11 | ANALYSING ANCIENT ECONOMIES AND SOCIAL RELATIONS

Nikola Koepke – Joerg Baten

Anthropometric Methods and the Interdisciplinary Conversation Between Archaeology and Economics

A Study of the Impact of the Specialization in Husbandry on Mean Height in Early-Historical Europeans

Abstract: In this paper we use possibilities of interdisciplinary work between archaeology and economics, focusing on the development of European living standard in terms of nutritional status in long-run perspective (1st to 18th century AD), and its determinants. We applied anthropometric methods using a data set of nearly 9500 human height measurements as proxy for mean nutritional status, and a data set of more than 2 million animal bones to measure the impact of changes in cattle production. Milk cattle husbandry, interacted with sparse population density, has had positive effects on mean height: (1) Proximity to protein production resulted in a low local shadow price of milk, as it could not be transported over distances. (2) This low price resulted in a low inequality of nutritional status; in contrast pork induced nutritional inequality, because it could be preserved and traded, thus becoming expensive and affordable only for the rich.

Impact of the Specialization in Husbandry on Mean Height in Early-Historical Europeans

Anthropometric history is concerned with the concept of the “biological standard of living” – using mean height as proxy for the nutritional status of a population – and its interdependence with environmental, political, economic and social developments. To study the nutritional status of populations of early-historic periods, an interdisciplinary approach is necessary, because all data (height data, as well as data on its determinants) stem from excavations and archaeological work, whereas the econometric methods come mostly from applied economic research. Mean height of a population is determined mainly by nutrient consumption, exposure to parasites, and disease environment. Of particular importance seems to be consumption provision which is determined by regional and temporal differences in the type of food production. For late 18th and 19th century societies, milk consumption was found to be one important determinant of the biological standard of living (and to a lesser extent beef: Baten 1999; Komlos 1998), with particularly a high local supply of milk leading to better nutrition and taller height, and thus – ceteris paribus – to better health and longevity values. As the milk could not be transported over long distances in remote milk-producing regions even low-income groups could consume a healthy diet. Hard cheese played a less important role in quantitative terms. In contrast, in cities only high-income groups could afford a protein-rich diet (primarily based on meat). As nutritional inequality tends to reduce mean height due to the declining marginal effects of food on height, this second effect

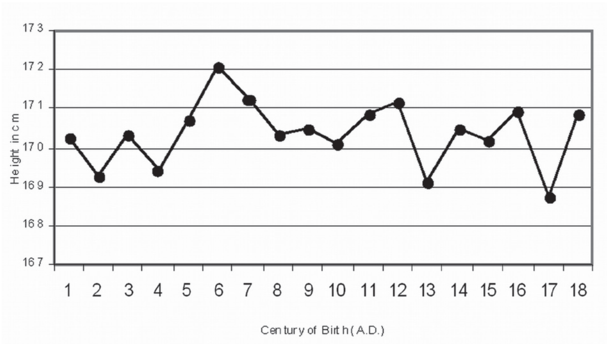

Fig. 1. Height development of the 1st to 18th century AD (in cm, male and female). The level of heights was adjusted to male heights of average Europeans (using the regional coefficients and weighting them with sample weights).

reinforced the proximity-to-nutrients effect on mean height in ancient and medieval times (Steckel 1995; Boix / Rosenbluth 2004). Those two relationships led us to the hypothesis that a higher cattle share should have been accompanied by higher mean height in Europe also during early historic periods. Hence we tested whether the relationship between milk intake – the "proximity-to-protein production effect" – and height also holds for ancient and medieval history.[1] Can we even explain the larger mean height of Germanic tribesmen with their milk consumption, as postulated by the ancient literature?[2]

Human Bone Data Set

The data we compiled on human height primarily stem from archaeological excavations, published or reported in archives.[3] We subdivided our data collection into (a) Central-Western (b) North-Eastern, and (c) (Western) Mediterranean Europe (Koepke / Baten 2005). We organized our height observations by century of birth and region. Heaping and truncation did not play a large role (Koepke / Baten 2005, Fig. 1a / 1b). We found that the distributions of well-documented centuries were all distributed normally, except for the eighth century.

