Worldwide inequality, living standards and its determinants during the 19th and 20th centuries

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Abbreviations

AR(1)	Autoregressive Model (of order 1)
BDT	Bayer, Dwyer and Tamura (2006)
BE	Baten and Enflo (2007)
CV	Coefficient of (height) Variation
DEA	Data Envelopment Analysis
DHS	Demographic and Health Surveys
DMU	Decision Making Unit
ELF	Index of Ethno-Linguistic Fractionalization
FDH	Free Disposal Hull Model
GDP	Gross Domestic Product
GLS	Generalized Least Squares
HHI	Herfindhal-Hirschman Index
ILO	International Labour Organization
LBMC	Larson, Butzer, Mundlak and Crego (2000)
LDC	Least Developed Countries
NFH	National Family Health Survey
N	Number of Observations
NHANES	National Health and Nutrition Examination
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PREG	Politically Relevant Ethnic Groups
PWT	Penn World Tables
SD	Standard Deviation
SF	Stochastic Frontier Model
TFP	Total Factor Productivity
UK	United Kingdom
US	United States of America
WWII	Second World War

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No new light has been thrown on the reason why poor countries are poor and rich countries are rich.

Paul Samuelson (1976)

1. Introduction and outline

One of the oldest incentives for research in economic history is the investigation of living standards and the question on how some countries are more successful in providing welfare to their people than others. However, in the course of economic development, the sheer number of goods and services produced and consumed in a society became an unsatisfying indicator of economic success. As a result, the distribution of wealth has caught the attention of scholars, politicians and the public.

Since the time the founding father of modern economics, Adam Smith, expressed his point of view on the causes of the (mainly monetary) wealth of nations (Smith 1776), the original focus has been widening. However, the classical welfare yardsticks – which are still the most popular ones – purchasing power and productivity based units, have been extended by alternative ones. Bairoch (1979), for example, was one of the pioneers compiling international comparable GDP estimations. Today, Maddison's (2001) per-capita income estimations along with a great deal of country country case studies serve as a valuable basis for research in economic history. Another monetary based measure in this regard is real wages. Among many others, Allen (2001, 2005) and Williamson (1998, 1999, 2000), provide estimates of purchasing power of wages in global perspective during the past centuries.

Those measures are necessary and important in the context of economic capacity, economic development as well as performance and productivity indicators. During the past several decades, however, a certain number of alternative welfare yardsticks have been introduced. Those offer additional insights and help to close gaps for places and periods for which modern information, particularly purchasing power based measures, are lacking. Particularly development economists and economic historians often face this problem and come back to alternative measures. The Human Development Index (United Nations 2010), for instance, is one approach to capture more aspects of well-being than monetary income. It is calculated on the basis of life expectancy, education as well as income; it is, however, hard to calculate it for historical periods due to data constraints.

For most of the developed countries in the 20th century the investigation of economic affluence and its distribution is a feasible exercise since national statistical offices have provided reliable and comparable statistics. The situation gets more difficult for emerging, developing and transitional countries – not to mention an analysis in historical perspective. To overcome this problem, primarily economic historians have become quite innovative in finding alternative indicators to overcome the lack of reliable and comparable data on well-being and economic inequality.

Among others, scholars have made extensive use of the *biological standard of living* (Komlos 1989) to avoid the above described problem. Richard Steckel's (1995, 2009) summary articles provide a magnificent overview on possibilities, limitations, and recent trends in the field of anthropometrics. This yardstick consists of mean average height (and its distribution) to capture monetary income; but it also emphasizes nutritional and health aspects in a population. This indicator has broadened the spectrum of welfare estimations and has opened up additional possibilities to look at living standards and inequality in a society. It is certainly correlated with purchasing power to some extent (as chapter 2 shows), but captures additional influences on human well-being, such as income from moonlighting, subsistence economy, and public goods due to its output-oriented character.

The central motivation of this thesis is to contribute to the discussion of living standards and the distribution of income in historical perspective. In contrast to the bulk of the existing literature, this thesis makes an attempt to offer some alternative and additional insights by applying athropometric indicators. This measure allows shedding light on periods and places for which conventional data are not available and providing an alternative view on living standards and inequality in the case data are available.

The thesis is structures as follows. Chapter two contributes height trends for 156 countries during the 19th and 20th centuries. This unique dataset contains a great deal of new information, since it is the first dataset that provides historical information on average height development on a global scale in historical perspective. The findings of this chapter suggest that anthropometric living standards were fairly uniform during most of the 19th century. However, heights in Anglo-Saxon settlements were above-average whereas stature in Southeast Asia was below the world average. Beginning in the 1880s, the global height distribution started to change leading to diverging height trends. The so-called 'Western Offshoots' and Western Europe took the pioneering role, soon followed by Eastern European regions. An analysis of the determinants of average height reveals that predominantly high-quality diets, measured by several animal protein proximate variables, as well as a beneficial disease environment, proxied by the infant mortality rate, have a positive influence on average height. According to the findings in this chapter, quality nutrition and disease environment account for a great deal of the height differences between countries. The only significant non-economic influence on stature is lactose intolerance, since it complicates the consumption of milk and reduces its benefits on health.

Chapter three also contributes to the determination of living standards. In contrast to the previous chapter, the focus is put on *state efficiency*, namely the transformation of macroeconomic preconditions, such as labor, physical and human capital, into welfare. In order to accomplish this, the *Data Envelopment Analysis* (DEA) is applied to estimate state efficiency values for 62 countries on a decadal basis between the 1850s and the 1980s. This technique allows using two yardsticks of human well-being at the same time. This broadens the scope and focus of the analysis compared to conventional efficiency analyses. Living standards, the measure for 'success', are quantified by adult male height and per-capita income. It is important to note that this chapter *does not* emphasize welfare in absolute terms, but rather captures the *efficiency* of the economic process which leads to living standards – compared to the given endowments at a time. In a second step the determinants of state efficiency are investigated by applying truncated regression techniques. The results indicate that wars and political unrest have a negative influence on state efficiency. The most important characteristics of 'successful states' in this regard are agricultural specialization, redistribution, and a homogeneous population.

Chapter four links welfare and its distribution within a society. Again, the yardsticks of choice are anthropometric ones. The measure of welfare is average male (adult) height; economic inequality is measured by the corresponding coefficient of height variation (CV). In this chapter it is argued that – apart from any normative normative views – inequality has a negative influence on average welfare. The theory of diminishing returns to income implies that aggregate welfare in a society is maximized if all resources are equally distributed. Otherwise low marginal returns to income among rich strata go along with high returns to income among poor ones. In such a situation, redistributing resources from rich to poor classes may cause increasing average living standards because losses of the rich are more than outweighed by gains of the poor. In this chapter evidence for this mechanism is provided. The results suggest that economic inequality, measured by the coefficient of height variation, exerts a negative influence on average height whereas social spending has the opposite effect.

Chapter five bridges the gap between economic inequality and *Skill Premia*. The latter is another important measure of inequality and it is defined as the wage ratio of skilled to unskilled building workers. Its advantage is its worldwide comparability and historical availability. High skilled laborers are characterized by high human capital, whereas unskilled workers tend to reach only low educational levels. Therefore, to some extent, Skill Premia is a proxy for wage inequalities in general. This chapter extensively discusses anthropometric within-country inequality and shows a correlation between both measures. In a further step, we estimate Skill Premia on the basis of anthropometric inequality during the 19th and 20th centuries.

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2. ON THE IMPORTANCE OF PROTEIN PRODUCTION FOR HUMAN HEALTH AND WELFARE OVER THE PAST TWO CENTURIES, 1810-1989

This Chapter is based on a working paper with the same title written by Prof. Dr. Jörg Baten and myself. The idea was developed jointly. Both the analysis and the writing were done together in equal shares.

2.1 Introduction[1]

Human stature is now a well-established indicator for the biological standard of living, positively correlated as it is, along with good health and longevity, with a nutritious diet.[2] In the 1980s Robert F. Fogel, Richard Steckel, and John Komlos pioneered its use in the field of economic history, and a large body of literature in this and other fields has emerged since (Steckel 2009, Komlos and Baten 2004, Harris 1994). Anthropometric studies of individual countries have made a significant contribution to social-welfare economics over the past several decades, and have in turn served as the basis for a number of collective analyses, in which several such studies are presented and compared (e.g., Steckel and Floud 1997, Komlos and Baten 1998). This is the first attempt, however, to collate the entire body of anthropometric evidence, on a global scale. By providing a comprehensive dataset on a global height developments we are able to emphasize an alternative view of the history of human well-being and a basis for understanding characteristics of well-being with other indicators than purchasing-power related ones such as GDP per capita.

In estimating height trends by world regions each of which comprises several nations, we aim to incorporate the maximum of previously published research. We find that 156 countries can be taken into account.[3] Height estimates are organised and

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[2] The term "biological standard of living" was coined by John Komlos (1989).
One of the rare exceptions to the height-longevity correlation is that of the relatively short, because protein-deprived, Japanese prior to the economic boom of the 1960s; their longevity values were above average thanks to their high valuation of personal hygiene, the importance of which was underscored by health-related instruction in the schools.

[3] All countries with more than 400,000 inhabitants are included for which evidence is available, using 1990 borders, in order to permit comparison with Maddison's 2001 GDP estimates.

analysed on the basis of birth decades wherever possible. However, continuous series are available for only some of these countries. Moreover, the series on individual countries, even some of those that are based on a substantial underlying number of cases, are prone to measurement error, since the the samples' regional and social composition are difficult to ascertain, and may introduce bias. To account for this potential bias, all problematic measurement issues are denoted with dummy variables, and their degree of bias will be carefully analysed.[4] For the estimation of world-region trends, data for a large number of countries is collected, with the result that most measurement errors are cancelled out. This unprecedented compilation project should facilitate further efforts of height analysis, providing as it does a realistic ground for further comparisons. As a main result, we find that regional height levels around the world were fairly uniform throughout most of the 19th century, with two exceptions: above-average levels in Anglo-Saxon settlement regions and below-average levels in Southeast Asia. After 1880, substantial divergences began to differentiate other regions -- making the world population taller, but more unequal.

The second major aim of this study is to shed light on one of the most important issues in anthropometric studies: the determinants of the biological standard of living on a global scale. That a population's average height is in large part a function of the disease environment and the availability of high-protein foodstuffs (chiefly meat and dairy products), and that lactose intolerance could play a role in this regard, is an issue that we consider. The impact of high-quality proteins and calcium on anthropometric values has been described in terms of a bottleneck (Baten 2010). The bottleneck concept implies that other food items necessary for a balanced diet, such as fruits, vegetable or grains, were much more easily available, whereas protein was expensive to produce in densely

[4] The underlying data set will soon be made public as part of the ClioInfra Project, a cooperative effort coordinated by Jan Luiten van Zanden and featuring partners in Utrecht, Amsterdam, Tübingen, and Debrecen. See w*ww.iisg.nl/news/clio-infra.php*

populated areas over most of the period under study. The historical record indicates that humans have always needed large amounts of protein to generate the antibodies needed to fight infectious disease, and today's underdeveloped countries are no exception. Especially milk helps to create antibodies (Grigg 1995). Added to this protein effect is that of the disease environment, which we will measure by means of infant-mortality rates.

We will also compare height trends with national income estimates. Because we consider GDP per capita to be an alternative indicator of biological well-being -- since it is a measure of purchasing power not only of high-quality foodstuffs but also, at least since the last century, medical goods and services -- we exclude it from our set of explanatory variables.

If economists are coming to use height as a valid complement to conventional welfare indicators, this is because it has some specific advantages. A given income level permits the purchase of a given quality as well as quantity of food and medical services, and is thereby correlated with health, which in turn is correlated with height. However, this income-height correlation is not one-to-one, modified as it is by important inputs not traded in the marketplace but provided as public goods, such as infant-nutrition programs and public hospitals, which account for slight deviations between purchasing power-based and height-based measures of biological well-being. Moreover, income fails to account for discrepancies within households. While it cannot account for every potential variable in a given population, the anthropometric approach permits economists and economic historians to capture important aspects of the biological standard of living (Komlos 1985, Steckel 1995), particularly in developing countries, hitherto neglected because reliable data were lacking. The well-known Maddison data set (2001), for example, provides only rough estimates for many such countries prior to 1910. While height is not without its deficiencies as a measure of the standard of living of a given population, it generates insights into global changes, and is particularly valuable as a countercheck as well as a complement to conventional indicators, permitting more reliable results than might otherwise be the case.

Life expectancy is among the many health indicators with which height is positively correlated. The economist Robert F. Fogel - drawing on the research of Waaler (1984), who measured several thousand Norwegian males and then followed them in a longitudinal study - reported in his Nobel Prize lecture (1993) that as late as the 1960s and 1970s a 17.5-cm height deficit meant for a Norwegian male a 71% higher risk of dying in the next period of their life: a staggering difference, especially when one considers that at the time Norway's nutritional ratings were unmatched. Having analysed height data for the birth cohorts of 1860, 1900, and 1950, Baten and Komlos (1998) concluded that every centimetre above and beyond a given population's average height translates into a life-expectancy increase of 1.2 years.[5] Thus a mere half-centimetre deviation from the average is significant, representing as it does six months of life. The correlation between height and longevity is even closer among children (Billewicz and MacGregor 1982, Martorell 1985).

The question of what role genetics, as well as nutrition, may play in determining a given population's average height was often raised in the early years of anthropometric research. It turns out that while genes are a key determinant of an individual's height, when it comes to groups of individuals genetic deviations from the mean cancel each other out. Moreover, there is considerable evidence that it is environmental conditions, not genes, which account for today's height gap between rich and poor populations, including those inhabiting a single nation. Habicht et al. (1974), for example, found that

[5] The third cohort comprises those who have attained adulthood at some point between the 1970s and the present. The authors found any variation in the coefficient among the three cohorts to be negligible.

the height gap between the rich and poor sectors of a less-developed country (LDC), Nigeria, was even wider than that between an LDC's elite and a reference population in the United States.[6] Fiawoo (1979), in his study of Ghana, reached the same conclusion as Habicht, as did Eksmyr (1970), working with data on several Ethiopian ethnic groups, and Graitcer and Gentry (1981), when they considered Egypt, Haiti, and Togo. What is more, the height-distribution percentiles for children from rich families in this last study are in line with those for a rich country, namely the United States. Of course, not all height differentials are due exclusively to environmental conditions: African bushmen and pygmies, for example, spring to mind. While they account for only a small percentage of their respective nations' populations, we will nonetheless test for the magnitude of the genetics factor on a large scale. When we compare world-region dummy variables, with and without explanatory variables, we find that the inclusion of availability of protein availability, disease environment, lactose tolerance, and geography reduces the unobservable world-region differences in height by more than a half.

The paper is organised as follows. After a review of the literature, we will discuss some core methodological issues before moving to the first world region height estimates that cover the last two centuries. Section 4 discusses the height – GDP relationship, and the final section analyzes the determinants of height.

2.2 A selective review of the literature on individual countries and regions

We begin with a selective description of the more prominent studies on which our data set is based. Thanks to the existence of a considerable body of scholarly work, long-term time series are available for a considerable number of countries around the world;

[6] The following review of the literature is based on Moradi and Baten (2005).

however, in other cases the documentation is limited to one or two benchmark years. The availability varies among world regions, but it is safe to say that in the past decade there has been an overall increase. Western Europe and European settlements have been the object of numerous studies, as our long list of references attests, and other world regions of a few (e.g., Floud, Wachter and Gregory 1990, Floud 1994, Baten and Komlos 1998, Steckel and Floud 1997). Costa and Steckel (1997) combined all U.S. studies in a trend estimate that is based on a number of individual studies. More recently, Southern Europe has been added to the data set (A'Hearn 2003, Pesacchi 2008, Martínez-Carrión 1994). Garcia and Quintana-Domeque (2007) and then Hatton and Bray (2010) extended the European data set, and Whitwell, de Souza, and Nicholas (1997) have documented Australia.

Eastern Europe and Central Asia have been given a thorough anthropometric treatment by Mironov (1999, 2004) thanks to a combination of archival and contemporary anthropological data (see also Mironov and A'Hearn 2008). Mironov's estimates of Russian and various other Eastern European height trends provide a valuable overview of this world region, even if Wheatcroft (1999) has offered a different interpretation. As for central Asia, we can draw on the so-called demographic and health surveys (DHS) conducted from the 1980s onward that allow to cover birth decades after the 1940s, whereas it is thanks to anthropologists that we have data for the birth period 1960-89 in Eastern Europe (e.g., Bielicki and Hulanicka 1998, Vignerova and Blaha 1998). Among Komlos' many studies are several on those regions of southeastern Europe that once composed the Habsburg Empire (1985, 1989, 2007). Kopczyński has done likewise for Poland (2006).

For pre-1950 Latin America data on Argentina and Colombia have been provided by Salvatore (1998, 2004), Salvatore and Baten (1998), López-Alonso and Porras (2003), Meisel and Vega (2004a, 2004b), Carson (2005, 2008), and recently Baten and Carson (2010). Brazil, Peru, and Argentina have been recently studied by Baten, Pelger, and Twrdek (2009) and Twrdek and Manzel (2010). In addition, there is scattered information regarding the Indian populations in these and other countries (Bogin and Keep 1998).

India, Asia, the Middle East, and North Africa are only modestly documented. We have access to Indian height data not only for the early 20th century (Guntupalli and Baten 2006) but also for birth cohorts dating as far back as the early 19th century (Brennan, McDonald, and Shlomowitz 1994a, 1994b, 1997, 2000). Although the latter studies are based on labour-migrant heights, and hence not necessarily a representative sample of India, the authors offer persuasive arguments that these heights were equivalent to those of the population as a whole. For Japan we turn to Mosk 1996, Bassino 2006, Shay 1994, and Honda 1997, and for China to Morgan 2006, 2008; Baten and Hira 2008; and Baten, Ma, Morgan, and Wang 2010. The latest of several studies of the two Koreas is one of North Korea by Pak, Schwekendiek, and Kim (2010). As for Southeast Asia, a modest amount of data on this region is available (Vietnam: Bassino and Coclanis 2005; Indonesia: van der Eng 1995, Baten, Stegl, and van der Eng 2009; the Philippines: Murray 2002). The Middle East and North Africa of the late 19th and early 20th centuries have been documented in Stegl and Baten (2009). Data from the Demographic and Health Surveys (DHS) program allow a trend estimate for Turkey and Egypt during the period 1950-89, while the 1970s and 1980s have been the object of a number of anthropological studies.

African height data on freed slaves and military recruits permit a rough estimate for the early 19th century (Eltis 1982, Austin, Baten and van Leeuwen 2010). Eltis (1982) has argued that the height discrepancy between freed slaves and others was negligible, because height was not an important pricing criterion; while slave heights varied from region to region, regional prices did not reflect this variation. Furthermore, any height differences among freed slaves were diminished by Africa's own demand demand for the strongest (and thus presumably the tallest) workers available, because Africa was a labor-scarce world region herself. At the same, there is no evidence that the slave market established anything like the military's minimum-height requirement. A comparison of soldiers' and slaves' height data indicates that the latter do not suffer from significant bias (Austin, Baten, and van Leeuwen 2010). For Africa during the period 1890-1930 a large number of anthropological studies are available: for example, one of two major Kenyan peoples, the Kikuyu and the Massai (Orr and Gilks 1931), as well as recent studies (Moradi 2009a, Austin, Baten, and Moradi 2008). The problem of potential survivor bias in the African DHS data sets, which span the years 1945-89, has been resolved by Moradi (2005).

