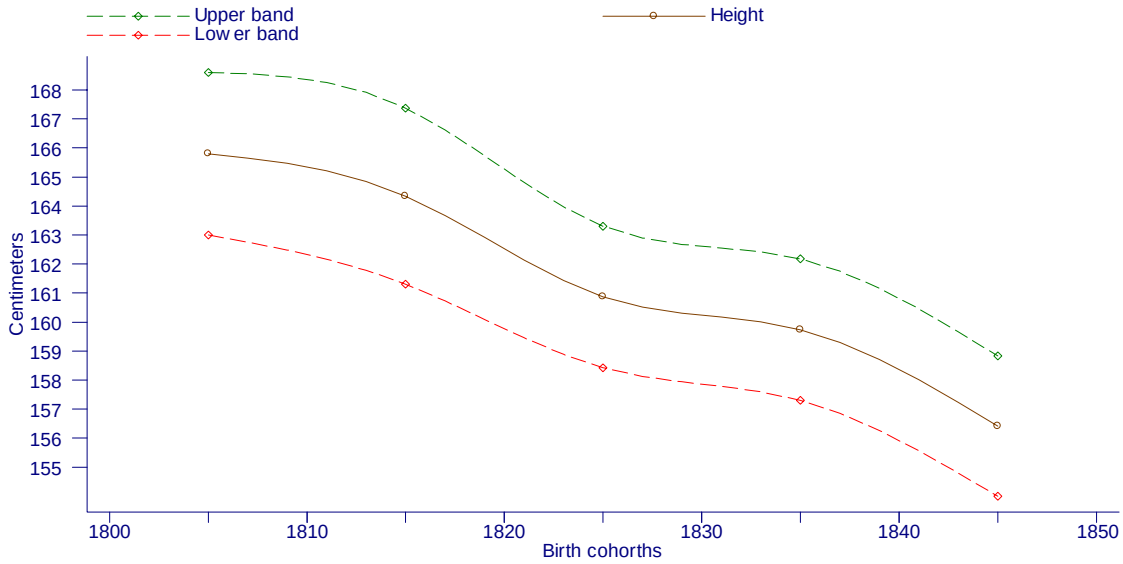

Figure 7. Height trends of youths

Note: the bands indicate two standard errors. The standard errors are adjusted for clustering.

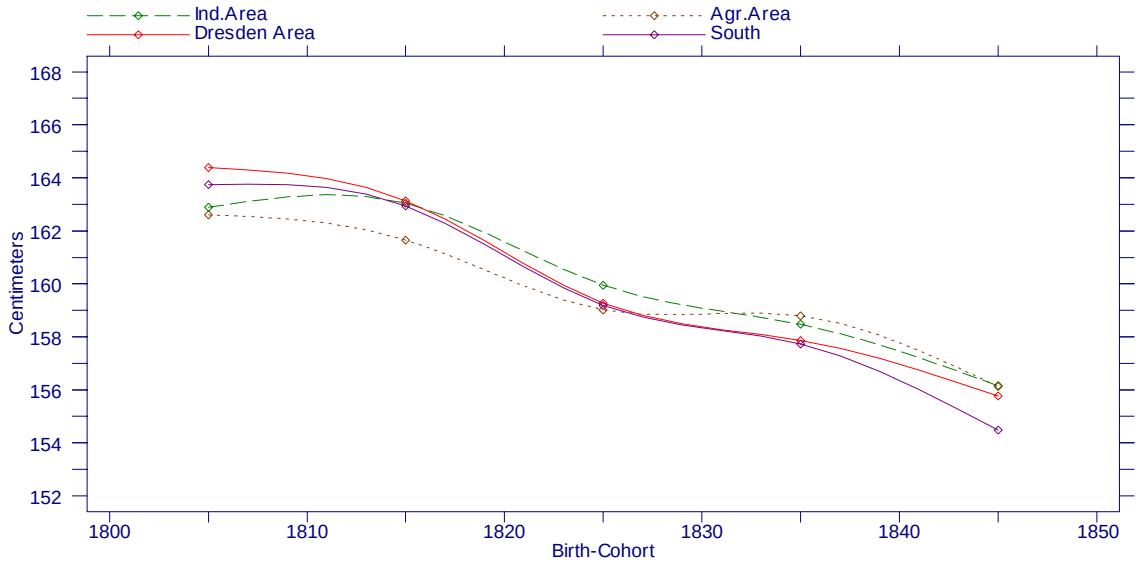

Figure 8. Height trend of youth by area

Table 2: Truncated regression for adults and youths

Dependent Var. Height	*Adults(23-49)*	*Youths(16-22)*
dcoho169099	-1.439	
	[4.22]***	
dcoho170004	-1.108	
	[4.20]***	
dcoho170509	-1.598	
	[8.17]***	
dcoho171019	-1.526	
	[6.46]***	
dcoho172029	-0.482	
	[2.09]**	
dcoho173039	0.001	
	[0.00]	
dcoho174044	-0.559	
	[3.33]***	
dcoho174549	-0.563	
	[2.23]**	
dcoho175059	-0.180	
	[0.82]	
dcoho176069	*Reference Group*	
dcoho177079	-0.195	
	[1.06]	
dcoho178089	-1.831	
	[6.55]***	
dcoho179094	-2.431	
	[13.68]***	
dcoho179599	-1.862	
	[9.08]***	
dcoho180009	-1.862	3.980
	[9.42]***	[15.76]***
dcoho181019	-2.170	3.362
	[10.21]***	[12.30]***
dcoho182029	-3.043	1.886
	[13.84]***	[8.59]***
dcoho183039		1.408
		[6.43]***
Officers	1.881	2.247
	[20.17]***	[8.99]***
Infantry	*Reference Group*	*Reference Group*
Leipzig	-0.312	-0.064
	[2.04]**	[0.48]
Dresden	-0.699	-0.998
	[4.82]***	[9.46]***
Chemnitz	-0.444	-0.609
	[1.81]*	[7.70]***
reg_agr	-0.298	-0.662
	[1.74]*	[3.56]***
reg_east	-0.357	-1.115
	[2.27]**	[8.78]***
reg_mount	-0.455	-0.837