As we had partially grouped data (i.e. some heights were only reported as group averages, not as individual heights), we used weighted regressions (weighted with square roots of N), and regressions with individuals only to estimate height trends first by gender, and then by European regions. The resulting height time series is given in *Fig. 1.* Overall, heights remained stagnant and indicated no real progress in European nutritional status until around 1800 AD. However, there is considerable variation between the centuries, as, for example, in the fifth and sixth centuries when heights increased, or during the medieval warm period (11th / 12th centuries AD). Height trends also developed with relative similarity over the regions and genders. Thus, we concluded that our estimates of height development were very likely reliable.

Animal Bone Data Set

In order to trace the effect of protein production quantitatively we compiled a data set on main domestic animal bones based on the data sets of King

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1 Due to space restriction here, please see our working paper Koepke and Baten 2007 for all detailed information, descriptions and discussion, as well as full bibliography. We thank Willem Jongman for providing the idea to use animal bone data.

2 see e.g. Tacitus Germ. 23; Caesar Gall. 6, 22,1.; Strabo 4,4,3; Plinius nat. VIII 179

3 Wherever possible, we collected disaggregated figures, but many of the total 9477 height measurements were aggregated by the excavators and original investigators. Thus, our final database is comprised of 2972 different height measurements after discarding extreme heights (< 145 cm, > 200 cm). When the dating was imprecise, we used the average of the earliest and latest date mentioned by the principal investigators, as the real date could have been both before and after the middle of a century. We experimented with estimation techniques granting smaller weight to imprecisely dated observations or discarded them completely, but the main results remained robust. The same applies to age estimates. Because of these data limitations, our units of analysis are restricted to entire centuries. We organized all heights by century of birth and discarded such individuals who were still in the process of growing (< 23 years). Heaping and truncation did not play a large role as is illustrated by the rather normal distribution of heights (see Koepke/Baten 2005, Figures 1a, b). We also performed Jarque-Bera and Kolmogorov-Smirnov tests for normality (by century of birth) and found that the distributions of well-documented centuries were all distributed normally, except for the eighth century (details available from the authors). Our intention was to collect as much height data as possible, with the consequence of having to accommodate different types of height information. The majority of measurements were based on excavated skeletons; to make the different reconstructions by different processors comparable we created transformation algorithms.

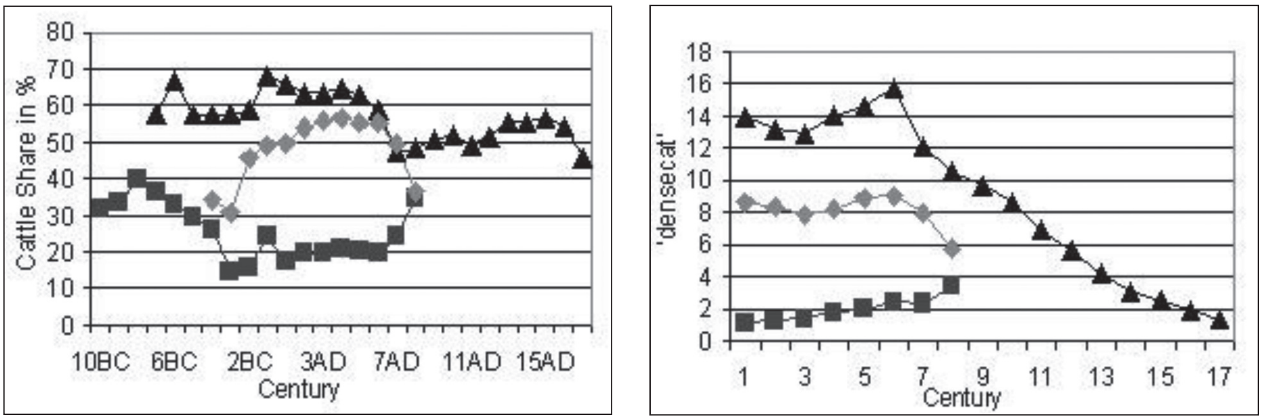

Fig. 2. a. Development of cattle shares in the three 'large' European regions. b. The interaction of cattle bone share and land per capita (source: see text). Black quadrats: Mediterranean Europe; pale rhombs: Central-Western Europe; triangles: North-Eastern Europe.