2.3 Methodological issues

How can we estimate the world height trend over a period spanning nearly two centuries? To compensate for the fact that until the middle of the twentieth century data are scarce for countries where poverty and illiteracy prevailed, we solicited a large number of recent anthropological measurements, with the aim of representing 164 countries, but were obliged to exclude eight for lack of evidence (Table 2.1, appendix).[7] Needless to say, in some cases only a few birth decades are documented, and certain height estimates are compromised by measurement errors. But we have been as accurate as possible under the circumstances, recording height by province whenever possible, and adjusting our calculations to take into account any modifications of national borders. Only certain combinations of countries and birth decades are sufficiently well documented to

[7] Bahrain, Cape Verde, Djibouti, the Palestinian Territory, Qatar, Reunion, the United Arab Emirates, and finally the trio Mayotte, Saint Helena, and Western Sahara (aggregated as in Maddison 2001).

contribute to our estimates for world regions and half centuries; for instance, no evidence is available for the Middle East and North Africa in the early 19th century, in large part because of the absence of precise height measurements in Ottoman Empire military data, the army having categorized each recruit as small, medium, or large -- and barefaced or bearded. In most other world regions, however, army data were available for the early 19th century. The year 1950 marks a turning-point in that from that moment on population censuses, health surveys, and similar sources include data on women -- in fact, considerably more than on men -- because institutions other than the military, particularly those related to the health sciences, begin to take interest in them. The fact that there is a correlation, if not a simple one, between male and female heights is by now beyond dispute (Baten and Murray 1999, Moradi and Guntupalli 2008) and it justifies our substituting one set for another when need be. Objections to this strategy might be raised by those who accept the female- resiliency hypothesis, which holds that for biological reasons the average height of a given female population is more resistant to adverse conditions than is that of their male counterparts. Some evidence of small pre-historic samples supported this hypothesis. However, drawing on the largest height sample available to date, Guntupalli (2005) has gone far to disprove this hypothesis for the last two centuries. Since the vast majority of historical height estimates are for males, we transform all estimates into male equivalents, estimating specific regression equations for each world region in order to account for potential differences (Appendix A.2).

It is reasonable to assume that a teen-age conscript from a malnourished population has yet to reach his maximal height. In such a case we calculate what it will be by applying the method presented in Baten and Komlos (1998).[8] Migrants, evidently not

[8] See the notes to Table 2.1 in the work cited. The authors suggest the following adjustments, derived from Mackeprang's 19th-century-growth studies, for societies in which males in their teens and twenties have yet to achieve their maximal height (as a rule, above 170 cm). Those who were 18 years of age were estimated to have 2.4 cm to go; those age 19 1.7 cm, those age 20 0.9 cm, those age 21 0.4, and finally those age 22

representative of the population into which they were born, are another potential source of bias; in some cases, the possession of skills and money motivate a person to migrate; in others, it is the lack of both that obliges such a move (Stolz and Baten 2010, Humphries and Leunig 2009). Such an ambiguous situation obliged us to generate reasonable adjustments. For example, if we could determine (thanks to data permitting us to compare the average height of migrants with the average height of the source population) the height selectivity of migrants from country A to country B, and if country C was very similar to country A in terms of development, then we adjusted the migrant height of country C by the same centimeter differential as country A migrants displayed, compared to the stayers of this country. However, this adjustment was necessary for only a small fraction of our sample, specifically, a mere 0.7%, out of the 1.5% of our sample observations based on migrant heights. The remaining 0.8% were removed from all regressions.[9]

We have taken great care to identify all the biases that may have been generated by the institutional context -- enlistment in the military, incarceration in prisons, and sale in the slave trade, chiefly -- in which heights were recorded.[10] Voluntary soldier samples were included only if satisfactory statistical methods had been used to eliminate the height bias of truncated samples. As for other potential biases, one way to estimate their possible effect is to regress stature on a full set of birth decade and country dummy variables.

As for those institutional contexts that are specific to certain world regions and time periods, we have included them in a series of bias-analysis regressions, each

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only 0.1 cm. Clearly these estimates are not valid for all populations, since growth in late adolescence is largely a function of the individual's environment, but without such simplification comparison of heights in this age group would be impossible. Moreover, the results presented in Table 2.13 (appendix) indicate that these estimates are generally valid.

[9] We also attempted to derive adult-height estimates from those of children but excluded these results, too, on account of their unreliability.

[10] We also did our best to rid our data set of social, ethnic, and regional biases.

designed to expose a potential bias typical of a given region or time period. For example, we had to rely on prison samples for Latin America and North America in the 19th century (Table 2.3, appendix), whereas for most European countries we could obtain conscript samples, which as a rule entail a broader portion of the social spectrum; and anthropological samples were virtually our sole source for certain world regions.[11]

Self-reported heights are particularly prevalent in industrial countries in the later 20th century. Since, according to a number of studies, male respondents tend to overestimate their own height, we have adopted the corrective recently proposed by Hatton and Bray (2010), and will test its accuracy.

When it comes to data sources for the study of height trends in the Middle East and Africa, there is a drawback of early anthropological surveys -- in that the importance of identifying individuals by birth cohort was not yet understood, because it was assumed that the physical measurements of a given population did not evolve from one decade to the next. The result is that, when dependent on anthropological data, we have been obliged to approximate birth decades, and accept the possibility that a small proportion of those individuals identified as belonging to a given cohort in fact belonged in one of the two adjacent ones. Koepke and Baten (2005, 2008) and Stegl and Baten (2009) succeeded in estimating average heights in such cases by using a large number of studies that reflect in sum the changes over time. It should be noted though that time trends that result from such estimations resemble moving averages in that they smooth out the evolution of height averages. For example, if there was a height decline among a given population during the 1880s but only 70% of the individuals in the data set upon which we draw in order to analyse this decline in fact belonged to the 1880s cohort (the remaining 30% having been born in the previous one), the decline would appear to be smoother than, in

[11] The cutoff criterion for including a world region and a half century was 10% with one notable exception: that of 'aggregated ages', for which we had to estimate the birth decade in which the majority of measured individuals were born; in this case we raised the level to 30%.

fact, it was.

When we regress human stature on a full set of country and birth-decade dummies and on those potential-bias variables, the coefficients of the latter turn out to be insignificant (Table 2.4, appendix). The coefficients are also small in most cases, with the exception of the slave coefficient. But not only is the negative coefficient for slaves (our slave data being limited to early-19th-century Africa) statistically insignificant; the only comparison group consists of military recruits. Thus it may very well be in this special case of slaves that an insufficient amount of data, for the purposes of comparisons, accounts for the large coefficient. For other anthropometric studies, it is a very important result that prisoners and voluntary soldiers did not differ significantly from other height sources, because this had been an issue in many earlier studies.

In the interest of accuracy we also assessed the possible biases of aggregate age, late-adolescent growth, self-reported heights, and migrants with and without adjustment (Table 2.13, appendix). We found these potential biases to be insignificant, with the possible exception of positive coefficients for migrants, underlining the need not only to exclude unadjusted heights but also, by means of dummy variables, to control for any and all other potential biases.[12]

2.4 Estimates of height trends

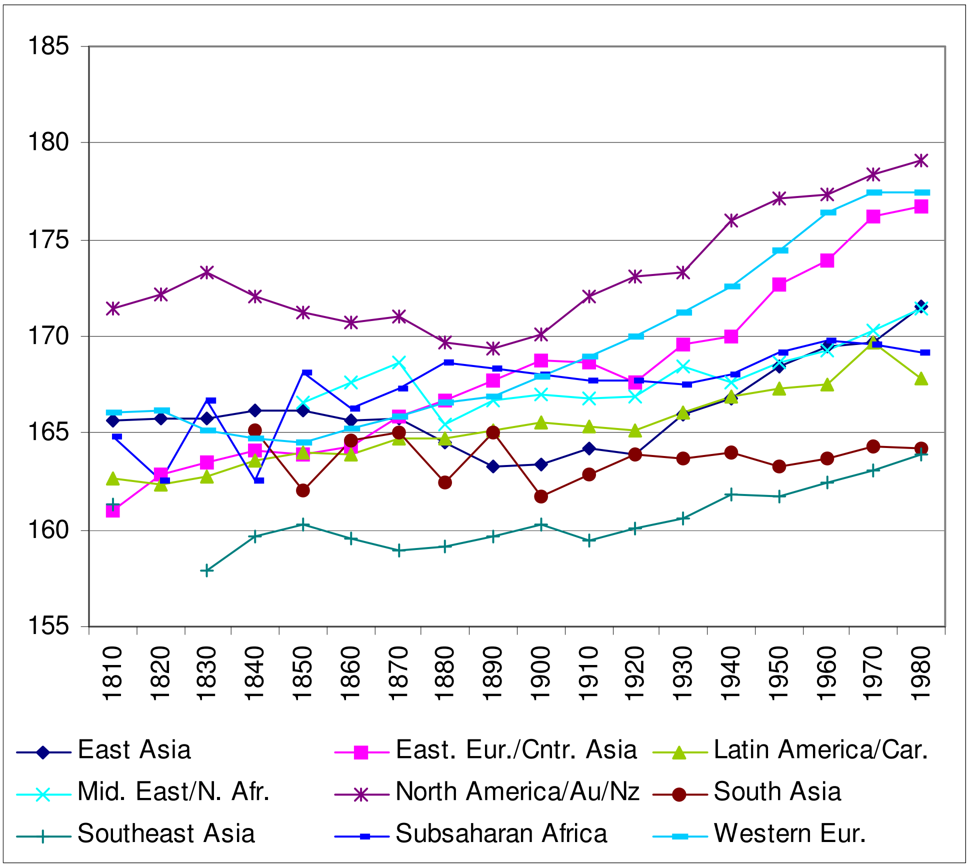
Our estimates of world-region trends for the entire 1810-1989 period are based on the population-weighted averages of 156 countries, without interpolations (Figure 2.1).

We used the standard world-region classifications with one exception: we aggregated the group comprising of North America, Australia, and New Zealand, because

[12] We also created dummy variables for the rare cases that we encountered of significant regional, ethnic, and social selectivity (e.g., workers in South Africa), and include those dummies in our regressions below. By "significant" we mean evidence (derived from more or less contemporary studies) of a one-centimetre (or greater) deviation from the national mean.

of certain demographic similarities (chiefly populations featuring European settlers and high cattle-per-capita values). We observe that this group at first had very high values but that toward the end of the 19th century they declined somewhat, converging with some of the other groups, but resuming their upward trend at the start of the next century. The first wave of globalisation, at the end of the 19th century, was not a boom for the populations of New World food-exporting regions. The shift of high-quality foodstuffs from local to export markets may not have been the only factor; immigration into these regions no doubt caused higher population pressure and changes in agricultural practices which in turn led to a decline in protein consumption per capita.

Figure 2.1: Height development by world region (no interpolations, weighted by population size)



Western Europe came close to their level during the 1950s and 1960s, which hence came to be known as its Golden Age of Western Europe. Eastern Europe and the socialist part of central Asia lagged somewhat behind Western Europe, whereas East Asia did quite well during the early 19th century, only to decline to the level of a middle group, composed of Latin America, Sub-Saharan Africa, and the Middle East. African heights were the only ones to decline during the period 1960-89 (cf. Moradi 2009b). The shortest heights worldwide were to be found in Southeast and South Asia.

However, the world-region estimates using only recorded measurements may be biased if samples are not random for the region in question: that is, if there were variations in the amount of reliable data available for each country in that region. To compensate for any such missing values, we applied the best possible interpolation strategy: whereever possible, we identified a benchmark level estimate for each country that allows obtaining levels that are close to true height values for the country to be interpolated. We then used the variation over time of other, nearby countries with similar characteristics. Linear interpolation was to be avoided, because of the risk that it might obscure certain fluctuations: for instance, declines that occurred in certain countries during the second half of the 19th century. Instead, we opted for backward- and forward-projection techniques, using the country-specific benchmark years and obtaining the changes between benchmark and estimated decades from a similar and neighboring country. For example, the change from the 1870s to the 1880s in Iraq is more similar to the change in Iran over the same period, than one would conclude from the results of a linear interpolation in Iraq between 1870 and 1890. Keeping the height level with the 1870 Iraq benchmark guarantees its accuracy. (The interpolated values are represented by the white cells in Table 2.16 (appendix), with the exception of the Middle East 1810-49 and South Asia 1810-29, for which no reasonable interpolation was possible.) The correlation between world-region trends based exclusively on real-height values and the series that include interpolations is quite close (Figure 2.2, appendix).

We can distinguish several groups of world regions.

(1) The Anglo-Saxon settlements had very high anthropometric values for much of the period under study, not converging with lower ones until the late 19th century, and then only moderately.

(2) Both Western Europe and those countries in Eastern Europe and central Asia that had ever experienced socialist rule recorded a strong upward trend after the 1880s. However, once the Soviet Union came into being the differential between these two regions increased (Komlos 1999, Mironov 2006; it is the latter's estimates that we apply). In contrast, levels in Latin America, the Middle East, and North Africa were at relatively high levels in the 19th century but during the 20th century experienced only modest increases (Salvatore 2004).

(3) East Asia and Sub Saharan Africa remained throughout the entire period near the global average except East Asia during the late 19th century (Figures 2.1 and 2.2). Africa is the only world region in which the average height has steadily declined over the last two decades (Moradi 2005).

(4) Finally, both South and Southeast Asia remained at a low level throughout the period under study. While no upward trend of any significance occurred in South Asia since the end of the 19th century, Southeast Asia experienced a slight upward trend, but at the start its heights were even lower level than were those of its neighbour (Brennan, McDonald and Shlomowitz 1994a, 1994b, 1997, 2000, Guntupalli and Baten 2006, Baten, Stegl and van der Eng 2010). In sum, we find that after the 1880s global heights increased on average, but also became more unequal.

2.5 Height and GDP

Height and GDP are complementary measures of the standard of living. GDP per capita is a measure of a nation's purchasing power, whereas height is more closely correlated with nutrition, health care, and inequality. Their interdependence has initially been stressed in the literature (Fogel et al. 1982), but over the past two decades evidence has emerged indicating that they should be regarded as independent indicators. Significant deviations have been found not only between height and GDP but also between height and real wages for unskilled labour (Margo and Steckel 1983, Komlos 1996). However, these findings are based largely on U.K. and U.S. data, and the correlation between real wages and heights was actually much closer elsewhere (Baten 2000).

A simple scattergram indicates some positive correlation between real GDP per capita and height (the correlation coefficient is 0.64, the p-value 0.00; Figure 2.3, appendix). The bulk of observations is between 160 and 180 cm, indicating that height averages are located in this range throughout the period under study. There being only a few cases at the low end of the scale, between 155 and 160 cm (mostly in Central America and Southeast Asia), and above 180 cm at the high end. Japanese values are exceptional in that they are marked by lower height than expected from GDP. But within Japanese observations there is a positive correlation over time between GDP and height. Deviations on the lower right include three countries of the African Sahel zone (Chad, Burkina Faso, Mali). Deaton (2007) suggests that selective survival of children may account for this deviation, whereas Steckel (2009) argues that the subsistence-level existence of a portion of the population and black-market activity should not be discounted, since they skew national income estimates. Moradi and Baten (2005) argue that local protein consumption was the most likely cause, since poor families unable to sell their protein-rich produce, for lack of a market, end up consuming it themselves. In fact, Chad, Burkina Faso, and Mali are paradigmatic cases of high protein production per capita and low market integration: short on purchasing power, they are nonetheless, thanks to their high-protein diet, relatively tall.

The relatively close overall correspondence between height and GDP – apart from the deviation above which can be explained by local protein consumption patterns -- also serves here as a plausibility-check that the new height estimates are reasonable.

2.6 Determinants of height

2.6.1 Environmental and economic versus biological effects

In the following analysis, we have chosen to focus on what we term "proximate" determinants: protein availability, the disease environment, lactose tolerance, and altitude.[13] In contrast, factors such as productivity, institutional design, income, education, trade, religion and similar variables would be more underlying causes which might determine the proximate ones of disease environment, the consumption of high quality foodstuffs and the lactose tolerance. We did not include the underlying, but the proximate determinants in our analysis. Only civil war and demography were included as more indirect determinants, because we wanted to control for the exceptional situation of civil war, and for the potential inequality effects of political autocracy.

We use panel data comprising exclusively genuine observations (i.e., no interpolations), checking for the existence of unit problems by considering the residuals of our regression by means of the Fisher test (Maddala and Wu 1999), which results in a chi2(112) value 268.63, p-value 0.00. As the null hypothesis of the Fisher test is formulated in such a way that the series are non-stationary, we conclude that there is no unit-root problem.

[13] The most important growth period is the very first (about 3) years in life. Therefore, all variables are arranged by birth decades since they ought to capture influences on height around that crucial time.

We include a range of variables to control for the availability of animal protein per capita, always a bottleneck factor when it comes to human nutrition, because a protein calorie requires a larger input than does a grain calorie (Baten 1999, 2010; for the sources, see Appendix D). In a bivariate graphical analysis of the cross-section of the 1900 birth decade, cattle per capita suggests a positive correlation (Figure 2.4, appendix) -- with

Table 2.5: Determinants of height (panel models)

Which protein indicator	(1) Cattle	(2) Meat	(3) Milk	(4) Cattle	(5) None
Cattle (log p.c.)	0.44* (0.078)			0.63** (0.013)	
Meat (log p.c.)		0.41* (0.067)			
Milk (log p.c.)			0.37*** (0.007)		
Infant mortality	-1.63*** (0.000)	-1.33*** (0.000)	-1.36*** (0.000)		-1.66*** (0.000)
Democracy	0.03 (0.85)				
Mountains	-0.03** (0.034)	-0.05*** (0.009)	-0.07*** (0.002)		
Civil War	0.26 (0.470)				
Time-fixed effects	YES	YES	YES	YES	YES
World region-fixed effects	YES	YES	NO	YES, FE	YES, FE
Constant	171.56*** (0.000)	179.29*** (0.000)	178.90*** (0.000)	162.61*** (0.000)	173.64*** (0.000)
Observations	414	219	200	604	551
Number of countries	76	58	53	103	106
R-squared (within)	0.92	0.88	0.90	0.83	0.91
R-squared (overall)	0.73	0.79	0.60	0.23	0.38

Note: Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10 percent. Estimates in column 1-3 are random effects panel estimates, column 4 and 5 feature fixed effects. Sources: see Data Appendix D.

three modest deviations to the lower right: Argentina, and to a lesser extent Cuba and Madagascar. Argentina's population may have been deprived of protein because the country exported most of its cattle products, and Cuba and Madagascar displayed similar mechanism during the early 20th century at least.[14]

The per capita availability of livestock is a useful protein-related indicator, since cattle is a valuable supplier of both meat and milk. The effect of (log) cattle per capita is positive and significant, of roughly half a centimeter (Table 2.5).

This protein indicator is available for a large number of observations, but because it does not account for productivity per head of cattle we developed a second model that replaces cattle per capita by the annual output of meat per capita, and a third model that permits us to estimate the amount of milk per capita. As a result, we were able to determine that animal-protein availability had a positive impact on height; the coefficient's level is consistently significant. The standard-deviation effect of the milk variable is some 50% higher than those of the cattle and meat variables.

We include the infant mortality rates to control for disease environment (Appendix D). The results confirm our expectations: a problematic disease environment is associated with lower heights, the standard-deviation effect being about twice the size of the protein effect.

Democracy was included to assess the possible effect of political institutions on the distribution of nutrition and health resources: could it be that, say, the biological standard of living in oil-producing countries run by non-democratic governments tends to be lower than in similarly wealthy countries? The coefficient is positive but to an insignificant degree, so the answer would seem to be no. The same conclusion holds for civil war (at least when all of the other variables were included).

Data on lactose tolerance are taken from Ingram et al. (2009) and Flatz (1995). It measures the share of a population (in %) which does not suffer from lactose intolerance. In some countries, cattle stock and milk production go hand in hand while in other places

[14] We experimented with cattle trade share data that might have helped to clarify this issue, but since the data were scanty the results were not decisive, and so they are not presented here.

the focus is mainly on meat production. Therefore, the idea behind this variable is to separate the ability to digest milk (actually the lactose in milk) and the availability of cattle.

A variable whose direct effect has been hypothesised in anthropological studies is the share of mountainous areas in a given region, but a consensus has yet to be reached. For example, Harrison and Schmidt (1989) argued that humans who live at high altitudes (such as Peruvians in the Andes) tend to be relatively short, contradicting previous studies of the Alps, the Scottish Highlands, and the French Jura. If Harrison and Schmidt do not prevail, it could be in part because the disease environment in such regions benefits from underpopulation; in addition, high-altitude Europeans in particular would have benefited from their proximity to protein production (Baten 1999). Having controlled for protein proximity and disease effect, we side with Harrison and Schmidt, although the effect is only slight. Since mountain dwellers in LDCs are relatively poor and mountains reduce agricultural productivity and raise infrastructure costs, economic variables no doubt also contribute to this pattern.

Both protein and the disease environment turned out to be significant, and with the expected signs, when included alone (Table 2.5, Columns 4 and 5). These two columns also include our estimation of fixed effects, reputed to be a particularly rigourous test of statistical relationships. Moreover, fixed effects control for national cultural differences and other forms of unobservable heterogeneity, with the result that the coefficients of protein availability and disease environment are even larger than in the random-effects regressions.[15] The R-squares are somewhat larger in the case of the regression in which the only variable is the disease environment.