	[2.67]***	[6.64]***
reg_ind	*Reference Group*	*Reference Group*
Unknown	0.196	-0.043
	[2.39]**	[0.28]
Industrial	-0.080	0.490
	[0.36]	[1.53]
Professional	0.190	2.453
	[0.43]	[4.60]***
Food	0.328	0.318
	[2.27]**	[1.61]
Unskilled	0.478	-0.202
	[2.63]***	[1.41]
Service	0.409	0.778
	[1.63]	[2.84]***
Textile	0.352	0.489
	[3.63]***	[3.20]***
Crafts	*Reference Group*	*Reference Group*
age16		-1.275
		[0.88]
age17		0.152
		[0.25]
age18		-0.854
		[1.73]*
age19		-0.498
		[1.40]
age20		-0.691
		[3.78]***
age21		-0.146
		[0.86]
age22		*Reference Group*
Constant	71.428	66.266
	[348.93]***	[293.42]***
Observations	20125	7717

Note: Robust z statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors adjusted for clustering.

Table 3. Marginal effects of the probit model.

Dependent variable: married	*Marginal effect*
height	0.000
	[1.03]
age	0.002
	[18.73]***
officers	0.035
	[12.88]***
dcoho169099	0.133
	[6.63]***
dcoho170004	0.159
	[9.68]***
dcoho170509	0.121
	[7.47]***
dcoho171019	0.081
	[6.85]***
dcoho172029	0.100
	[6.16]***
dcoho173039	0.154
	[7.55]***
dcoho174044	0.169
	[7.32]***
dcoho174549	0.073
	[6.09]***
dcoho175059	0.067
	[5.15]***
dcoho176069	0.044
	[5.22]***
dcoho177079	*Reference Group*
dcoho178089	0.027
	[4.26]***
dcoho179094	0.018
	[2.72]***
dcoho179599	0.009
	[1.52]
dcoho180009	-0.004
	[0.90]
dcoho181019	0.018
	[1.98]**
dcoho182029	0.072
	[5.64]***
Regional dummies	*yes*
Occupational dummies	*yes*
Observations	20127

Note: Robust z statistics in brackets. Standard errors adjusted for clustering. * significant at 10%; ** significant at 5%; *** significant at 1%. Reference group: infantrymen previously employed as craftsmen and coming from the industrial region.

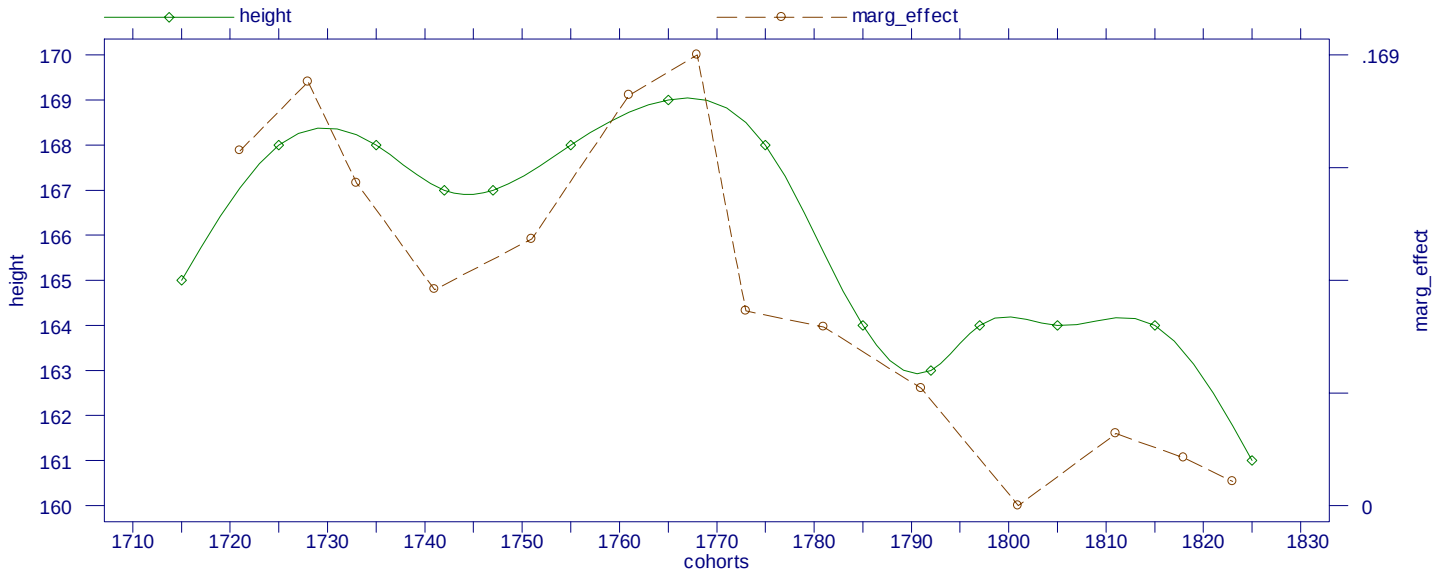

Figure 9. Height trend and variation of probability getting married