(1999 and further years) for the Roman Empire, supplemented with a significant amount of data for Northern and Eastern Europe (e.g. Luff 1982; Benecke 1986; and others), which we also organized by the three major European regions. Our data set came to comprise animal data from 415 sites, covering the centuries between 400 BC and 600 AD satisfactorily for all regions. To ensure that animals were meant for daily food consumption, no sites of burial or other sacral background were taken into account. Bone assemblages which represented remnants of craft production were excluded, as well.

The development of the cattle share in the three regions was dramatic between the 10th century BC and the 17th century AD *(Fig. 2a)*. In Mediterranean Europe in particular, an extreme decline occurred over the centuries before the turn of the eras; after the first century AD, the cattle bone share stagnated on a low level until the sixth century AD. In Central-Western Europe the development of the cattle bone share followed a different pattern: After a substantial increase from the third century BC onwards, the share of cattle remained relatively constant throughout the second and sixth centuries AD; but in the following the share declined. The North-Eastern European cattle bone share displayed a less volatile development: A slight decrease became apparent over the centuries, with long periods of rather constant values. Overall, the North-Eastern cattle share was constantly higher than the Central-Western one, with the share in Mediterranean Europe ranking lowest[4].

Working with archeozoological data we have to bear in mind that bones might have a differ-

[4] When comparing the development of of the domestic animals species by regions (not shown), we found that in all three parts of Europe, the pig and cattle share developed more or less antipodally, whereas the sheep/goat share developed 'independently' and was overall relatively stable. Although the Romans substituted beef with pork the overall meat consumption was still relatively high in the Roman Empire (e.g. Jongman forthcom.) – albeit not necessarily per capita. We argue that cattle husbandry provided particularly important advantages in terms of proximity to milk production, and based our results not directly on meat per capita values. By levels of absolute bone numbers it can be deduced that the diet of the Mediterranean region with its high population density was probably marked by much lower overall meat consumption. The Mediterranean population was larger; and in the Mediterranean, only one seventh of the Central-Western Europe bone number was found, for the first century AD. For the second century and thereafter, the gap is even wider. A part of this gap can certainly be explained by taphonomic distortions. It is unlikely that the Mediterranean population consumed more meat per capita than the Central-Western Europeans. The differential of pig bone levels is much smaller (only 1:3 in favour of Central-Western Europe in the first century AD, and about 1:4 in per capita terms), whereas the differential of cattle bones is almost 1:20.

[5] The field has made considerable progress over the last decades (see e.g. Hambleton 1999; Lyman 1994; O'Connor 2000; Wilson 1996), but depositional biases are highly site-specific and time-variant, thus no overall valid formulae are available to estimate the original numbers (Nicholson 1996). To assure best possible 'representativity' of the data all animal bone remains should be related to regular food consumption activities (e.g. Doll 2003; Lauwerier 2004). Bones from specialized large slaughterhouses and data from ritual offerings as well as grave goods and workshops were not taken into account here in order to minimize the bias.

ent probability of being included in the data set on which our estimates are based; this means, we have to be aware of various taphonomic biases, which can influence survival of faunal remains (see LYMAN 1994; DENYS 2002), but generally at least parts of a consumed animal are preserved and can be analysed.[5] Furthermore one has to keep in mind that the method to estimate the composition of the bone assemblages used in each case can result in biased outcomes.[6] Overall, fortunately in our study most of the possible measurement errors are of rather unimportant effect or are averaged out, given that we have considered only large regions.