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[15] However, the larger number of observations available for those regressions with only one explanatory variable may indicate that countries and time periods other than those in Table 2.5, Columns 1-3, should be included as well.
A joint test of infant mortality and cattle per capita is not possible -- the sample size would be too small to

2.6.2 Autocorrelation structure

Since there is a risk of autocorrelation (despite the fact that unit roots are not a problem) we estimated by means of a panel-data model using feasible GLS, with an AR(1) autocorrelation structure (Table 2.7); the coefficients of the protein-availability indicators

Table 2.7: Determinants of height. Panel data model using feasible GLS, with an AR(1) autocorrelation structure

Which protein indicator	(1) Cattle	(2) Meat	(3) Milk
Cattle (log p.c.)	0.82*** (0.000)		
Meat (log p.c.)		2.99** (0.046)	
Milk (log p.c.)			0.64*** (0.005)
Infant mortality	-1.73*** (0.000)	-1.58*** (0.000)	-0.53 (0.270)
Mountains	-0.04*** (0.000)	-0.06*** (0.000)	-0.05*** (0.000)
Civil War	-0.04 (0.900)		
Time-fixed effects	YES	YES	YES
World region-fixed effects	YES	YES	YES
Constant	182.84*** (0.000)	192.55*** (0.000)	185.01*** (0.000)
Observations	411	213	192
Number of countries	71	52	45
Wald Chi-sq	1052	858	703
p-val. Chi-sq	0.00	0.00	0.00

Note: Standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. Sources: see Data Appendix D.

permit accurate estimates of fixed effects, since they emphasise changes over time as opposed to cross-sectional differences. (Moreover, in all macroeconomic regressions changes over time feature a relatively high measurement-error rate; see Durlauf 2004) proved to be even greater than were those in the models estimated in Table 2.5. The disease environment registers as insignificant on one occasion, in Column 3, on account of the relatively small number of cases for which milk-production estimates were available, but otherwise the results are robust.

2.6.3 Lactose tolerance or protein effect?

We use three proxy indicators for the availability of high-quality protein: cattle per capita, meat consumption, and milk consumption, which is in part a function of lactose tolerance (defined as the ability of those over the age of seven to consume considerable quantities of milk without experiencing digestive problems). In his bold attempt to explain the evolution of capitalism in terms of cattle-raising patterns, Crotty (2001) argued that a largely lactose-intolerant population could not make sufficient use of dairy cattle, since lactose-intolerant adults tend to exclude milk from their children's diets. East Asians (east of Tibet and Rajasthan), American Indians, and certain Africans are prone to lactose intolerance. The situation in southern Europe is ambiguous; one study named Spain among those countries with the lowest intolerance levels (30% or less), another categorised Greece among those countries where the intolerance level is moderate (30-70%), and Italy and Turkey were rated among those with the highest levels (Mace et al. 2003). However, even lactose-intolerant people can digest fermented milk products such as kefir and lassi. Moreover, a lactose-intolerant individual's intestinal bacteria can be gradually modified until they are able to digest a maximum of one cup of milk a day -- more than most economies have been able to provide. In South Korea, where lactose intolerance has long prevailed, milk consumption has increased through such deliberate modification, to the point that it has become a status symbol.[16]

[16] We thank Barry Bogin of the University of Michigan and S. Pak of Seoul National University, for their

There is a systematic correlation between lactose tolerance today and height around 1880 (Figure 2.5, appendix). Papua New Guinea, Vietnam, Indonesia, Congo, and Japan had low height values, whereas in Sweden, Niger, New Zealand, and Denmark both lactose tolerance and average-height levels were at the other end of the scale. The explanation for those countries -- Morocco, Cyprus, Nigeria, and Ethiopia -- where the people tend to be tall but lactose intolerant (and where, not coincidentally, the protein-per-capita rate is quite high) may be that lactose-intolerant adults provide their children with adequate protein from sources other than milk, and perhaps with modest amounts of milk as well. On the other hand, the populations of Yemen, Colombia, and Spain tend to be lactose tolerant but short, perhaps on account of a low overall protein-consumption rate; low cattle-per-capita values during the 19th century help to account for this discrepancy in Yemen and Spain, if not Colombia (Stegl and Baten 2009).

It is relatively easy to determine whether lactose tolerance and protein availability are more influential, since they can be tested directly in a horse-race. In fact, we find that these two variables have exerted an influence on heights during the period under observation (Table 2.8, Column 1). While their coefficients are of roughly similar size, the standard-deviation of lactose tolerance is only one third of the cattle-per-capita variable. But we also need to take into account potential interaction effects. It seems reasonable to assume that the significance of the cattle-per-capita rate in a given population is greater if the parents are lactose tolerant than if they are not. The mean value of log cattle/c is negative (due to absolute values below 1 and the log transformation, see Table 2.6, appendix). If the negative mean is inserted into the estimation formula derived from Model 1 in Table 2.8, the interaction effect becomes positive. This result suggests that the capacity of milk production (cattle) and the ability

observations on this issue.

to consume milk without side effects reinforce each other. Therefore, countries with large cattle stocks and a high percentage of people with the ability to digest lactose end up being taller than a country having only one of the both characteristics.

Table 2.8: Horse race: is there a direct protein effect, lactose intolerance, or an interaction?

	(1)	(2)	(3)
Cattle	1.29*** (0.003)	0.57*** (0.006)	
Lactose tolerance	1.50*** (0.000)		0.66*** (0.000)
Cattle*lactose tolerance	-0.23*** (0.007)		
Infant mortality	-2.46*** (0.000)	-2.66*** (0.000)	-2.24*** (0.000)
Time fixed effects	YES	YES	YES
Constant	167.93*** (0.000)	174.91*** (0.000)	172.56*** (0.000)
N	296	417	357
R-square	0.89	0.88	0.89

Note: Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10 percent. Sources: see Data Appendix D.

2.6.4 Endogeneity

Because lactose tolerance is genetic and hence was generally exogenous during the period under study, the lactose-tolerance variable also allows us to conduct an endogeneity test of the protein- availability variable. Over the long term this variable may be to some degree endogenous, too, since in cattle-producing countries the survival rate of the children of lactose-tolerant individuals would have been relatively high, and hence their genetic makeup would have been passed down through the generations.

Instrumenting cattle per capita with lactose tolerance, we obtain a significantly positive coefficient even larger than the aforementioned cattle coefficients (Table 2.9, appendix), indicating that the protein-availability indicator is probably an exogenous variable. The first stage results documented in the notes below the table indicate that lactose tolerance could be a valid instrument for the potentially endogenous variable cattle per capita.

Between 1870 and 1949 the coefficient is significant. In the period 1950-89, the p-value is 0.12, just short of statistical significance, although it must be cautioned that this calculation is based on only 124 observations.

The disease environment is insignificant in those regressions. One could imagine that the disease environment rate may be endogenous as well. However, since the infant-mortality rate is considered to be the most exogenous among all of the disease-environment indicators, and because good instruments for the disease environment in so many countries are not easily available, we do not instrument it here.

2.6.5 Early and late developments

Thanks to a sufficient number of observations, we could distinguish a middle (1870-1950) and a late (1950-89) period (Table 2.10, appendix).[17] We would expect to find a decline in the importance of local protein production and health advantages during the late period, thanks to the development of refrigeration and other storage methods that would permit an expansion of the international market in both foodstuffs and medical materials.

We find that in the period 1870-1950 both the country-specific output of protein and our disease proxy had a fairly large coefficient, indicating that the effect was greater than during the period 1950-89, when, in fact, the coefficients for both diminished (Table 2.10, Column 3, appendix). However, if we confine our analysis to those countries included in our data for both periods, the apparent effect suggests that the difference of

[17] As for the early period, 1810-70, there was an insufficient number of countries providing all of the explanatory variables to permit accurate analysis.

the protein coefficients might also be a statistical artifact due to the selection process, permitting us to conclude that both variables had a long-term effect.

2.6.6 A lower-bound estimate of the effects of genetic potential, food behavior, intergenerational effects, culture, and other currently unobservable factors

We also included a full set of birth-decade and world-region dummies in most of the aforementioned regressions. The comparison of the latter in regressions with and without explanatory variables permits us to estimate the size of various unobservable characteristics. While the early generations of anthropologists firmly believed in the existence of races (a term later replaced by "genetic potential") today there is a consensus among the leaders in the field that height potential is primarily a function of environmental factors (Bogin 1988).

Secondly, human preferences and behaviour related to food might play a role. Especially in rich industrial societies, the consumption of red meat and other protein-rich foodstuffs seems to stagnate or decline. There are a number of stories about food taboos in poor countries as well, which supposedly caused some ethnicities and religious groups to consume less protein than they could have done. Two of the most famous religious taboos are the Hinduist ban on beef, and the Muslim ban on pork. However, the question is whether those taboos would have a strong effect given that substitution of other protein sources might be possible.

The third possible factor is that of intergenerational size limits. Cole (2003) has argued that Japanese height levels could not quickly catch up with Western ones because of a biological check mechanism on the size of a baby relative to that of the mother. The body prevents the foetus from growing too large, if the birth channel of the mother is not as large. Another intergenerational factor might be dietary habits. For example, dietary habits of migrants may persist in a second generation, even after moving to a new environment with different relative prices; the offspring of migrants from low-protein to high-protein regions may continue to eat the low-protein dishes favoured by their parents.

A final word of caution: just as average income is only a rough indicator of a population's well-being, cattle per capita is only a rough indicator of protein availability, since, thanks to the pressure of the export market, little meat may, in fact, end up in local markets. Perhaps even more important, the output of protein per animal varies.

Those and some other potential unobservable factors should be reflected in world region dummy variables in regressions, after the effect of observable explanatory variables has been removed by including those. We therefore compare two such sets of regressions, that is, one with and the other without explanatory variables. Western Europe is the constant.Among the other world regions, there is a sharp decline in the coefficients if the explanatory variables are included. For example, when differences in cattle per capita, lactose intolerance and similar factors are not controlled for, East Asians' heights are lower by 8.2 cm, but when they are the difference is only 4 cm. We should note that, because measurement error produces a downward bias to coefficient size, the shrinkage of the coefficient may yield a lower-bound estimate of the effect of explanatory variables. Similarly, the coefficients of Latin America, South Asia, and Africa diminished by about 50%, that of Southeast Asia somewhat less. When explanatory variables were controlled for, the Middle East and Eastern European coefficients diminished to the point of insignificance. The region comprising North America, Australia, and New Zealand was characterised by a positive coefficient relative to Western Europe. These results indicate that the explanatory variables proposed in this study reduce the size of world-region coefficients and thereby enlarge our understanding of the causes of global height differences to the same, considerable, degree.

2.7 Conclusion

Drawing on anthropometric information from 156 countries spanning the period 1810-1989, we find that regional height levels around the world were fairly uniform throughout most of the 19th century, with two exceptions: above-average levels in Anglo-Saxon settlement regions and below-average levels in Southeast Asia. After 1880, substantial divergences began to differentiate other regions. We find that most of the anthropometric divergence between today's industrial and developing nations took place after this period. While the impressive height level that the region comprising the Middle East and North Africa had enjoyed prior to that point fell back in relative terms, South and Southeast Asia remained from the outset at the back of the pack. Africa performed surprisingly well during the period 1900-65 but has struggled since. In short, after 1880 the world population became taller on average, but more unequal.

If height trends are any indication (and by now it is beyond doubt that they are), the first wave of globalisation, at the end of the 19th century, was not a boom for the populations of New World food-exporting regions. The shift of high-quality foodstuffs from local to export markets may not have been the only factor; immigration into these regions no doubt caused higher population pressure and changes in agricultural practices which in turn led to a decline in protein consumption per capita.

This study introduced a new data set on heights in 156 countries, which was used to estimate height trends by world region and which will be made publicly available. We found that the major determinants of biological well-being, and hence height, are the quality of nutrition, the rate of lactose tolerance, and the disease environment, whereas geography is a minor one. The role of protein production provided by cattle agriculture plays a crucial role in determining human health and welfare, because this is the variable which can be influenced by human decision-kaing most easily: economies which decided for a high share of cattle and dairying were able to achieve the most advanced levels of welfare and development. In addition, we discovered that lactose intolerance and protein availability -- issues not previously addressed in the literature -- had effects independent of one another, and we found solid evidence that sets in doubt earlier notions, promulgated by the first generation of anthropologists, that fundamental food-related behaviour is a function of genetic constraints. This study thus makes possible for the first time the application of anthropometric estimates to patterns of biological well-being on a global scale. Our results thus constitute a conclusion, but a beginning as well.

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The following list first reports the author's last names with year of publication, then the authors with first names, finally the title of the study. Some additional titles, especially on Europe and North America, were considered in our study for comparison, but as they were considered by previous compilations (such as Costa and Steckel, Hatton and Brey, etc.), they are not cited here for reasons of brevity.

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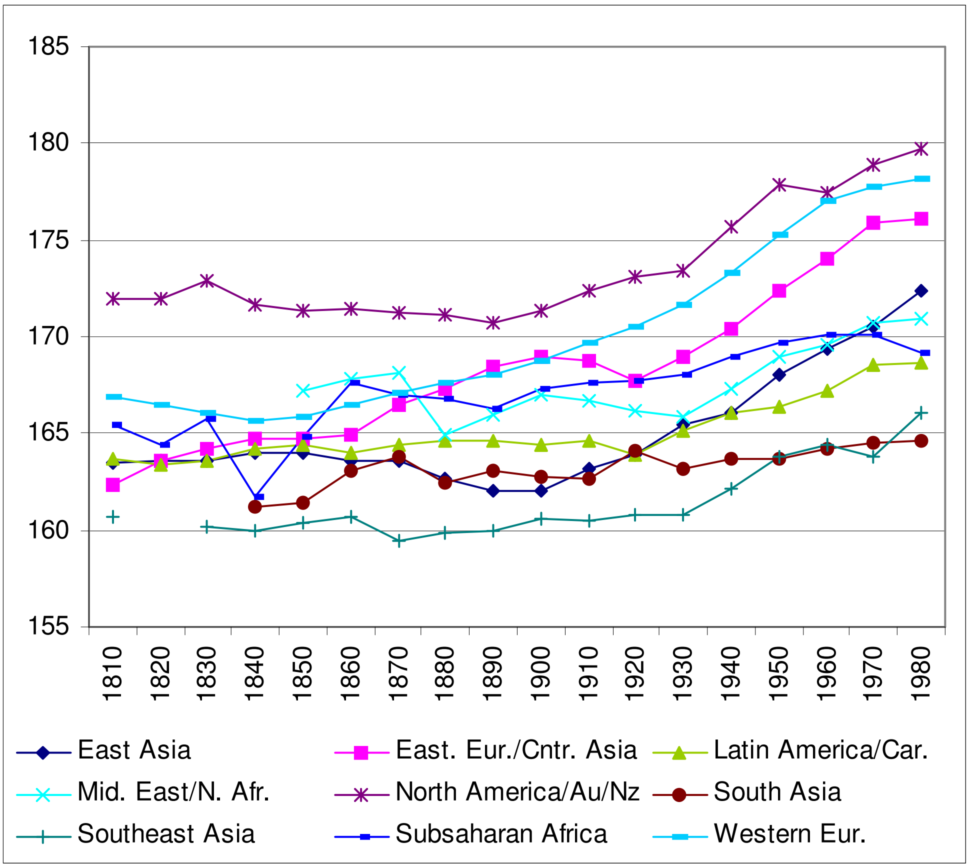
Appendix A.1:

Figure 2.2: Height development by world region (using interpolations, weighted by population size)



Note: Migrant heights are included; see Table 2.1.

Figure 2.3: Correlation between (log) income per capita and height. Sources GDP: Maddison (2001); Heights: see Data Appendix