also traction, fertilizer) (e.g. GREENFIELD 2005), because milking yields four to five times the protein of meat production, even if milking is admittedly more labour-intensive (DAVIS 1987; FOLEY ET AL. 1972; LEGGE 2005; SHERRATT 1981). Evidence on milking practices of cattle comes from archaeology, historical sources, art, as well as mass spectrometric analysis. The most important and therefore commonly used possibility to determine the dominant use of cattle is the zooarchaeological method of studying the sex and age structure of the kill-off patterns (e.g. MCCORMICK 1992; WILSON 1994). Are there regional and temporal differences in the use of cattle in Europe? At prehistoric sites the predominant part of the stock

	Coeff-1	*p-val.*	Coeff.-2	*p-val.*	Coeff.-3	*p-val.*	Coeff.-4	*p-val.*	Coeff.-5	*p-val.*
Constant	131.20	*0.01*	148.35	*0.02*	168.42	*0.00*	171.37	*0.00*	168.55	*0.00*
Population-Urban-share	-0.01	*0.63*	-0.06	*0.19*						
Plague	0.49	*0.34*								
Gender inequality	-0.29	*0.55*								
Climate warm	4.35	*0.39*	1.95	*0.74*			-0.35	*0.95*		
Land per capita									1.02	*0.52*
Cattle share			0.08	*0.09*					0.05	*0.39*
'densecat'					0.21	*0.00*	0.23	*0.09*	0.07	*0.82*
Mediterranean	-0.93	*0.26*	2.76	*0.13*			0.64	*0.55*	2.08	*0.17*
North-East	0.85	*0.10*	0.64	*0.27*			0.47	*0.54*	0.50	*0.54*
Antiquity	-1.07	*0.10*	-1.21	*0.13*			-1.10	*0.07*	-1.11	*0.04*
LateMiddle Ages	-0.19	*0.81*	0.13	*0.85*			0.65	*0.55*	0.56	*0.57*
Modern	0.35	*0.83*	0.20	*0.94*			-1.1	*0.58*		
Adj. Rsq	0.31		0.55		0.38		0.55		0.56	
N	35		25		25		25		25	

Tab. 1. Five regressions: Determinations of height in Europe: WLS Regression (i.e. weighing the units with the square roots of aggregated observations). Constant refers to a hypothetical height value for the Early Middle Ages & Central-West.

Debate: Milk Consumption and Alternative Cattle Product Use in Antiquity

Cattle were certainly used for both milk and meat, but milk has a stronger influence on regional human nutrition. In general cattle farming was always multipurpose (CRABTREE 1996; BARTOSIEWICZ / VAN NEER / LENTACKEr 1997; LUFF 1993; SEETAH 2005). The question remains, whether milk was the most important component in the output. Most of the literature views the use of cattle for meat, hide and bone as less important than the use for milk (and

are adult cows. When Central and Western Europe became part of the Imperium Romanum more cattle were used for traction power (which probably reduced milk output). Grain agriculture grew. Researcher's opinions diverge as to whether this was due to the predominant use of cattle or still for milk production (e.g. ROTHENHÖFER 2005). Certainly autochtonic people consumed cow milk, whereas the "Italians" of the Imperial period considered it as "barbaric" (TUFFIN / MCEVOY 2005). On average meat seems to have been a tertiary aim for the keeping cattle, as this product was used to supply the urban

[6] E.g. in case of the, in the compiled literature commonly used concept of NISP (Number of Identified Specimen) there is a risk of overestimating the number of large animals while underestimating small animal counts. For our study the bias from zooarchaeological counting strategies is relatively limited, because we do not compare large and small animal species.

population and the army. After the Roman Empire broke down, the main concentration in husbandry was breeding and milk production (Doll 2003; Thompson 2005). Overall, we can conclude that the consumption of bovine milk and quality meat was more prevalent in the regions outside the imperium Romanum. In contrast, traction power was the main motivation in the heartland of the imperium Romanum – and after Romanization, perhaps also in some of the Northern provinces.

Results: Determinants of Mean Height in Ancient and Medieval Europeans

In order to test whether, and to which extent, the cattle bone share – as a proxy for specialization on protein production – and various other factors influenced mean height in Europe until 1800 AD, we applied panel data analyses on the level of the three European regions outlined above. Panel data analysis uses the variation both over time and across regions in order to improve the assessment of relationships.[7] By including the cattle share into a regression model (Koepke / Baten 2005), we were able to obtain much greater explanatory power. Potential determinants of height (discussed in Koepke / Baten 2005) are the factors land per capita, urbanization, climate, social inequality, Roman public health and technology, gender inequality, and the disease environment, which is very difficult to measure in a comprehensive way (for alternative strategies, see Steckel / Rose 2002). Which variables have the greatest explanatory power for the long-run development of mean height? In the base-line model without the cattle bone variable, only the regional dummy for North-Eastern Europe and the period dummy for antiquity were statistically significant (on the 10% level, see Model 1 in *Tab. 1*). The only difference to the earlier (Koepke / Baten 2005) model was hence that in the new model we experimented with a combined index of population density and urbanization, since both variables were highly collinear. However, this combined index, along with most other variables, proved insignificant. We must therefore admit that our rough proxies – as the ones for gender inequality or climate – are likely to contain a large measurement error. Thus, it is not surprising that the coefficients are statistically insignificant.

If cattle share is added to the model, however, the adjusted R^2 increases from 0.31 to 0.55 (Model 2 in *Tab. 1*). Hence we conclude that the proximity to protein production was the most important variable. Moreover, whereas the older anthropological literature assumed "racial" differences in height between different European populations to be most important, it is particularly noteworthy that the significance of the dummy for North-Eastern Europe disappeared here as soon as we controlled for specialisation in cattle farming. Mediterraneans would even appear taller once the very low cattle share of the region is taken into account (although the coefficient is statistically insignificant). At an equal level of protein supply, Mediterranean people were still at least not shorter in relative terms. It is also striking that once cattle share was used for control, our population / urbanization index became economically (but not statistically) significant, with an additional standard deviation of this index resulting in a decrease of mean height by 1.53 cm, which is indicative of a substantial urban penalty, or "density penalty". To determine the amount of high-quality protein available to the average inhabitant of a region and century we incorporated population density (or rather an index of population density and urbanization) into the regression, and added the cattle bone share variable. Next we created an interaction term of "land per capita" (1 / population density) and cattle share – by multiplying [cattle bone share] * [land per capita] – in order to obtain a variable ("densecat") that approximated an agricultural system characterised by high per capita milk and beef production and high land per capita values. Low population density could be an important causal variable due to two aspects: Low population density allows greater specialization on milk cattle agriculture which affects heights positively; but at the same time, low density also has a direct positive effect on heights through a more benign disease environment. Therefore, the empirical strategy should be aimed at disentangling these two effects. In *Tab. 1* (Model 5), we added a regression in which the interaction term, as well as land per capita and cattle, enter side by side. Given the high multicollinearity, all three variables are individually insignificant. However, a joint F-Test indicates that they are jointly significant ($F(3,17)=5.54$, $Prob > F$ 0.008).[8] We concluded that mean height increase is composed of the three components, of which the cattle share is apparently the strongest. The component of

[7] For a comprehensive introduction to statistical data analysis: see e.g. Wooldridge 2000.

medium-strong importance (land per capita, or its inverse: population density) can be related to the more benign disease environment, plus potentially half of the interaction term. Thus, we can quantify the potential contributions of the protein proximity effect as somewhat more than one half, and the potential effect of the disease environment as a bit less.

The development of the interaction variable over time is shown in *Fig. 2b*. Similar to the height series *(Fig. 1)*, it is characterized by a notable increase in the fifth century. This is especially true for North-Eastern Europe, but to a certain extent for the other regions as well. After the sixth century, North-Eastern Europe experienced a long-term decline. Central-Western Europe began a similar decline after the sixth century, although we lack data beyond the eighth century. The values for the Mediterranean region resembled those of the other two regions, but on a lower level[9].