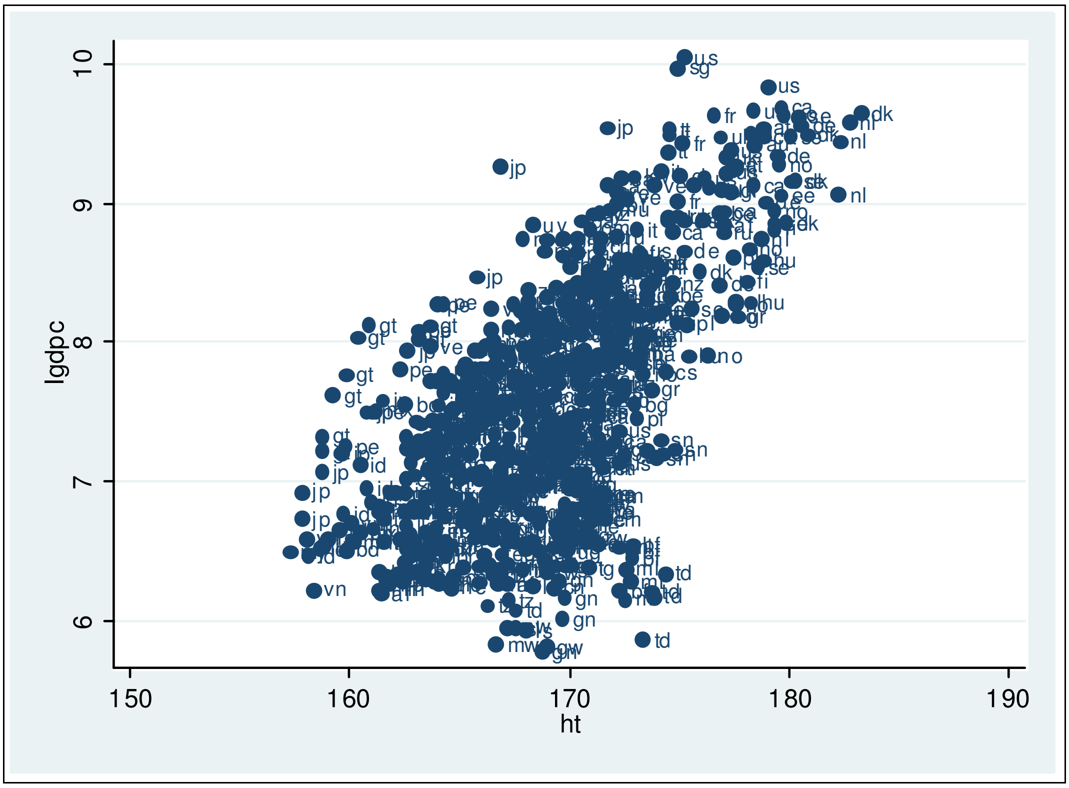


Figure 2.4: Correlation between (log) cattle per capita and height in 1900

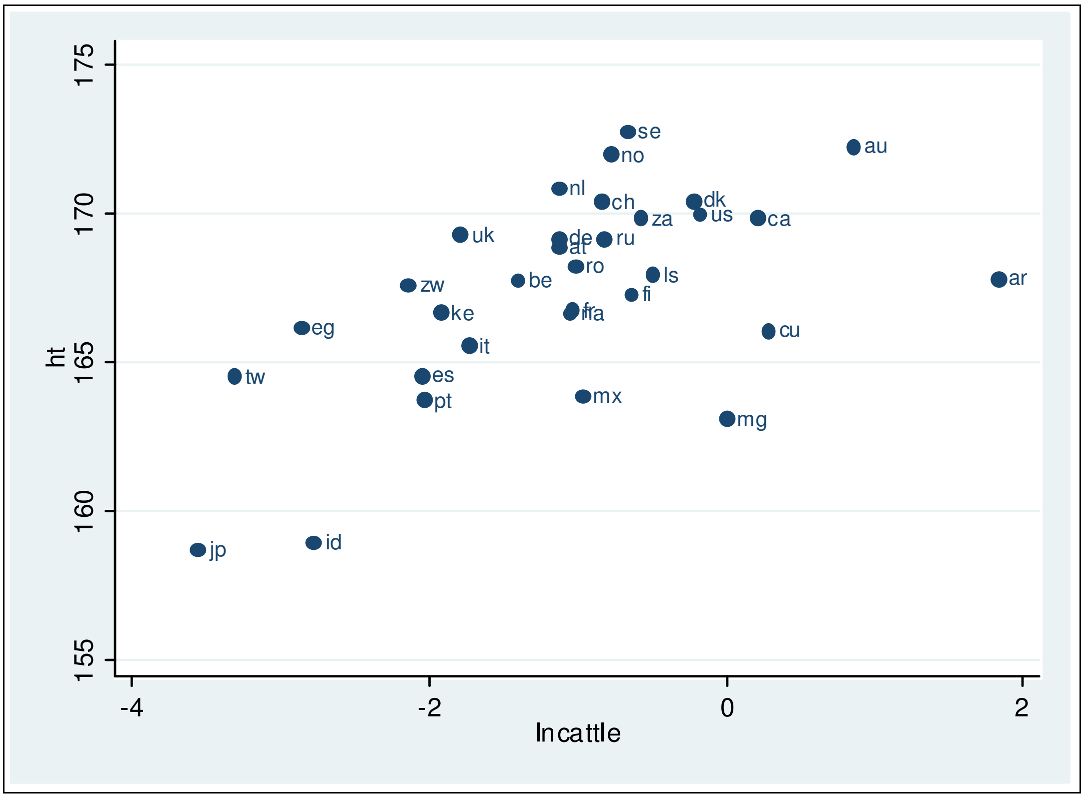


Figure 2.5: Lactose tolerance today and average height around 1880

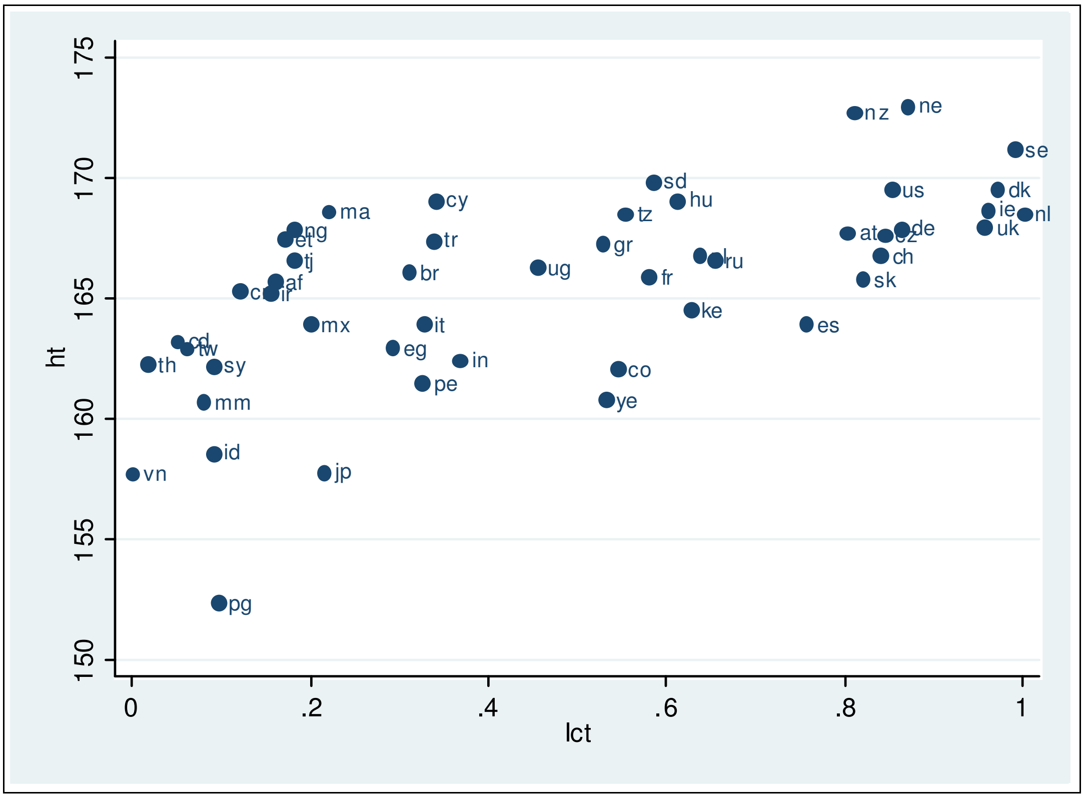


Table 2.1: Number of birth decades documented by country

Country	N	Country	N	Country	N
Afghanistan (af)	3	Germany (de)	18	Norway (no)	18
Albania (al)	3	Ghana (gh)	13	Oman (om)	0
Algeria (dz)	3	Greece (gr)	10	Pakistan (pk)	8
Angola (ao)	7	Guatemala (gt)	8	Palestinian Territory (ps)	0
Argentina (ar)	15	Guinea (gn)	10	Panama (pa)	1
Armenia (am)	9	Guinea-Bissau (gw)	8	Papua New Guinea (pg)	5
Australia (au)	10	Guyana (gy)	5	Paraguay (py)	2
Austria (at)	14	Haiti (ht)	6	Peru (pe)	14
Azerbaijan (az)	6	Honduras (hn)	4	Philippines (ph)	8
Bahrain (bh)	0	Hong Kong (hk)	2	Poland (pl)	12
Bangladesh (bd)	7	Hungary (hu)	11	Portugal (pt)	18
Belarus (by)	3	India (in)	14	Puerto Rico (pr)	5
Belgium (be)	10	Indonesia (id)	16	Qatar (qa)	0
Benin (bj)	8	Iran (ir)	11	Reunion (re)	0
Bolivia (bo)	8	Iraq (iq)	4	Romania (ro)	7
Bosnia and Herzegovina (ba)	0	Ireland (ei)	14	Russian Federation (ru)	18
Botswana (bw)	2	Israel (il)	4	Rwanda (rw)	7
Brazil (br)	18	Italy (it)	18	Saudi Arabia (sa)	4
Bulgaria (bg)	4	Jamaica (jm)	6	Senegal (sn)	13
Burkina Faso (bf)	16	Japan (jp)	11	Serbia and Montenegro (cs)	5
Burundi (bi)	2	Jordan (jo)	5	Sierra Leone (sl)	8
Cambodia (kh)	14	Kazakhstan (kz)	11	Singapore (sg)	1
Cameroon (cm)	13	Kenya (ke)	9	Slovakia (sk)	7
Canada (ca)	18	Korea (North) (kp)	9	Slovenia (si)	4
Cape Verde (cv)	0	Korea (South) (kr)	9	Somalia (so)	6
Central African Republic (cf)	8	Kuwait (kw)	0	South Africa (za)	10
Chad (td)	10	Kyrgyzstan (kg)	9	Spain (es)	16
Chile (cl)	2	Laos (la)	11	Sri Lanka (lk)	3
China (cn)	18	Latvia (lv)	5	Sudan (sd)	7
Colombia (co)	12	Lebanon (lb)	5	Swaziland (sz)	5
Comoros (km)	3	Lesotho (ls)	5	Sweden (se)	16
Congo (cg)	10	Liberia (lr)	7	Switzerland (ch)	9
Costa Rica (cr)	2	Libya (ly)	2	Syria (sy)	5
Cote D'Ivoire (Ivory Coast) (ci)	13	Lithuania (lt)	2	Taiwan (tw)	13
Croatia (Hrvatska) (hr)	12	Macedonia (mk)	4	Tajikistan (tj)	6
Cuba (cu)	7	Madagascar (mg)	8	Tanzania (tz)	11
Cyprus (cy)	4	Malawi (mw)	8	Thailand (th)	8
Czech Republic (cz)	16	Malaysia (my)	6	Togo (tg)	7
Democratic Republic of the Congo (cd)	11	Mali (ml)	12	Trinidad and Tobago (tt)	1
Denmark (dk)	16	Mauritania (mr)	4	Tunisia (tn)	2
Djibouti (dj)	0	Mauritius (mu)	0	Turkey (tr)	13
Dominican Republic (do)	4	Mayotte, Saint Helena, West Sahara (ytsheh)	0	Turkmenistan (tm)	3
East Timor (tp)	1	Mexico (mx)	17	Uganda (ug)	10
Ecuador (ec)	0	Moldova (md)	5	Ukraine (ua)	6
Egypt (eg)	12	Mongolia (mn)	2	United Arab Emirates (ae)	0
El Salvador (sv)	0	Morocco (ma)	6	United Kingdom (uk)	18
Equatorial Guinea (gq)	1	Mozambique (mz)	10	United States (us)	17
Eritrea (er)	3	Myanmar (mm)	9	Uruguay (uy)	2

Estonia (ee)	8	Namibia (na)	7	Uzbekistan (uz)	8
Ethiopia (et)	10	Nepal (np)	8	Venezuela (ve)	6
Finland (fi)	13	Netherlands (nl)	18	Viet Nam (vn)	12
France (fr)	18	New Zealand (Aotearoa) (nz)	5	Yemen (ye)	6
Gabon (ga)	7	Nicaragua (ni)	4	Zambia (zm)	5
Gambia (gm)	1	Niger (ne)	11	Zimbabwe (zw)	6
Georgia (ge)	3	Nigeria (ng)	12		

Note: Migrant heights (unadjusted) were included on the following countries in this Table, but not in the following Tables and Figures, except where noted (in parentheses the number of birth decades: Algeria (2), Armenia(1), Bangladesh (4), Croatia (Hrvatska) (1), Czech Republic (1), India (6), Israel (1), Korea (North) (6), Malawi (1), Mozambique (1), Pakistan (1), Poland (2), Romania (1). Sources: see Data Appendix

Table 2.2: Share of possible birth-decade and coutnry observations covered by real data

	1810-1849	1850-1899	1900-1949	1950-1989
East Asia	0.89	0.94	0.98	0.99
East. Eur./Cntr. Asia	0.62	0.76	0.61	0.59
Latin America/Car.	0.61	0.66	0.79	0.74
Mid. East/N. Afr.	0.00	0.60	0.55	0.61
North America/Au/Nz	0.74	1.00	0.97	0.96
South Asia	0.24	0.95	0.71	0.87
Southeast Asia	0.30	0.94	0.84	0.54
Sub-Saharan Africa	0.19	0.40	0.77	0.86
Western Eur.	0.91	0.96	0.97	0.95

Sources: see Data Appendix. Migrant heights were included in this Table.

Table 2.3: Share of sample measurements taken in prisons by world region and half century

	1810-49	1850-99	1900-49	1950-89
East Asia	0	0	0	0
East. Eur./Cntr. Asia	0	0	0	0
Latin America/Car.	0.813	0.375	0.039	0
Mid. East/N. Afr.	n.a.	0	0	0
North America/Au/Nz	0	0.263	0	0
South Asia	0	0	0	0
Southeast Asia	0	0	0	0
Sub-Saharan Africa	0	0	0	0
Western Eur.	0.020	0	0.014	0

Sources: see Data Appendix

Table 2.4: Potential biases caused by the institutional context of measurement

	(1)	(2)	(3)	(4)
Voluntary soldiers	-0.31 (0.28)			
Women		0.31 (0.47)		
Prisoners			0.82 (0.21)	
Slaves				-2.45 (0.44)
Time-fixed effects	YES	YES	YES	YES
Country-fixed effects	YES	YES	YES	YES
Constant	166.63***	165.04***	163.03***	162.95***
	(0)	(0)	(0)	(0.000010)
N	91	401	416	67
R-square	0.79	0.83	0.90	0.96

Note: Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. The cutoff criterion for including a world region and half century was usually 10%. Only in the case of "aggregated ages," for which we had to estimate the birth decade in which the majority of measured indivduals were born, we resorted to a 30% criterion. The other constant refers to all other observations in which the potential bias does not appear. Sources: see Data Appendix D.

Table 2.6: Descriptive statistics (cases included as in Model 1 of Table 2.5, except milk and meat)

Variable	Obs	Mean	Std. Dev.	Min	Max
Height	414	169.49	4.60	156.00	182.30
Cattle (log)	414	-1.03	1.08	-4.93	2.14
Infant mortality (log)	414	4.54	0.75	1.76	5.76
Democracy	414	6.21	3.84	0.00	10.00
Mountain share	414	17.45	19.14	0.00	82.20
Civil war	414	0.04	0.20	0	1
Meat (log)	219	-10.69	1.03	-14.05	-8.15
Milk (log)	200	-8.98	1.62	-15.58	-5.87
Lactose tolerance	293	0.59	0.31	0	1
Eastern Eur./C Asia	414	0.06	0.24	0	1
Latin America/Car.	414	0.17	0.37	0	1
Middle East/N Afr.	414	0.04	0.19	0	1
North America/Au/Nz	414	0.08	0.27	0	1
Sub-Saharan Africa	414	0.18	0.39	0	1
East Asia	414	0.05	0.21	0	1
South Asia	414	0.00	0.05	0	1
Southeast Asia	414	0.02	0.15	0	1

Sources: see Data Appendix D.

Table 2.9: Cattle instrumented with lactose intolerance

Period	(1) 1810-1989	(2) 1870-1949	(3) 1950-1989
Cattle	3.91*** (0.00033)	2.37** (0.014)	6.42 (0.19)
Infant mortality	0.37 (0.56)	-1.06 (0.38)	2.59 (0.25)
Mountainous	-0.04*** (0.00012)	-0.03** (0.038)	-0.06* (0.070)
Time-fixed effects	YES	YES	YES
Region-fixed effects	YES	YES	YES
Constant	149.70*** (0)	169.90*** (0)	152.39*** (0)
N	296	133	124
R-square	0.69	0.72	0.39

Note: Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. Sources: see Data Appendix The First-stage regression summary statistics are as follows:

Regr.model	Adj. R-sq.	Robust F(1,251)	Prob > F
(1)	0.6381	11.754	0.001
(2)	0.7470	28.227	0.000
(3)	0.6327	1.189	0.278

Table 2.10: Determinants of height, early and late periods (panel data model using feasible GLS, with an AR(1) autocorrelation structure)

	(1)	(2)	(3)	(4)
Which protein indicator	Overall	Early	Late	Late (cases early)
Cattle (log p.c.)	0.81***	1.61***	0.50*	3.78***
	(0.000)	(0.000)	(0.064)	(0.000)
Infant mortality	-1.71***	-3.79***	-0.88	-1.56**
	(0.000)	(0.000)	(0.120)	(0.024)
Mountains	-0.04***	0.00	-0.05***	0.02
	(0.000)	(0.950)	(0.000)	(0.370)
Time-fixed effects	YES	YES	YES	YES
World region-fixed effects	YES	YES	YES	YES
Constant	175.86***	190.03***	181.30***	186.59***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	411	167	186	72
Number of cono	71	37	60	24
Wald Chi-sq	1033	348	568	764
p-val. Chi-sq.	0.00	0.00	0.00	0.00

Note: Standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. Sources: see Data Appendix D.

Table 2.11: Lower-bound estimates of the effects of genetic potentials, food behaviour, intergenerational effects, culture, and other unobservable factors

	Effects of genetics etc. (regr. with explan. var.)	Overall region effect (without expl. var.)
East Asia	-3.97***	-8.22***
	(0.001)	(0.000
East. Eur./Cntr. Asia	0.15	-0.98*
	(0.780)	(0.051)
Latin America/Car.	-4.44***	-8.33***
	(0.000)	(0.000)
Mid. East/N. Afr.	-0.98	-5.98***
	(0.230)	(0.000)
North America/Au/Nz	1.84***	2.71***
	(0.000)	(0.000)
South Asia	-3.83***	-7.16***
	(0.000)	(0.000)
Southeast Asia	-7.54***	-13.11***
	(0.000)	(0.000)
Sub-Saharan Africa	-2.20**	-5.60***
	(0.010)	(0.000)
Western Eur.	Reference	Reference

Note: Included explanatory variables are cattle, infant mortality, mountain, civil war, lactose, birth decade. OLS estimation. Standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. Sources: see Data Appendix D.

Appendix A.2:

Table 2.12: How to estimate male heights on the basis of female height by world region

	Americas	Asia (exc. SE)	Europe	SE Asia/Pacific	Sub-Sah Africa
Female	1.05***	0.94***	0.97***	1.02***	1.11***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	3.63	20.53	16.53*	6.59	-6.72
	(0.740)	(0.370)	(0.061)	(0.370)	(0.120)
Observations	45	13	22	36	38
R-squared	0.88	0.87	0.88	0.92	0.97

Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10 percent. Sources: see Data Appendix

Those regressions are based on the data provided in Gustafson and Lindenfors' (2004), a data set on male and female height, which is currently the standard anthropological data set for this kind of question. For Africa, we relied on the estimates of Moradi (2009b).

Appendix B.1:

Table 2.13: Other potential biases caused by the institutional context of measurement

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Aggregated age	0.13 (0.61)							
Age 18		0.84 (0.16)						
Age 19			-0.64 (0.26)					
Age 20				-0.84 (0.13)				
Age 21					-0.08 (0.92)			
Self-reported						0.52 (0.19)		
Migrant (unadj.)							2.13 (0.15)	
Migrant (adj.)								1.23 (0.21)
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Country fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Constant	161.86*** (0.00)	168.60*** (0.00)	164.92*** (0.00)	175.32*** (0.00)	167.49*** (0.00)	165.70*** (0.00)	177.25*** (0.00)	166.10*** (0.00)
N	1401	396	121	127	121	63	66	66
R-square	0.81	0.89	0.78	0.94	0.79	0.83	0.96	0.94

Standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10% . Sources: see Data Appendix

Appendix C:

How to estimate GDP on the basis of the height data set

The original idea of anthropometric research during the 1980s was to find a proxy indicator for GDP per capita. However, since some prominent countries displayed deviations between height and GDP development, this approach was not actively pursued in the literature afterwards. The correlation coefficients in our global dataset turn out, in fact, to be quite high, encouraging us to use height to estimate GDP ("HtGDP") If GDP estimates for a given country are unavailable, those HtGDPs might provide an indication of the standard of living. Moreover, given the strong demand for instrumental variables, our data set provided may allow for the application of models in which GDP but not HtGDP may be endogenous.

We regressed our height estimates on Maddison's (2001) estimates of log GDP per capita first for all birth decades with sufficient observations (Table 2.15, appendix). We note larger coefficients after 1950. Hence, we used two panels for the periods 1870-1949 and 1950-89. There were two problematic countries, requiring us to exclude them from some of the following calculations: Japan, where the influence of genetic height potentials or intergenerational effects is probably greatest; and Guatemala, because our early height data refer to Indios only. In fact, however, whether or not they are excluded has little if any effect (Table 2.16, Columns 2 and 3, appendix). Similarly, fixed-effects estimation and OLS yield similar results. A marginal, one-centimeter, height increase is somewhat more prevalent in the period 1950-89 than in earlier ones; however, it should be noted that the constant has a lower value.

The fixed-effects regression (Table 2.16, Column 3, appendix) prompts us to recommend the following conversion for the period 1870-1949:

(1) $Ln(GDP) = -10.094 + 0.105 * Height$

For the period after 1950, the formula in Column 4 might be applied; for the period before 1870, formula (3) is our recommendation.

Table 2.14: Height regressed on GDP per capita, for individual birth decades

Birth dec.	Coeff.	p-val.	N	R-sq
1870	0.10***	(0.000)	38	0.38
1880	0.11***	(0.000)	20	0.51
1890	0.12***	(0.000)	25	0.44
1900	0.13***	(0.000)	30	0.48
1910	0.14***	(0.000)	38	0.57
1920	0.11***	(0.000)	28	0.56
1930	0.09***	(0.000)	32	0.46
1940	0.10***	(0.000)	31	0.61
1950	0.12***	(0.000)	75	0.33
1960	0.13***	(0.000)	74	0.44
1970	0.15***	(0.000)	78	0.46
1980	0.15***	(0.000)	79	0.52

Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. Sources: see Data Appendix

Table 2.15: Regressions of log GDP on height

	(1)	(2)	(3)	(4)
Period	1870-1949	1870-1949	1870-1949	1950-1989
Estimation	OLS	FE	FE	OLS
Countries excl.	JP/GT	JP/GT	None	JP/GT
Height	0.119***	0.102***	0.105***	0.143***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-12.384***	-9.615***	-10.094***	-16.717***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	242	242	251	306
R-squared	0.53	0.46	0.47	0.44

Robust standard errors in brackets. *, **, *** refer to significance levels of 1, 5, and 10%. Sources: see Data Appendix

Appendix D: Data Appendix

References for explanatory variables:

Democracy:
Marshall, Monty G., and Jaggers, K.(2008): Polity IV Project: data set. last accessed March 31st, 2010.

Civil War:
data is from the Correlates of War Project, see Singer, J. David and Melvin Small (1972): The Wages of War, 1816-1965: A Statistical Handbook. New York. Or see http://www.correlatesofwar.org last accessed March 31st, 2010.http://www.systemicpeace.org/polity/polity4.htm#top

Mountainous terrain
indicates the percentage of a country's land area coveredby mountains. Source: Collier, Paul and Anke Hoeffler (2004): Greed and grievance in civil war. Oxford Economic Papers. 56(4): 563-595

Infant Mortality and Cattle per Capita:
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World Bank Development Indicators, Washington, DC: Bank, 1994-1995

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Chesnais, J-C. La Transition Demographique. PUF, Paris 1986.
Collver, O. Andrew: Birth Rates in Latin America: New Estimates of Historical Trends and Fluctuations. Berkeley, Calif. : Univ. of Calif., Inst. of Internat. Studies, 1965

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Federico, Giovanni: Feeding the world: an economic history of agriculture, 1800-2000. Princeton University Press, 2005
Hübner's geographisch-statistische Tabellen aller Länder dieser Erde. Wien: Seidel (several years)

Lactose intolerance:
Flatz, Gebhard : The Genetic Polymophism of Intestinal Lactase Activity in Adult Humans; in: Scriver, C.R. et al. (eds.): The Metabolic and Molecular Bases of Inherited Desease, Seventh Edition, Mc Graw-Hill, New York. 1995
Ingram, C.J.E. et al. (2009): Lactose digestion and the evolutionary genetics of lactase persistence, Hum Genetics 124:579–591

Table 2.16: World regions, individual countries, and birth decades: coverage of the data set (colored fields indicate that real data were available and accepted)

wreg	co	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980
ea	cn	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
ea	hk													■	■				
ea	jp								■	■	■	■	■	■	■	■	■	■	■
ea	kp								■	■	■			■	■	■	■	■	■
ea	kr							■	■	■	■				■	■	■	■	■
ea	mn											■		■					
ea	tw					■	■	■	■	■	■	■	■	■	■	■	■	■	
eeu	al								■	■	■								
eeu	am					■	■			■	■	■			■		■	■	■
eeu	az					■	■									■	■	■	■
eeu	ba																		
eeu	bg								■					■	■	■			
eeu	by				■						■								■
eeu	cs					■		■	■	■							■		
eeu	cz	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	
eeu	ee				■			■		■	■	■					■	■	■
eeu	ge				■		■			■									
eeu	hr	■	■	■	■	■	■	■	■		■			■		■	■		
eeu	hu	■	■	■	■	■	■	■	■							■	■	■	
eeu	kg								■	■	■	■	■	■		■	■	■	
eeu	kz				■	■		■		■	■	■	■	■		■	■	■	
eeu	lt				■										■				
eeu	lv				■				■	■	■				■				
eeu	md				■											■	■	■	■
eeu	mk										■	■	■	■					
eeu	pl				■		■	■	■	■	■	■		■	■	■	■		■
eeu	ro				■	■	■	■	■		■				■				
eeu	ru	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
eeu	si							■					■			■		■	
eeu	sk					■	■	■	■				■	■	■				
eeu	tj						■	■	■	■	■	■							
eeu	tm									■		■	■						
eeu	ua		■	■	■	■		■	■										
eeu	uz									■	■	■	■		■	■	■	■	
lac	ar	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
lac	bo									■	■			■	■	■	■	■	■
lac	br	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
lac	cl															■			■
lac	co							■	■	■	■	■	■	■	■	■	■	■	■
lac	cr														■				■
lac	cu							■	■	■	■	■			■	■			
lac	do														■	■	■	■	
lac	ec																		
lac	gt									■		■	■	■		■	■	■	■
lac	gy								■	■	■							■	■
lac	hn															■	■	■	■
lac	ht												■	■		■	■	■	■


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wee	**nl**							
wee	**no**							
wee	**pt**							
wee	**se**							
wee	**uk**							

Note: Migrant heights (unadjusted), with the number of birth decades in parentheses, in the following countries: Algeria (2), Armenia (1), Bangladesh (4), Croatia (Hrvatska) (1), Czech Republic (1), India (6), Israel (1), Korea (North) (6), Malawi (1), Mozambique (1), Pakistan (1), Poland (2), Romania (1). Sources: see Data Appendix. Abbreviations see Table 2.1 in Appendix A.1. wwe = Western Europe; eeu = Eastern Europe/ Central Asia; men = Middle East / North Africa; ssa = Sub-Saharan Africa; sea = South-East Asia; sa = South Asia; ea = East Asia; naa = United States, Canada, Australia, New Zealand; lac = Latin America and the Caribbean.

3. ON THE CHARACTERISTICS OF A SUCCESSFUL STATE: STATE EFFICIENCY BETWEEN THE 1850s AND THE 1980s. A DATA ENVELOPMENT APPROACH.

This Chapter is based on a working paper with the same title. It has been written together with Dominic Behle and Luis Huergo. Dominic Behle and I developed the idea. Luis Huergo implemented the bootstrapping algorithm and provided methodological input. The analysis and the writing were equally shared between me and Dominic Behle.

3.1 Introduction

Governments nowadays strongly intervene in their country's economic activity and exert a strong influence on the welfare of their populations. During the course of the twentieth century, public spending ratios increased in many countries, reaching levels of around 40% in the European Union (Joumard, Kongsrud, Nam and Price 2003). Among others, this includes investments in social spending, health care systems, and education. The huge amounts that are spent by governments and the strong influence they exert on the whole economy point out that it is a question of central political importance that governments use their resources in an efficient manner to enhance the prosperity of the people. One of the reasons for the low welfare level in many developing countries, even in those that have rich natural endowments, can be traced back to bad governance (Sachs and Warner 2001, Gylfason 2001) or a state's efficiency in general.

The empirical literature on state efficiency is concerned with several questions. The first one refers to the development and the use of comparable indices. The most conventional approach are GDP-estimations, however others, especially economic historians and development economists, have noted the limitations of such indicators and have become quite innovative in finding alternatives, e.g. anthropometric indicators such as height, weight or mortality. Another branch of research tries to categorize countries according to their welfare regimes (Herrmann, Tausch, Heshmati and Bajalan 2008). The idea behind this approach is to distinguish between different kinds of social states, e.g. the Scandinavian Model versus the models of the new EU member states, using a factor analysis or index number approach. Studies employing this methodology combine different outcome variables into few numbers to distinguish between countries and systems. Denmark and Ireland, for example, have high expenditure for housing as a direct action against social exclusion, while the Netherlands show low state expenditure on social security systems but high individual expenditure on insurances.

A third field of literature is concerned with the measurement of efficiency of governments and institutions. Good institutions (or government) are defined according to theoretical considerations or factors that were found to foster economic growth. Examples of such institutions are protection of property rights, the degree of democracy, the rule of law or a market economy (Kaufmann, Kraay and Mastruzzi 2008, Kaufmann and Kraay 2008). This literature also tries to identify factors that lead to better institutions. In this regard, Kaufmann, Kraay and Mastruzzi (2008) find that ethnic heterogeneity, a more socialist regime or centralized religions, such as Catholicism or the Islam, lead to worse institutions.

The approach which we will follow here calculates state efficiency by estimating the relationship between a country's preconditions (or 'inputs') and the actual welfare outcome ('output'). The higher the amount of output a country achieves given a constant quantity of inputs the more successful a country is considered in terms of (state) efficiency. The rational behind this idea is not only to take into account the money spent on welfare or the achieved average welfare level, but to look at the *process involved in converting inputs into outputs*. In other words: we neither measure general welfare nor answer the question which country was the wealthiest, but we investigate which countries used their available resources reasonably (efficiently) and which did not.

The question concerning state efficiency is of central importance because a more efficient use of endowments releases resources that can be used elsewhere in order to increase welfare. The European Union is strongly encouraging performance comparisons between its member states hoping that the negative results of some countries will motivate them to find ways to increase their performance (see Pochet 2005 for more information on the so called Open Market Competition method). Some studies cover the OECD countries after 1990; only a few studies look at developing countries (Rayp and Van de Sijpe 2007) or historical periods, particularly due to data limitations (Henderson and Zelenyuk (2007) go back until 1965).

There are two possible ways to estimate state efficiency. One possibility is by regressing a welfare indicator on its determinants and evaluating the residuals. Positive residuals indicate high governmental efficiency, while negative residuals show low levels of efficiency (WHO 1999). The second approach, which is applied in this paper, uses non-parametric frontier models to estimate efficiency with multiple outputs (see Afonso, Schuknecht and Tanzi 2008 for an example). This paper expands the existing empirical literature by going back further in time to the period before the onset of the modern social security systems. This is one central contribution of this paper to the debate on the development of government performance and its determinants. We calculate efficiency values for 62 countries between the 1850s and the 1980s on a decadal basis in order to get an impression of how state efficiency evolved over time. For more modern times, we are also able to include some countries that are not taken into account by the existing literature, like former African and Asian colonies along with Latin American countries during the 20th century.

After estimating state efficiency with frontier models (the Data Envelopment Analysis or 'DEA') in a first step, we identify determinants of state efficiency using regression techniques. Simar and Wilson (2007) show that conventional approaches are not valid due to the bounded nature of the efficiency scores (they cannot increase over 100%). To overcome this problem they propose a bootstrapping-algorithm which leads to consistent results. By employing their approach here, we are able to provide reliable regression results. This has only rarely been the case in the literature so far, as pointed out by Simar and Wilson (2007).[18]

The paper is structured as follows. Section 3.2 explains the methodology in more detail. Section 3.3 discusses the choice and sources of the variables that are useed as inputs and outputs in the first stage. Section 3.4 shows long-run state efficiency developments in a global and comparable perspective. In section 3.5 the factors supposedly affecting government efficiency are discussed while section 3.6 tests these hypotheses empirically. Section 7 concludes.

3.2 Methodology

Most authors who aim at measuring state efficiency usually regress output - e.g. life expectancy - on its determinants (e.g. GDP/c; see Gerring, Thacker, Enikolopov and Arévalo 2008). The resulting residuals of these regressions can be interpreted as efficiency. However, in this case the most significant disadvantage is that the measurement of 'success' is restricted on one single yardstick. The Data Envelopment Analysis (DEA) overcomes this problem and allows the inclusion of multiple inputs in combination with multiple outputs.

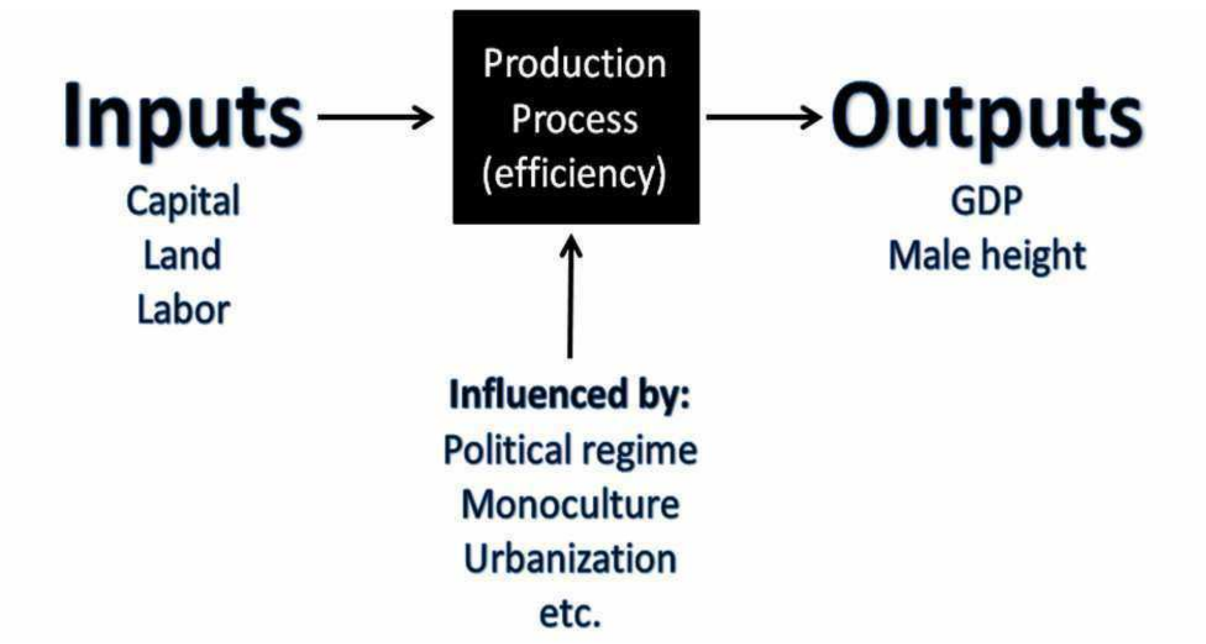
The DEA is a flexible method which requires only a few assumptions about the production process and can handle inputs and outputs without having to consider their price. Therefore, we are able to use several outcome variables and reduce the risk of obtaining results that depend on the choice of one single outcome variable. We take two measures of welfare into consideration, namely a GDP-oriented and an anthropometric one. We first use the DEA to estimate the efficiency of the welfare production process – including its institutional, economic and social structures – of several countries over time.

[18] See Appendix B for details on the bootstrap.

In the second stage, we use regression analyses to assess the determinants of the measured efficiency (see Figure 3.1). To avoid biases due to the truncated character of the distribution of our efficiency values, we apply truncated regressions as suggested by Simar and Wilson (2007).

The DEA assumes the existence of a concave production frontier, which serves as an evaluation reference for all observations (country-time combinations; called 'decision-making units' or ‘DMU’). It is important to note that the DEA offers the choice between two different estimation techniques.

Figure 3.1: the model setup



The first one is based on the assumption that - ceteris paribus - every additional unit of input increases the output level at the same pace. The second one - which we apply - recognizes the law of diminishing marginal returns to inputs and allows for variable returns to scale, so that additional inputs might increase the output at a diminishing rate. In the case of a welfare-producing process, the first unit of input (e.g. capital, land) has a larger positive impact than the second one (see Fernald 1999); therefore we will employ a variable returns to scale model.

We do not have to specify a functional form between inputs and outputs a priori, which reduces the risk of getting spurious results which rely on the assumed production function. It is possible to specify the DEA models from an input- and an output-oriented perspective. In an input-oriented model, the efficiency score describes the proportion by which the inputs have to be reduced so that the DMU is located on the efficiency frontier. In the output-oriented model, the score describes the proportions by which the outputs have to be increased to reach the frontier.[19] The production frontier consists of the most efficient observations and can be interpreted as the highest output possible given a certain input level. Since we investigate internal processes of countries which influence its outputs at a given number of inputs, it is useful to apply the output-oriented model.

One basic DEA-model for n DMUs can be represented by the following linear program (Cooper, Seiford and Tone 2006).

$$\max_{\mu,v} \theta = \mu_1 y_{1o} + \ldots + \mu_s y_{so}$$

subject to

$$v_{1o} x_{1o} + .. + v_m x_{mo} = 1$$
$$\mu_1 y_{1j} + \ldots + \mu_s y_{sj} \leq v_1 x_{1j} + \ldots + v_m x_{mj} \ (j = 1, \ldots, n)$$
$$v_1, v_2, \ldots, v_m \geq 0$$
$$\mu_1, \mu_2, \ldots, \mu_s \geq 0$$

where θ denotes the efficiency score, μ refers to the weights for the s outputs, and y the corresponding output; v describes the weights for the m inputs, while x indicates the inputs.

[19] The two models produce identical results if constant returns to scale are assumed, while for variable returns to scale the results may differ.

DEA estimates are often biased upwards, as missing DMUs sometimes lower the production frontier and therefore the efficiency scores of the other DMUs are higher than they would be without missing observations (see Simar and Wilson 2000). Additionally, as each efficiency score depends on the other observations included into the analysis, the error terms for any second stage regression are correlated. While the regression is still consistent, standard errors no longer decrease at the normal rate of $\sqrt{n}$, but at a much slower rate instead. Therefore, standard regression approaches with few observations are not reliable.[20] We deal with this problem by using the bootstrapping algorithm proposed by Simar and Wilson (2007).[21] They suggest using a parametric bootstrapping algorithm in the truncated regression model and show that this procedure leads to more reliable results than the Tobit approach that is commonly employed in the literature.

Ravallion (2005) raises a number of concerns about the existing literature. For example, the reasons for the choice of variables for the first or second stage are often not clear. We discuss the variables included in our analysis and the idea behind their inclusion below. It is also claimed that an insufficient number of observations may cause erroneous results. Using only few inputs and two representative outputs in the first stage (which gives us a comparably large number of observations) and the bootstrapping procedure in the second stage allows us to tackle this problem effectively.

There are two possible alternatives to the DEA model (see Coelli et al 1998 and Rayp and Van de Sijpe 2007). The first is the stochastic frontier (SF) model that allows for noise. In DEA, any deviation from the production frontier is considered as inefficiency, so the scores are vulnerable to measurement errors. Even though this is an

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[20] Simar and Wilson (2007) show the rate as $n^{\frac{-2}{(p+q+1)}}$, where p is the number of inputs and q the number of outputs. Even in a small model with 3 inputs and 2 outputs the rate is $n^{-\frac{1}{3}}$, which decreases with more variables being added.

[21] Estimations are performed using R and the FEAR package by Paul W. Wilson.

issue when applying the technique to historical data, the advantages of the DEA outweigh this disadvantage. The SF only outperforms the DEA when the assumed functional form is close to the actual one. Unfortunately, we could only guess the functional form of the (SF-)production function between inputs and outputs which made it unlikely to obtain reliable results.

The second best alternative is the free disposal hull model (FDH, see Deprins, Simar and Tuskens 1984 who introduced this technique), which uses only existing DMUs to evaluate the present observation. In contrast to this approach, the DEA uses the entire frontier including linear combinations of existing DMUs in order to close gaps and provide a consistent and straight efficiency frontier.[22] There is no reason for the assumption that only some levels of welfare are attainable while others in between are not. Welfare usually increases gradually and does not jump from one level to another. Several scholars who simulated and experimented with the existing techniques proposed the use of the Data Envelopment Analysis (Cooper and Tone 1997, Resti 2000, Banker, Chang and Cooper 2004).

3.3 Data

3.3.1 Macroeconomic input measures

Every single component of an economy can be classified and aggregated into three categories (Feenstra 2010): capital - including physical and human capital (Mankiw, Romer and Weil 1992) – labor, and land. These are the resources a country's economy has to deal with and it is the efficient use of them what makes an economy successful. We apply this scheme in the following analysis.

[22] If we observe country A with a life expectancy of 76 years and a GDP of 12000 $ and country B with a life expectancy of 68 years and a GDP of 11000 $, a linear combination could be for example country C with a life expectancy of 72 years and a GDP of 11500 $.

Particularly in earlier periods, one of the most important factors of production is the area of arable land. Mitchell (1993) provides information on arable land used for the cultivation of crops. Furthermore, he offers information on the number of livestock available by country and year. Both are elementary components of an economy's primary sector and are therefore included in the analysis.[23] The latter serves as a proxy for farmland used for the production of animal products (Moradi and Baten 2005, Moradi 2005, Koepke and Baten 2008). This is an essential complement to Mitchell's arable land estimations, since livestock is a valuable supplier of animal proteins. In the course of economic development, the consumption of animal proteins increases leading to improved nutrition and taller adult stature (Grigg 1995, Steckel 1995). In the case of land abundant countries, the export of animal proteins may even enable economic growth in terms of per-capita GDP (Jonsson 1998, Salvatore 2004).