Conclusion

The economic history of Europe and the standard of living was influenced by changes in the agricultural specialization. As population density and urbanisation increased on the Apennine peninsula, husbandry switched from an initial emphasis on cattle and goat breeding during the centuries BC – which implied a relatively high and egalitarian protein supply – to a completely different system: During the Roman Imperial period, pork was the prominent food of the urban high-income strata of society, whereas the poorer ancient Roman population consumed primarily vegetarian food. By bringing together economic history and archaeology, we tested the hypothesis that protein-rich milk and beef were major determinants of the biological standard of living in early history just as in the 19th century. Type and emphasis of husbandry in general, and the decisive protein production bottleneck in particular, could be documented quantitatively (based on a sample of over two million animal bones) for the first time in this study. The share of cattle bones – as ceteris paribus an indicator of specialization on milk (and beef) production – turned out to have been a very important determinant of human stature. Population density may also have had a major impact via its typically accompanying worse disease environment.

Three main arguments support our use of animal shares as important and more or less reliable evidence for ancient and medieval agricultural specialization: (1) we consider only the shares of three animal types. The strongest taphonomic biases tend to affect the total number of surviving bones, but not so much the shares of large animal types. (2) If any of our three groups is more vulnerable, it is the sheep/goat category (given the smaller size of these bones). However, our account is driven by the 'pig versus cattle bones' argument, and those were of similar solidness. (3) Most of the literature on taphonomic bias refers to single excavation sites, whereas we consider three large regions of Europe, and only interpret broad trends and temporal or regional differences in husbandry specialization (in terms of animal species percentages), and thus differences in consumption conditions. Hence, a substantial part of the measurement error averages out or has only modest influence in our study.

Our newly created milk/beef indicator, together with the share of cattle bones and a set of nine other variables (such as population density, climate, etc.) is able to explain 55% of the height differences for the period 0–1800 AD. It could be demonstrated that

[8] Of course, multicollinearity leads to increased t-statistics, but not to biased coefficients. If we multiply the three coefficients by the standard deviations, we obtain three positive, but slightly different effects: an additional standard deviation of cattle share implies 0.77 additional centimetres in height, one additional standard deviation log land per capita equals 0.55 additional cm, and one additional standard deviation of the interaction term equals 0.30 cm in additional height (calculated only for those 25 cases for which all information is available).

[9] Studying the relationship in a scattergram (not shown here) one can see that the relationship is not perfect, but quite obvious. The observations on the Mediterranean are clustered in the lower left corner, displaying very low levels of milk and beef supply ("densecat") as well as low heights. This is also the case for 17th century North-Eastern Europe. Central and Western Europe experienced only modest changes in the first five centuries, whereas in the sixth century, both variables reached higher values. During the seventh and eighth centuries, Central-Western European mean height declined along with the diminishing per capita protein supply of this region (caused by strong population growth). The development of heights was most dynamic in North-Eastern Europe. However, the values for the Mediterranean and Central-Western region do not diverge very far from an imagined regression line reflecting the development of North-Eastern European heights only.

mean height is influenced by land availability per capita and the cattle share (with the adjusted R^2 increasing to 0.56), and a partial effect can also be explained by the adverse disease environment of a high population density.

The important result of our study is that early scholars have drawn wrong conclusions when trying to explain the fact that the populations of Northern and Eastern Europe were taller than the Mediterranean populations due to genetic reasons. They neglect to take the milk/beef indicator into consideration. When we controlled for the milk/beef-indicator statistically insignificant dummy variable coefficients resulted for North-Eastern Europe. This means that North-Eastern Europeans were taller than Mediterranean Europeans due to the fact that they produced and consumed more milk and beef. Despite certain shortcomings of our estimates due to the lack of data which is unavoidable for study periods without quantifyable written data, we are conscious that our methodology could also engender interesting findings in other contexts. When aspiring after knowledge over the very long run of economic history, the interdisciplinary approach of combining anthropometry and archaeozoology is an ideal method, because it makes available dispensable insights into some of the central aspects of human life.

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Nikola Koepke

University of Tübingen,
Department of Economic History
Mohlstraße 36
72074 Tübingen, Germany
nikola.koepke@uni-tuebingen.de

Joerg Baten

University of Tübingen,
Department of Economic History
Mohlstraße 36
72074 Tübingen, Germany
joerg.baten@uni-tuebingen.de