Moreover, we use Baier, Dwyer and Tamura's (2007) estimates of real physical capital stock in the analysis.[24] In their study they apply the perpetual inventory on investment rates in order to estimate the stock of physical capital per worker. They provide estimations on capital endowment on a decadal basis for 155 modern countries starting as early as 1830.[25]

Data on human capital also stem from Baier, Dwyer and Tamura (2007). We use their measure of human capital (per worker) because of its broad and comprehensive character. It covers both education in schools, universities, and working experience. The latter is an important source of practical knowledge which is often neglected by the literature. They measure the actual stock of human capital in the population by decade

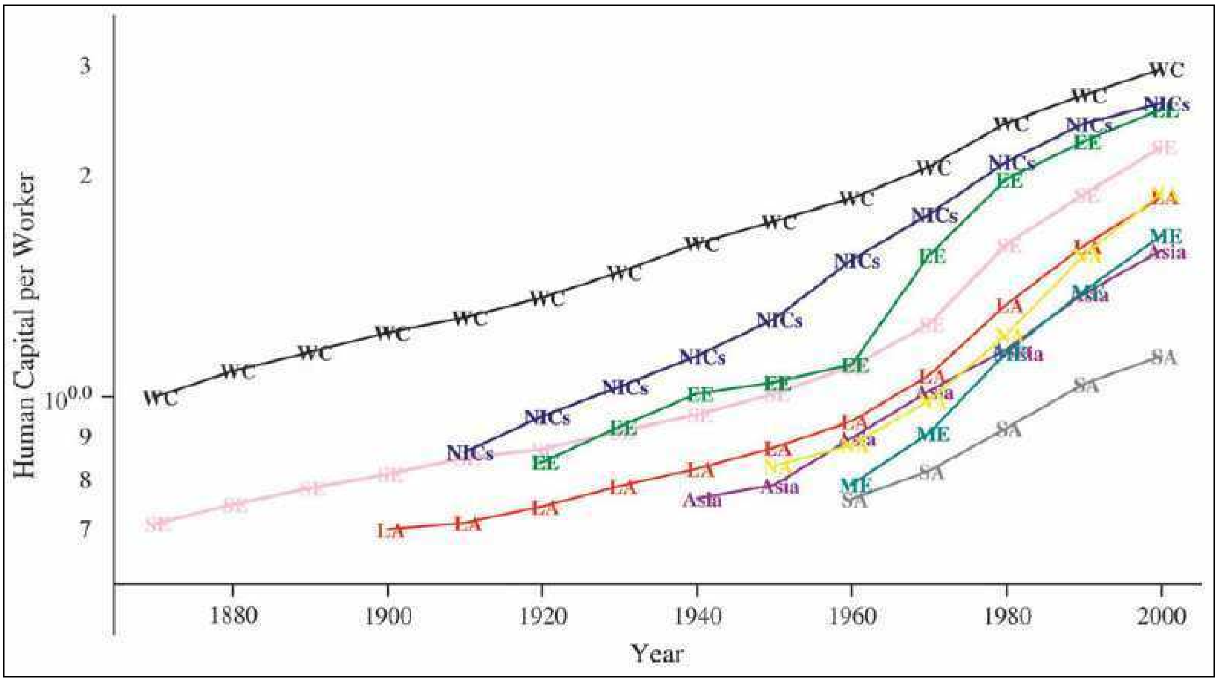
[23] Data come from Mitchell (1993) as well as Baten and Blum (2010) who compiled additional statistics on cattle stocks.

[24] They use Purchasing Power Parities exchange rates from Summers and Heston (1994) to convert the estimates into international dollars, see their footnote 3.

[25] A comparison of Baier, Dwyer and Tamura's (2007) estimates with possible alternatives can be found in Appendix C.

and do not only look at those currently being in education. By including both of these measures, Baier, Dwyer and Tamura (2007) avoid one problem that sometimes appears when using basic indicators like school enrollment rates. The values of these yardsticks are often limited to 100 per cent which leads to insufficient increases in human capital estimations during advanced development stages. Figure 3.2 shows that even during the second half of the 20th century, human capital values are still rising without being limited by an upper bound. Our panel consists mainly of developed countries, whose populations have already reached a certain level on human capital.

Figure 3.2: Human Capital Development by regions



Source: Baier, Dwyer, Tamura (2006), Figure 5.

In a last step before running the analysis, we need to qualify all of the above mentioned endowments by including the current number of inhabitants of each country (The World Bank 1999, Maddison 2001). Only by including information on the size of the population we are able to compare international data. Hence, livestock, capital, and arable land are always expressed in per capita figures.

A common concern in this discussion is the direction of causation (Holtz-Eakin 1994, p.13). He states that the positive correlation between the prosperity of a state and its investments in public capital might occur just because rich countries are able to invest and poor countries are not. In this study this problem does not play a role, since we analyze the quality of governance at any given instant and do not make statements about its inter-temporal role or its influence on future development.[26]

Another concern might be the inter-temporal effects of changing preconditions. The DEA is only able to compare observations without considering possible inter-temporal relations. For example, it is reasonable to question if increasing investments in capital stock immediately result in rising welfare or whether a change in endowments can only influences a country's future welfare. In such a case, today's investments downward biased today's efficiency because they do not lead to improving outputs immediately but with a lag. The fact that all our variables are calculated on a decadal basis allows ruling out such biases at least in the short to medium run, since returns with lags (up to ten years) are still captured.

3.3.2 Macroeconomic output measures

One advantage of the DEA methodology is the possibility to define more than one target variable. In this paper, we want to measure a country's success and therefore need one or more proxies that can perform this task. Probably the most popular measure of a successful (economic) policy is national income. In absolute terms, it indicates a nation's economic weight and power. As a per-capita-measure, it serves as an indicator for the level of economic development; it is a way to make reasonable comparisons between

[26] We also included time-fixed effects to control for path dependence.

countries that vary in size. In order to allow an international and inter-temporal comparison we use Maddison's (2001) GDP/c estimates as one target variable.[27]

Since there are a number of periods in the history of mankind that make clear that measures based on purchasing power do not fully describe a population's welfare and GDP per capita values do not necessarily mean a high standard of living, we need an alternative measure of human well-being. Among others, Sen (1999) and Haq (1995) argue convincingly that only focusing on economic growth and material well-being might be too narrow. In this sense, Inglehart et al. (2008) state that economic development is only one element of happiness. Since the use of the corresponding measures - happiness or the Human Development Index - is rather problematic in historical perspective due to its limited availability, we have to apply another alternative yardstick to measure human well-being. Several scholars have highlighted that adult stature serves as an excellent indicator of this kind (Komlos 1985, Steckel 1995, 2009, Baten 1999, Komlos and Baten 2004). Among others, the *Biological Standard of Living* is correlated with high-quality nutrition (positively) and the disease environment (negatively). One of the most prominent examples can be found in 20th-century Germany. In order to get prepared for war, Nazi-Germany increased its military expenditures at the expense of public health measures. In addition, food imports were impended and prices partly under state control. Baten and Wagner (2003) report that during this period, particularly in highly developed urban areas and coastal regions in northern Germany, heights decreased due to their dependence on foreign trade. Height values for this study are adopted from a recent study by Baten and Blum (2010).[28]

27 As our model allows for variable returns to scale it is not necessary to use GDP in logs.

28 We prefer to use male heights, since they are widely available due to conscription, convict lists and anthropological surveys.

Including both monetary and anthropometric measures as our target variables and applying the DEA methodology enables us to evaluate the success or failure of a country's economic policy.

3.4 Results – the development of government performance

In general, state efficiency was increasing during the period under observation among industrialized countries. Figures 3.3, 3.4 and 3.5 give an overview of state efficiency trends in selected countries, other trends are shown in the appendix. The efficiency trends of some countries were interrupted by exceptional events like crises or wars.[29] Latin American as well as African countries experienced a continuous decline during the 20th century. A closer look reveals that Latin America (including the Caribbean) shows a relatively uniform picture. The most successful country seems to be Haiti, reaching 100 percent efficiency thoroughly between the 1950s and 1980s. Haiti was certainly among the poorest countries; however, given the even lower endowments of physical and human capital, its state efficiency was surprisingly good. Other countries in this region were at best stagnating. Mexico's state efficiency decreased after the 1920s. This is true even after the Mexican civil war ended, probably due to the ongoing interior conflicts and the Great Depression. Only after the 1940s Mexico managed to stop this downfall. Peru appears to be very successful until the 1930s. Not even the Colombian-Peruvian War in 1932-33 changed the exemplary figures. Peru's decline of state efficiency started in the 1950s after the military coup in 1947. Until the 1960s, it stagnated on a lower level but dropped tremendously in the 1970s and 1980s after the junta took over and conducted economic experiments, such as the nationalization of Peru's oil deposits.

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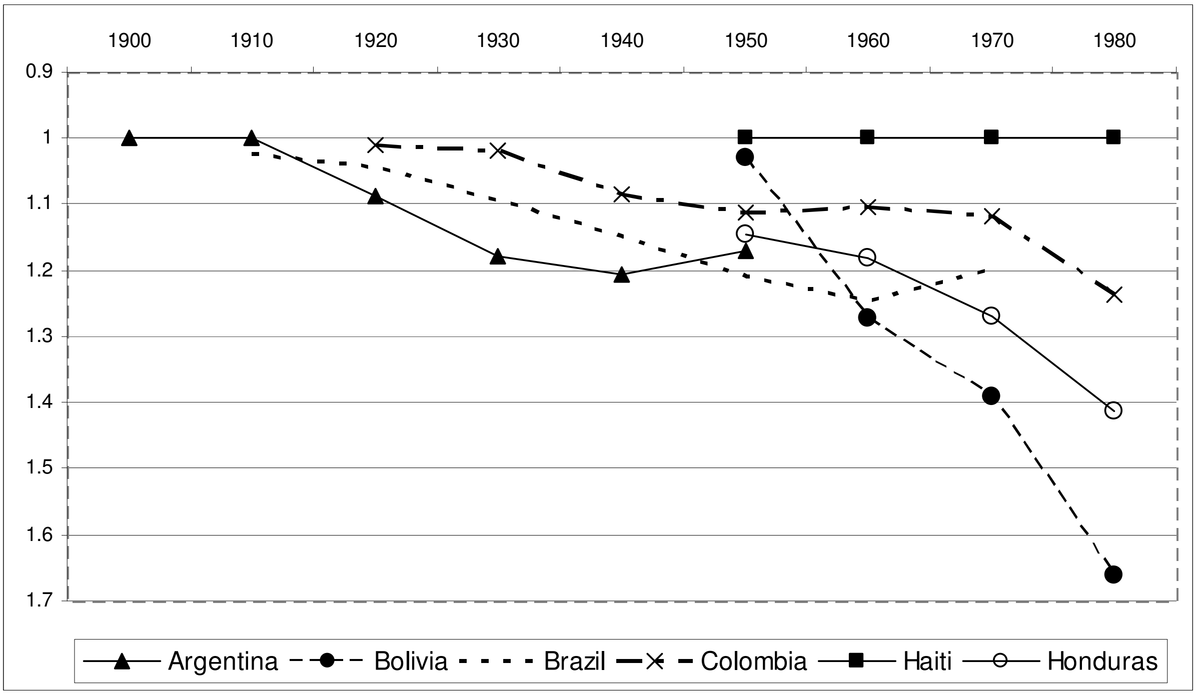
[29] The impact of wars often starts before its formal declaration and may continue after the peace treaty. Therefore, we can not simply control for wars periods in the regression analysis by including dummies for those periods. We therefore prefer to have a detailed look at the efficiency trends.

The state efficiency trends of Colombia and Brazil suggest a development similar to that of Peru. Brazil started on a remarkably high level in the 1910s and was declining over more than half a century until the 1960s. Beginning in the 1940s with the civil war, the so-called *La Violencia*, Colombia experienced a permanent downturn in state efficiency until the 1980s. The most dramatic decline of performance can be observed in Bolivia, Honduras and the Dominican Republic. After the nationalization of some national resources and a land reform in the 1950s, Bolivia's state efficiency fell dramatically. During the whole period between the 1950s and the 1980s Bolivia's performance dropped sharply.

Figure 3.3: Governmental Performance in Latin America 1900s to 1980s (selection)



Note: A value of 1 means a fully efficient country. Higher values indicate a worse performance. Additional trends of Latin American state efficiency can be found in Figure 3.11 (appendix)

For Sub-Saharan countries data are only available for the period between the 1950s and the 1980s.[30] Apart from Rwanda, all countries show a permanent and sometimes an even dramatic decline in state efficiency. Rwanda started on a relatively high level in the 1960s, but experienced a drop in the 1970s. In the 1980s, Rwanda's state efficiency rose again and reached an optimal level. The other Sub-Saharan countries did not do equally well. Starting from different base levels in the 1950s and 1960s each country in Sub-Saharan Africa experienced a steady decline. It is also interesting to note that former French colonies tended to do better both in terms of their initial efficiency level of as well as the severity of the decline after independence, as is visible in the graphs.[31]

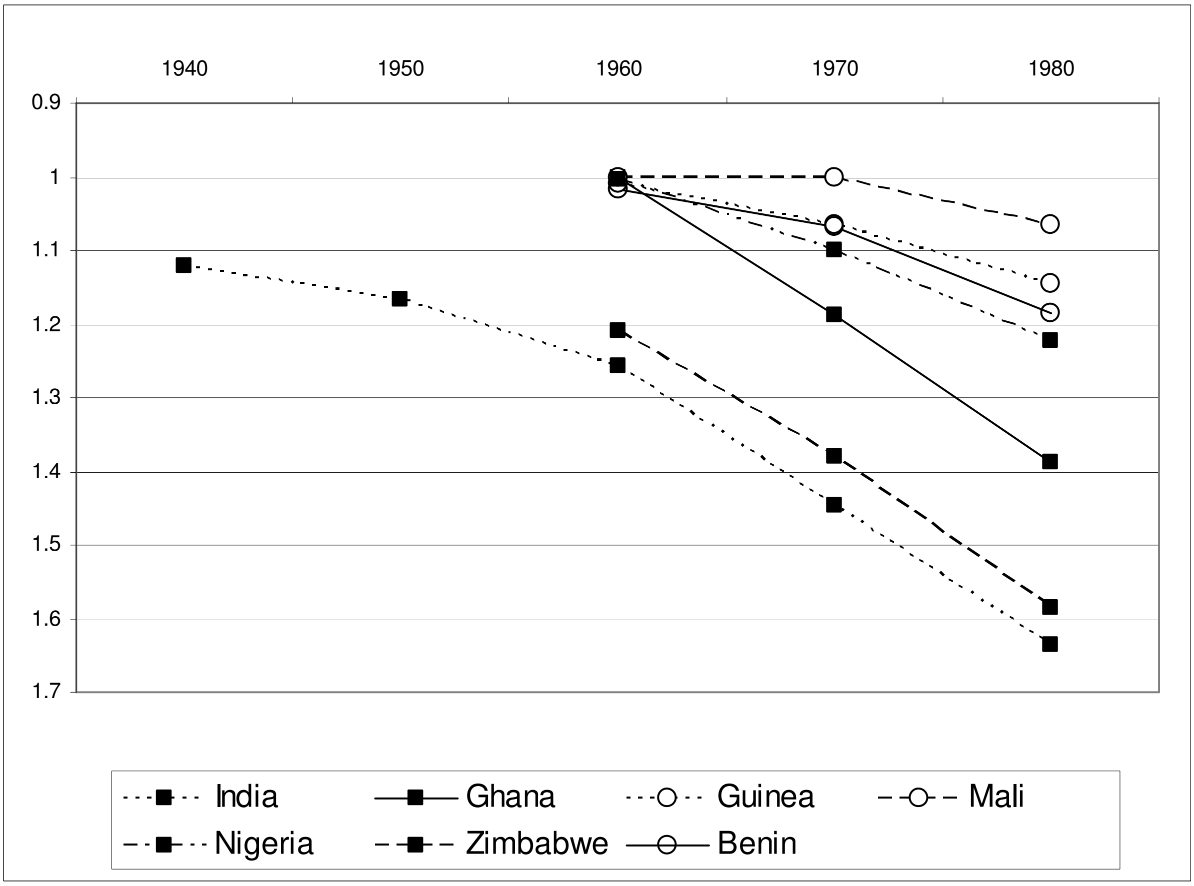
Among the northern African and Middle Eastern countries the results suggest that Egypt performed best. Beginning in the 1950s state efficiency was already on an extremely high level and reached an optimal level in the decades afterwards. On the other hand, Morocco and Turkey performed worse. During the decades after the Second World War Turkey experienced a continuous downturn of state efficiency despite the political, social and economic reforms initiated by Mustafa Kemal Pasha. In Morocco, the influence of the Algerian war of independence and the Moroccan independence from France seem to have left their traces. Between the 1940s and the 1980s Morocco's governmental performance decreased constantly after it became a sovereign state. Iran's efficiency values were already on a high level in the 1960s and increased further in the 1970s. The Islamic Revolution and the Iran-Iraq war, however, caused a sharp decline in the 1980s.

In Asia, we can trace Korean (until the 1940s, the *Republic of Korea* from then on) state efficiency from the 1940s to the 1980s. Surprisingly, (South) Korea's efficiency

[30] See also Figure 3.6 (appendix)
[31] Due to the small number of cases we cannot test this econometrically.

values reached 100% even in times of Japanese occupation and the devastating events during the Korean War. Only after the military coup and the reign of Park Chung-hee in the 1960s, Korea experienced a temporary decline. Another interesting case study in this regard is India, whose performance at the time of independence was relatively high. However, during subsequent years India was mainly shaped by the reorganization of its structures, particularly socialist tendencies and the involvement in several wars. Therefore, it is no surprise that India's efficiency values declined dramatically in the ensuing decades. In this regard, India can be added to a number of (mainly African) examples where independence appears to have caused major turmoil which caused in a decline in state efficiency.

Figure 3.4: Governmental Performance in former colonies 1940s to 1980s (selection)

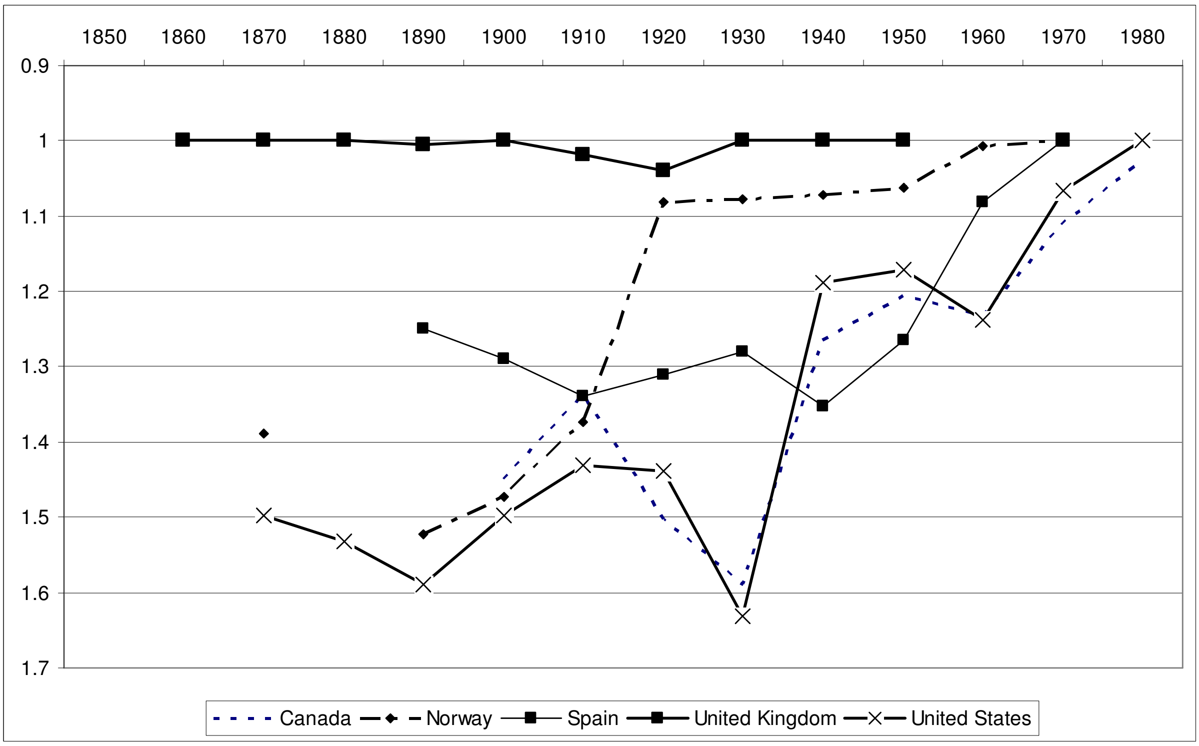


Note: A value of 1 means a fully efficient country. Higher values indicate a worse performance.

Among the industrialized countries Denmark serves as an exemplary country.[32] Its efficiency values stagnate on a low level until the turn of the twentieth century. From then on, it increases moderately, but the trend is interrupted by the Second World War. However, immediately after the war, its performance reaches 100%.

A similar pattern can be observed in a number of industrial countries. The overall Spanish efficiency trend, for instance, fluctuates moderately on a rather low level and declines remarkably in the aftermath of the Spanish civil war and the first years of Franco's authoritarian regime. Interestingly, Portugal's performance appears to have been superior to that of Spain; however, it fluctuated during the time of the Republic, after the military coup and the first years of Salazar's reign.

Figure 3.5: Governmental Performance in Industrialized Countries 1850s to 1980s (selection)



Note: A value of 1 means a fully efficient country. Higher values indicate a worse performance.

[32] Additional graphs on state efficiency trends of industrialized countries can be found in Figures 3.7 and 3.8 (appendix)

Beginning in the 1950s, both Spain's and Portugal's state efficiency were increasing. Basically the same is true for the cases of Finland, the Netherlands, Italy, Norway, Sweden, Canada and the United States. Their efficiency values move at a low level until the 1930s and the 1940s. There are certainly differences regarding the exact point in time or the initial level of state efficiency, but the general pattern of those countries' efficiency development is obvious. The period between the 1930s and the 1950s seems to be a crucial point in the economic history of those countries. From then on, negative trends turn to the better or even make giant leaps forward.

The efficiency trends of Japan and the United Kingdom could serve as a model for the efficient use of endowments. The estimation reveals perfect values in almost every single decade during the 19^{th} and 20^{th} century for the UK and Japan.

Moreover, the consequences of the First World War and the Great Depression cannot be ignored. Particularly Canada and the U.S., but also Germany and Greece experience a remarkable decline in terms of efficiency during this period. Surprisingly, the Second World War does not seem to have an influence on the trends in the industrialized countries. Only Denmark and Greece seem to suffer from the German occupation in the 1940s. During these years Denmark's state efficiency was remarkably lower in comparison to previous years. Greece's performance begins to decline in the aftermath of the Greco-Turkish war and reaches a low during the German occupation.

Possibly the most surprising results are Canada and the United States, who belong to the most inefficient economies until the mid-twentieth century. Although they are often considered as flagships of modern and efficient economies we find that their performance in terms of state efficiency is rather disappointing. Of course, their overall wealth was remarkable and still is, but it seems that they were not always able to use their enormous economic potential efficiently. By looking at the trends the close economic linkage between Canada and the U.S. becomes clearly visible. Both countries show an almost identical efficiency path. They share low levels of efficiency until the Second World War and a common increase during the 1940s as well as a slow increase during the Cold War. The 'New Deal' and the high war-induced demand seemed to have had a positive impact on their economies.[33]

3.5 How did we distinguish inputs, outputs and explanatory variables?

At first sight, it is not entirely clear which variables should be considered as inputs for an economy and which should serve as explanatory variables in order to explain state efficiency in the second step. We use several criteria to draw a line between inputs and explanatory variables. According to economic theory, classical inputs – or preconditions – are physical and human capital, land, and labor force. The explanatory variables can be divided into two sub-groups. The variables are put in one group if they can be influenced by government's policy in the short or medium run – such as military burden, the degree of democracy and social spending – and are put into the other group if the variable is considered a country's characteristic, such as the heterogeneity of the population.

In contrast, the definition of outputs is clear. In general, the success of a country is often connected to its monetary wealth and the general welfare its population enjoys. Hence, we use per-capita GDP and mean adult (male) height as measures of success.

[33] This result is robust to all specifications and does not depend on a particular variable.

3.6 Data used in the second step – correlates of state efficiency

An important influence on state efficiency is the heterogeneity of the population. Different ethnic groups are often separated by different languages and religious beliefs and often have an unsightly common history (e.g. when one part of the population has dominated others). In other cases – Switzerland is probably the most successful example – heterogeneity is nothing more than cultural diversity and several minorities complement each other. Unfortunately, this is not always the case. Cyffer (2001) reports that even a taxi ride from one outlying district of an African capital to another may require skills in several languages, because not everyone speaks a common standard language. In the northern parts of Nigeria, English played almost no role until the 1970s (Cyffer 1977). In sum, Cyffer reports that there are nearly 400 different languages in Nigeria alone. It is a reasonable assumption that linguistic diversity complicates the implementation of working institutional structures in every province of the country. Moreover, linguistic fractionalization may exclude minorities from education because one part of the population does not speak the official language used in schools or universities. Linguistic differences may also make it easy to identify a member of an ethnic group and therefore might lead to discrimination or nepotism.

Easterly and Levine (1997) find that ethnic diversity helps to explain political instability, underdeveloped financial systems, distorted foreign exchange markets, high government deficits and insufficient infrastructure. Mauro (1995, 1998) even goes one step further. He uses an index of fractionalization as an instrumental variable for corruption and finds that it goes along with lower investments, lower economic growth and lower government spending on education and may lead to adverse budgetary consequences due to tax evasion. We follow their example and use the ELF (ethno-linguistic fractionalization) Index as an indicator for the heterogeneity of a population.

The ELF is probably the most common index of heterogeneity. It is computed as one minus the Herfindhal-Hirschman Index (HHI) of ethno-linguistic group shares and can be interpreted as the probability that two randomly selected persons in one country belong to different ethno-linguistic groups. It is constructed from data gathered and published by Soviet anthropologists in the 1960s (Atlas Narodov Mira 1964, Taylor and Hudson 1972) and therefore reflects a country's ethnic composition during the survey period. The most common critique regarding the ELF is that it is sensitive to the definition of an 'ethnic group'. There is a continuous transition between different languages and accents of the same language, which makes it difficult to standardize and measure ethnic differences around the globe and to control for the importance of ethnic differences. Moreover, it neither includes religious nor racial differences. In order to circumvent these problems we also apply other indicators in alternative models, which are in principal, however, all based on the same idea.

In contrast, the aim of Fearon's (2003) strategy was to construct a list of ethnic groups previously mentioned in the literature.[34] This list served as a basis to distinguish ethnic and cultural groups and it helped to take the above mentioned methodological problems into account. The author only includes ethnic groups that make up at least 1% of a country's population in order to control for the relative importance of ethnic differences. His index obtains similar results than the calculations based on the Atlas Narodov Mira (correlation of 0.75). Only in North Africa/Middle East and Latin America/Caribbean, he obtains systematically higher estimations of ethnic fractionalization.

Posner (2004), on the other hand, argues that ethnic, cultural or religion-based indicators are inappropriate to capture economic or political rivalries within one country

[34] Fearon's (2003, p.202) most important sources to identify ethnic groups were the CIA's *World Factbook*, *the Encyclopedia Brittanica*, the *Library of Congress Country Study* as well as country-specific sources.

because they do not take actual political engagement and competition into account. Instead, he suggests using his index instead – the PREG (Politically Relevant Ethnic Groups) – which is based on politically relevant ethnic groups. Unfortunately, this index is limited to 42 African countries and is therefore unsuitable for our analysis.

Alesina et al. (2003) provide heterogeneity estimations on about 190 countries. They compute separate indexes of religious, ethnic and linguistic fractionalization, and find that their estimations of ethnic and cultural diversity are similar to the ELF. Their measure of religious heterogeneity, however, shows only a weak correlation (0.372) with the ELF. Therefore, this yardstick serves as a valuable alternative to investigate the influence of heterogeneity on state efficiency.

Urbanization goes along with many different changes and is therefore only the symptom of a complex process in an economy. On the one hand, cities can have negative effects on the welfare of its citizens because transportation and transaction costs separate them from food growing areas. Particularly economic historians emphasize the role of transportation regarding the so called 'urban penalty' (Gould 1998, Woods 2003, Martínez-Carrión and Moreno-Lázaro 2007, Baten 2009). In contrast to cities, people in rural areas enjoy food proximity, particularly the proximity to animal proteins, which are more difficult to transport than carbon hydrates. However, even when transportation costs account for a small portion of the total food costs, the question whether there is enough food for a growing urban population is still important. Probably the best documented country in this regard is the U.S. Komlos (1987), for example, finds that urbanization and the labor force in Antebellum American cities grew faster than its food production. He reports that, due to the nutritional gap, the stature of 20-year old cadets declined by 3.2 cm between the 1830s and the 1850s. This phenomenon existed at least until the beginning of the 20th century. Particularly meat and milk were more abundant in rural places nearby its production facilities. Among conscripts who fought in World War II, the ones from locations of 2,500 inhabitants or less were 1.2 cm taller compared to those from cities with a population of more than 500,000 inhabitants (Steckel 1995, p. 1922). Steckel (1995) even goes so far as to argue that the ongoing urbanization trend in the late 19th century played a strong role in the U.S. height decline during that time.

On the other hand, cities serve as industrial, educational and social hotspots. Cities are often characterized by a higher productivity, better education, higher wages and therefore higher purchasing power. Schools, universities, manufactories, and governmental institutions can be operated with higher efficiency in places where economies of scale are possible. Firms in urban agglomerations face better access to information and tend to be more innovative (Bianchi and Bellini 1991, Porter 1990, Pouder and St. John 1996, Bell 2005). The main reasons for this advantage are educational institutions along with low transaction costs for the exchange of information. Firms located in geographic proximity to government institutions are able to deal more efficiently with red tape and might take advantage of their special location (Henderson 2003, Duranton 2008). Moreover, competitors are able to observe each other and innovations and mutations become more likely. They also access a common pool of specialized workers and suppliers (Burt 1987, Pascal and McCall 1980, March 1994, Rogers 1995). Glaeser and Maré (2001) state that cities make workers more productive, which can result in wage growth. In addition, urban workers who move to smaller cities or rural areas do not experience wage decline but tend to remain at the same income level. We expect the positive influences of urbanization to prevail, because the period and the majority of the countries under observation allowed governments to use the positive aspects of urbanization and to compensate its negative influences. We use the data on the rate of urbanization gathered by Banks (1971), which measure the share of the population living in cities with more than 50.000 inhabitants.

We also include Lindert's (1994, 1996, 2004) data on social spending in the analysis. There are several studies that indicate that redistribution means an intelligent use of a nation's resources. The fear, however, remains that redistributing resources from the person who owns it causes inefficiency because the one who loses money has less incentive to be productive. Moreover, government bureaucracies which are set up in order to redistribute money might also cause inefficiencies by the process itself. However, Lindert (1994) argues that social spending causes little, if any, deadweight loss.

Following the law of diminishing return to income, redistribution primaryly causes a more sensible and efficient use of resources. Among rich social strata, for instance, an additional unit of purchasing power results only in a little increase of welfare compared to lower strata. The explanation is simple: The marginal returns to purchasing power among wealthy people are low because all basic needs are already satisfied. In contrast, poor strata have a high marginal utility of purchasing power because these people have many unsatisfied (basic) needs. Therefore, the same amount of purchasing power can have different benefits, depending on the preexisting welfare level of the consumer. Although redistribution leads to an absolute loss of rich individuals, the gains of the poor outweigh the losses for the rich (Steckel 1983, Steckel 2009, Carson 2009, Blum 2010).

We use military expenditure data gathered by Eloranta (2007) as an explanatory variable, because more military expenditure is often associated with distortions in the economic sector. Since military expenditures can be considered as a special kind of public expenditure, high expenditures may exert a neutral or even a positive influence on particular industries. However, male adult height is used as a measure of welfare. While military expenditure may increase the welfare of some parts of an economy, it is incomparable with other public responsibilities, such as social spending. Aizenmann and Glick (2006) argue that military spending might be beneficial for economic growth if a country faces an acute threat, because military spending ensures safety. This is a convincing argument in the case of a certain threat, but in comparison to a situation without threats (and less military expenditure) this is no more than a second best alternative. Apart from that, large military forces tend to have inefficient bureaucracies as well as large military orders. These organizational structures may lead to corruption and rent seeking (Gupta, Mello and Sharan 2001). Therefore, we do not expect military spending to increase state efficiency, but rather the opposite.

In order to take different institutional settings into account we include the polity 2 index (Marshall and Jaggers 2009), which ranges from -10 (perfect autocracy) to +10 perfect democracy). The rationale behind this measure is that in autocracies, people cannot force its leaders to keep their commitments (Olson 1991). In countries with less developed democratic institutions the political elite often uses its outstanding position to peculate resources at the expense of lower classes (Przeworski and Limongi 1993). In democracies, the lower social strata have more influence and therefore demand a greater share of a country's resources. Moreover, in a democracy there is the possibility to replace bad governments. Political leaders have incentives to increase welfare of the population in order to stay in power.

On the other hand, democracies are often associated with the rule of law, property rights, free markets, government consumption and human capital. However, Barro (1996) analyzes the effects of democracies on growth in a panel of 100 countries. He finds that the overall effect of democracy on growth is slightly negative. His findings correspond with the skeptics arguments regarding the negative influence of democratic regimes on growth. Przeworski and Limongi (1993) describe the most common arguments in this regard. They conclude that democratic regimes are forced to redistribute income from richer to poorer strata in order to stay in power. In addition, democratic regimes tend to have more powerpul labor organizations which are able to drive up wages at the expense of the entrepreneur's profits. Lower social strata, however, are more consumption oriented compared to their richer counterparts. As a result, those resources spent for consumption cannot be used on investments. In this context, Rao (1984) argues that dictatorships are better able to enforce savings and invest surpluses. In the ongoing analysis, about 70% of all observations have positive democracy values (according to the polity 2 scale). In other words: we are mainly dealing with different democratic systems. Therefore, the results do not indicate a difference between the efficiency of democracies and dictatorships but rather the difference between liberal and interventionist democracies.

We also include the type of agricultural production. The two extremes in this respect are perfect monoculture and a great diversity of crops. Since Mitchell (1993) provides arable land per crop type it is also possible to compute a Herfindahl index of the shares of the total land used for farming.

The most obvious advantage of a large portfolio of crops is the reduced risk of fluctuating market prices. Since farmers are forced to make decisions under uncertainty, diversification means a secure income because high and low market prices are expected to cancel each other out. On the other hand, monocultural structures tend to lead to a dependency on the demand of one single crop and susceptibility to climatic, political and technological shocks (Moradi 2005, Moradi and Baten 2005, Sylvester 2009, Moschini and Hennessy 2001). Furthermore, the diversification of agricultural production goes hand in hand with the demand for labor force. Sylvester (2009) argued that diversification requires more labor power than homogeneous production. This finding indicates that diversified agricultural sectors go along with greater participation of the population; it enables broader strata to participate in productive economic activities but also causes higher costs for labor compared to agricultural specialization.

However, monocultures allow economies of scale because the equipment, workflow and education of the employee can be designed and used more efficiently. In general, monoculture goes along with a high degree of specialization and a great deal of experience of the employees. Therefore, it is not entirely clear what kind of influences dominate agricultural efficiency.

3.7 Regression Results

The most robust result in the regression models (Table 3.1) is the negative influence of fragmented societies on state efficiency. No matter which measure of heterogeneity we apply the result remains the same. Similar to Mauro's (1995, 1998) and Easterly and Levine's (1997) result we find that diverse societies tend to be more corrupt and instable. The results suggest that these characteristics influence state efficiency due to high transaction costs, for example to overcome different languages or ethnic prejudices (Cyffer 2001). The available endowments are not distributed among all groups of the society equally but are concentrated on those groups that are able to speak the lingua franca and are not discriminated or secluded by their religion or cultural peculiarities.

At first glance, democratic institutions seem to lower state efficiency. This coefficient is not always significant but is has a consistent negative sign. Hence, the results do not confirm Przeworski's and Limongi's (1993) or Olson's (1991) expectations. But does this result suggest that authoritarian or dictatorially ruled countries are better off? More than 70 per cent of the observations come from countries and regions that have positive democracy values (according to the polity 2 scale). For comparison, Chile after

Table 3.1: Determinants of state efficiency (independent variable: DEA efficiency scores) 1850s – 1980s in a panel of 62 countries

	I	II	III	II	III	IV	V	VI	VII	VIII
Monoculture	0.28*	0.29**	0.38**	0.31**	0.45**	0.38**	0.46***	0.41***	0.31**	0.59**
Degree of democracy	-0.21	-0.78**	-0.76*							
Urbanization	-0.03	0.005	-0.009	-0.0021	-0.015	0.04	0.004	-0.02	-0.002	0.03
Military Burden										1.26
ELF (Fearon)	-0.022		-0.17*		-0.26**					
Religion (Alesina et. Al)						-0.35***				
ELF (Taylor and Hudson)							-0.34***			
Culture (Fearon)								-0.51***		
Language (Alesina et. al)		-0.33***		-0.38***					-0.38***	-0.46***
Social Spending		0.03*	0.04**	0.016	0.03*	0.01	0.027*	0.04**	0.016	0.05
Time Dummies included?	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	-1.07***	-1.25***	-1.38***	-1.17***	-1.35***	-1.19***	-1.35***	-1.33***	-1.17***	-1.56***
N	134	77	78	77	78	77	78	78	77	50
pseudo-R2	0.23	0.34	0.28	0.32	0.25	0.28	0.31	0.32	0.32	0.31

Note: DEA-efficiency values were multiplied by (-1) in order to obtain intuitive results. Therefore, positive coefficients express a positive influence of the independent variables on efficiency. *, ** and *** denotes significance at 10%/5%/1% levels. Time dummies are included to control for unobserved trends. As described above, we used a bootstrapping approach with truncated regression models to link the efficiency scores to the explanatory variables. This procedure yields valid standard errors. The pseudo-R² can be used to compare the models, but they do not allow the standard interpretation.

Pinochet's coup d'état in 1973, for example, had a democracy value of -7.[35] At the same time, France and the United States show values of 8 and 10, respectively.

Figure 3.5 reveals that countries like the U.S. and Canada show inadequacies in terms of efficiency although they have highly developed and stable democracies. In other words, the negative influence of the applied democracy yardstick does not imply a superiority of dictatorships compared to democracies but rather a disadvantage of liberal democracies compared to more restrictive ones.

A common concern against the cultivation of a small number of cash-crops is that it might worsen the consequences of bad harvests and increase the dependency on fluctuating market prices. However, monocultures allow specialization and economies of scale. Since there are two opposing forces at work, the clear and unambiguous results are somewhat surprising. Despite all the difficulties that are correlated with monoculture, its advantages seem to outweigh its disadvantages since we find a consistent positive and statistically significant influence on state efficiency.

We expected a nation's military burden to decrease state efficiency because this money is lost in the welfare producing process in an economy and high military expenditure may even lead to corruption and rent seeking (Gupta, Mello and Sharan 2001). In fact, both models reveal a negative sign. Unfortunately the number of observations drops to 50 once we include military spending, which might be the reason for the statistically significant coeficients.

The inclusion of social spending in the analysis indicates the expected benefits. We consider this variable to be important for explaining state efficiency since redistribution helps to ease the negative influences of inequality by narrowing the gap

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35 For remembrance: the range of definition is -10 (perfect autocracy) to +10 (perfect democracy).

between unequal marginal returns to income between rich and poor strata. As Steckel (1983, 2009), Carson (2009) and Blum (2010) show, less inequality can – ceteris paribus – increase welfare even when the richer strata lose wealth via the redistributing mechanism because their losses are outweighed by the gains of the poor. Therefore, redistribution serves as a tool for governments to increase state efficiency. In all estimated models, this coefficient suggests a positive – often a statistically significant – influence of social spending on state efficiency.[36]

In contrast, urbanization does not seem to have a robust influence. The coefficients are neither significant nor do they have a consistent sign. In this paper we chose both income per capita and biological welfare as criteria for economic success in order to capture two important characteristics of the standard of living. Urbanization may increase the former but it does not necessarily increase the latter. The results might be explained by the miscellaneous influences of urban agglomerations. Positive influences on state efficiency like low transaction costs, high productivity and higher education might be outweighed by the phenomenon economic historians call the 'urban penalty', primarily the lack of fresh foodstuffs and bad hygienic conditions.

3.8 Conclusion

This study estimates state efficiency in terms of welfare production for 62 countries between the 1850s and the 1980s. We are able to supplement the existing literature which is limited to the post-1965 period. We give a first view on the long-run evolution of state efficiency and show improving performance in many countries over the course of the 19th and 20th century. During the 20th century Latin American countries and from the middle

[36] Social spending is the bottleneck-variable in our regression. By including this variable, we lose half of our observations.

of the 20th century on their African counterparts experienced a significant decline. In addition, our results indicate a negative influence of wars, particularly occupation, and political instability. Japan and the United Kingdom had very high efficiency scores throughout the period under observation while the United States, Canada, Norway, the Netherlands and Sweden used their resources in a remarkably inefficient manner, particularly during the pre-WW II period.

This study offers several methodological improvements compared to existing studies. The DEA-methodology provides efficiency estimates which yield reliable standard errors, when used as the dependent variable in a second stage regression. We use the bootstrapping algorithm proposed by Simar and Wilson (2007) which provides consistent inference. In addition, we are able to draw a more realistic picture of the economies under observation, since we use several inputs and outputs rather than only relying on per-capita GDP.

The regression results show that agricultural specialization and redistribution increase state efficiency, while a heterogeneous population has the opposite effect. The reasons are manyfold: mocultural structures in agriculture allow specialization and economies of scale. Redistribution, however, leads to a convergence of marginal returns to income in a society. It leads to an absolute loss for rich social strata, which is more than outweighed by the gains of the poor. Heterogeneous societies go along with high transaction costs and may sometimes even lead to corruption. A careful interpretation is required in order to interpret the negative influence of liberal democracies in comparison with rather restrictive ones. Liberal democracies, like the U.S. or Canada, seem to produce lower efficiency values than restrictive ones.

The results presented in this paper suggest several framework conditions through which governments might increase the efficiency of the economy and thereby increase welfare. The first point refers to the reduction of the negative side-effects of ethnic differences, for example conflicts over the distribution of government resources or obstacles regarding the education of ethnic or religious minorities. Our results regarding redistribution can be interpreted as an appeal to incorporate large sections of the population into the economy by introducing obligatory education and, if needed, social benefits. In addition, our results emphasize the importance of peace and stability, because the trends indicate that state efficiency suffers from wars and crises during the period under observation.

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Appendix A:

Figure 3.6: State efficiency in selected African countries

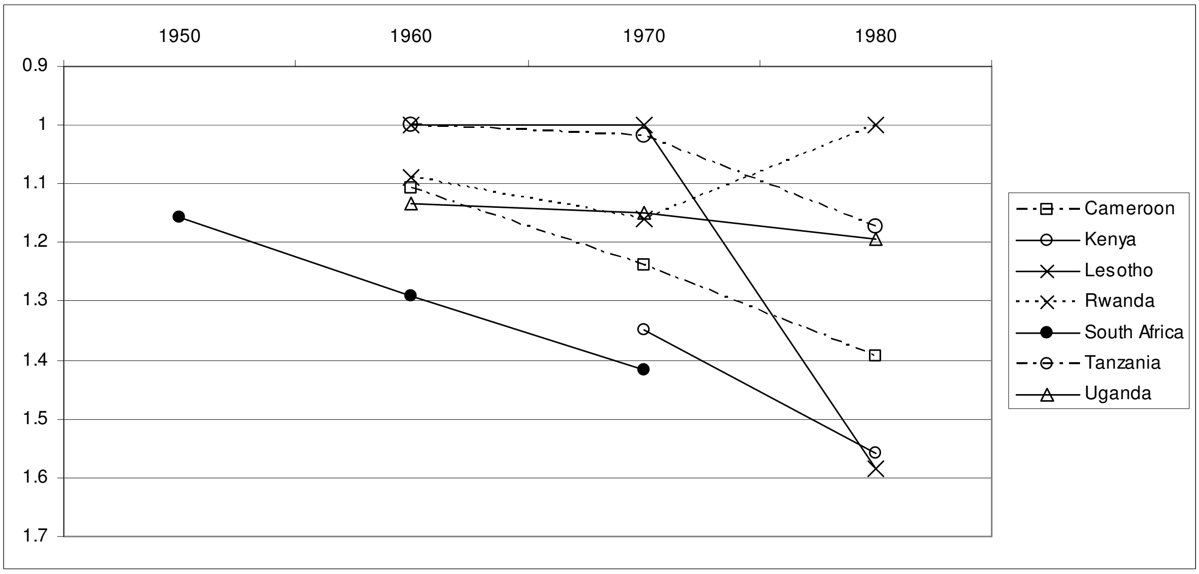


Figure 3.7: State efficiency in selected Industrialized Countries (part II)

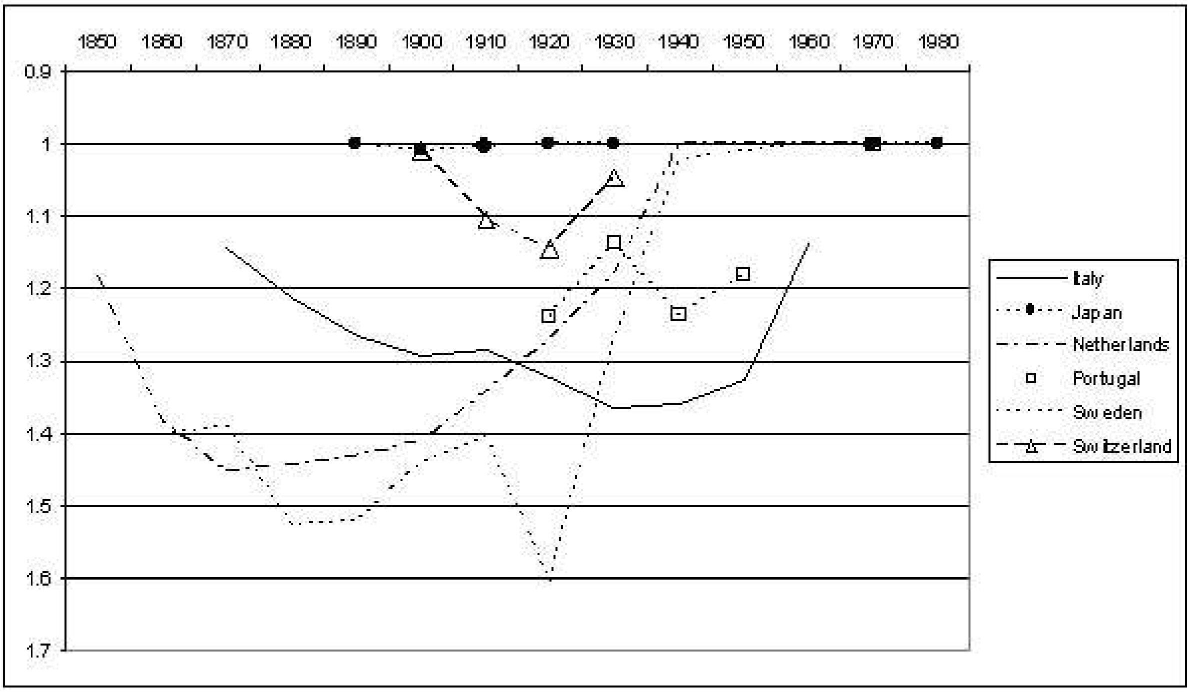


Figure 3.8: State efficiency in selected Industrialized Countries (part III)

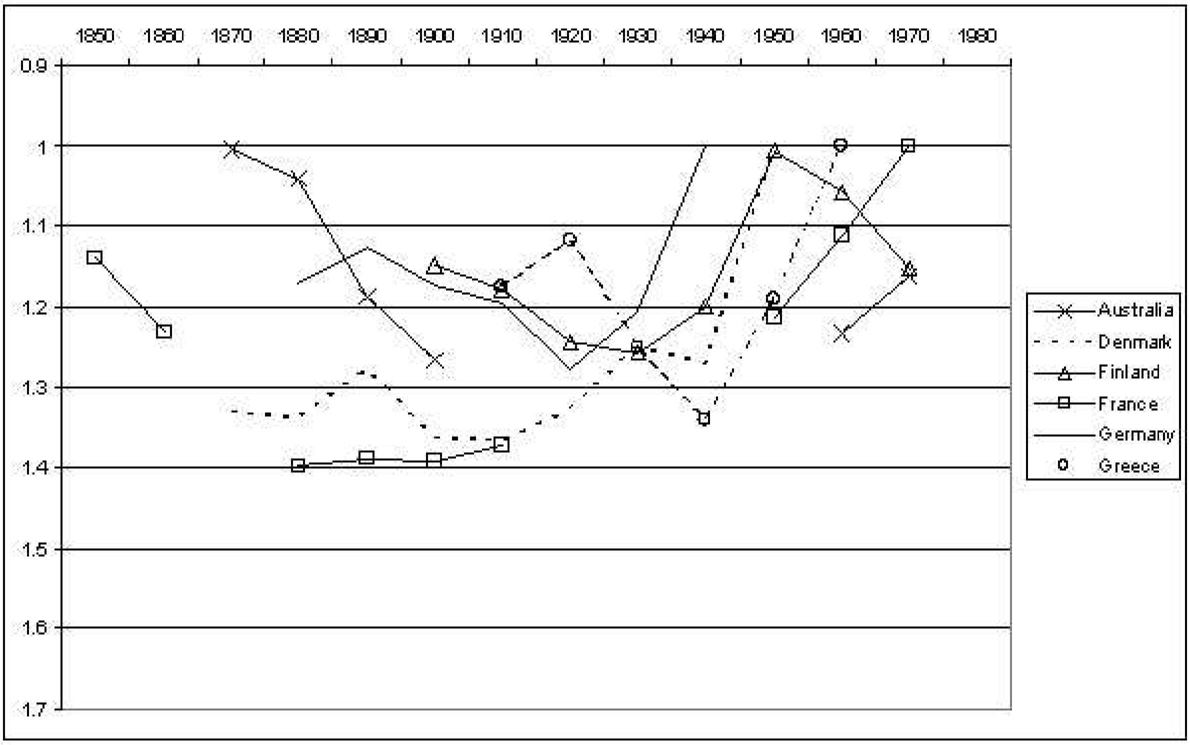


Figure 3.9: State efficiency in selected Asian countries

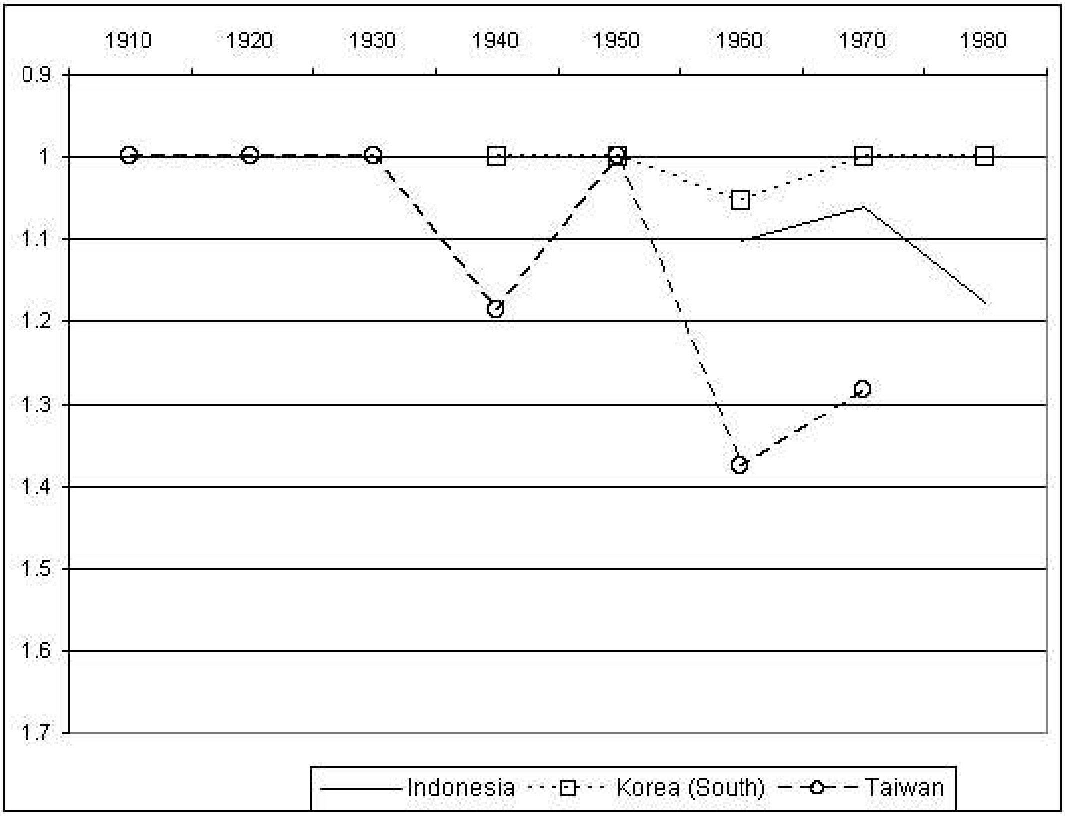


Figure 3.10: State efficiency in selected Eastern European countries

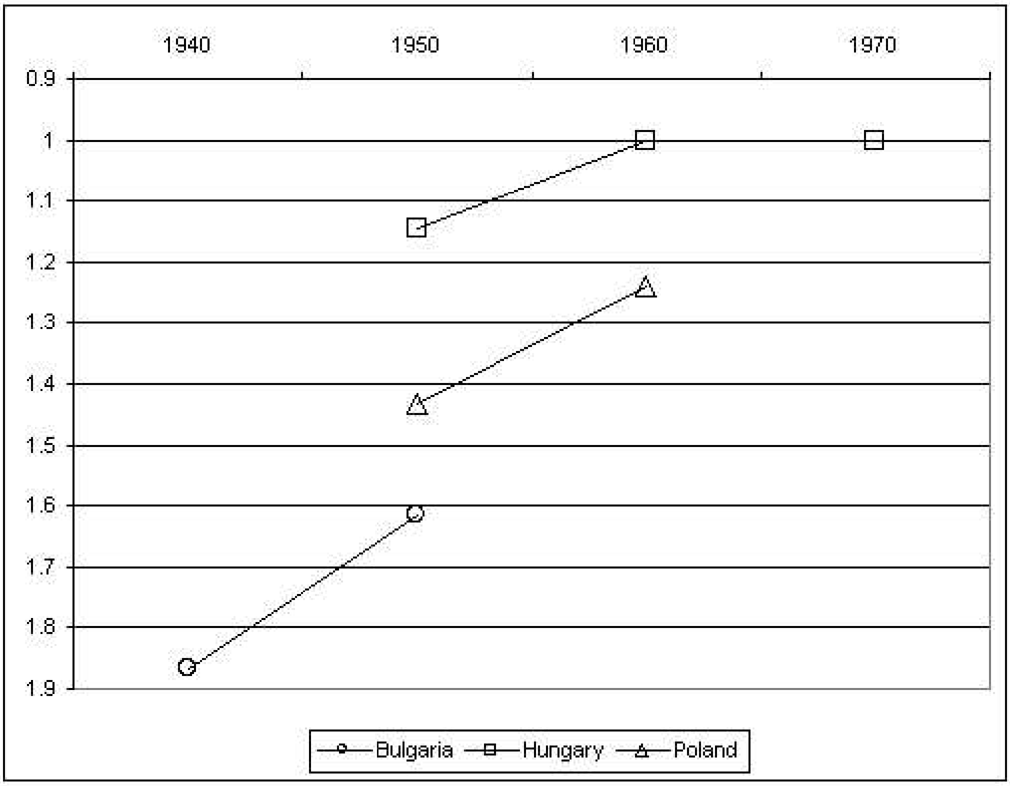


Figure 3.11: State efficiency in selected Latin American countries

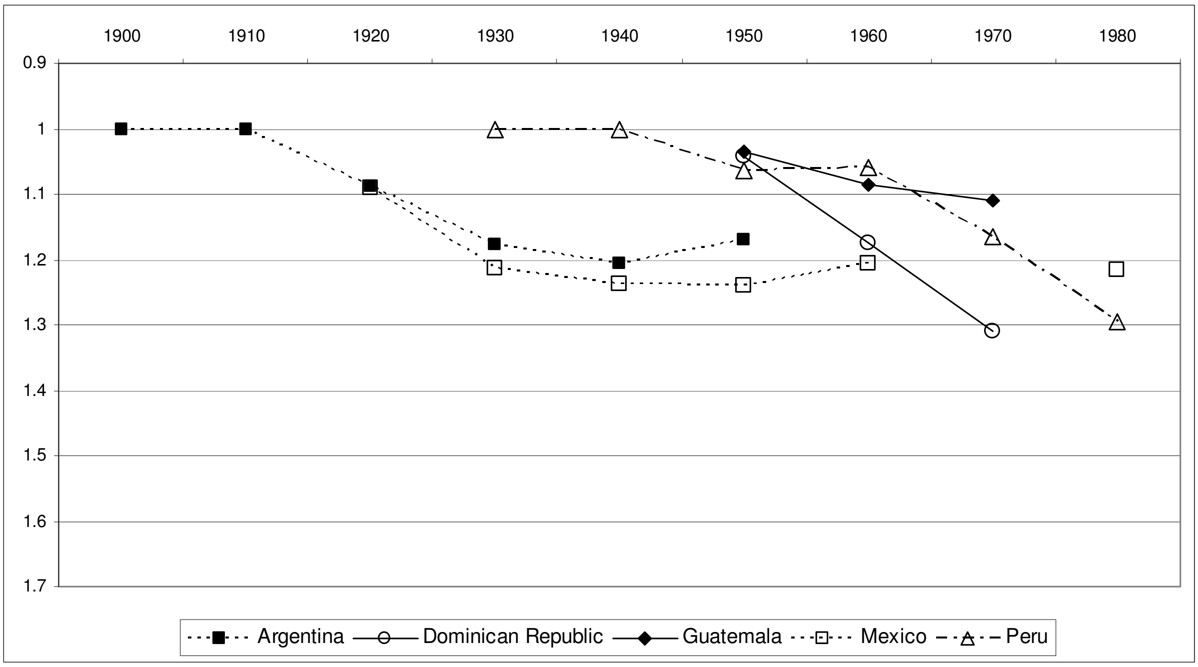
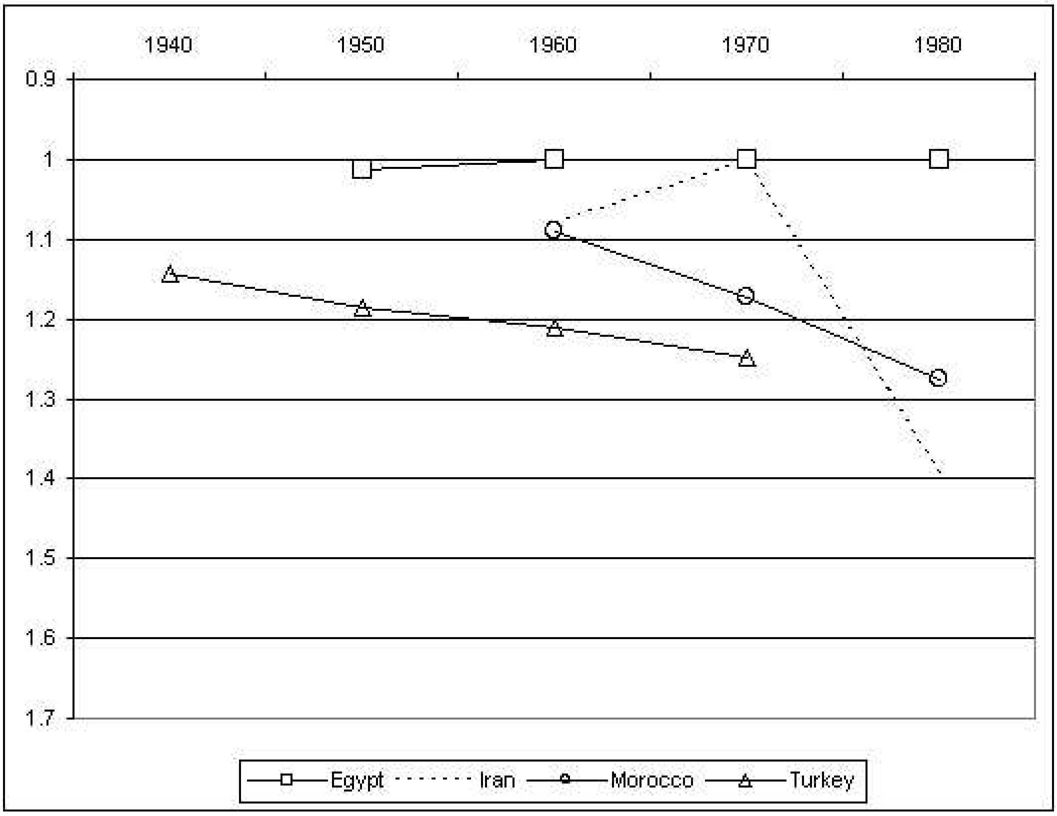


Figure 3.12: State efficiency in selected Middle Eastern countries



Appendix B: The Bootstrap

In this paper a two-stage approach is used, in which efficiency is estimated on a first stage and then the estimated efficiency values are regressed on environmental variables.

Simar and Wilson (2007) provide a framework in which this two-stage estimation procedure makes sense. In their setting, the relationship between the efficiency measures δ and the environmental variables *z* is defined by the following model:

$$\delta_i = \psi(z_i, \beta) + \varepsilon_i \geq 1 \tag{1}$$

where ψ is a smooth function, β is a vector of parameters and ε_i is distributed $N(0, \sigma_\varepsilon^2)$ with left truncation at $1 - \psi(z_i, \beta)$ for each *i*.

Like most of the two-stage studies, we specify $\psi(z_i, \beta) = z'_i \beta$, so that equation (1) results in

$$\delta_i = z'_i \beta + \varepsilon_i \geq 1 \tag{2}$$

Simar and Wilson point out, however, that this approach carries a problem arising from the fact that the efficiency estimates on the first stage are serially correlated, with this correlation disappearing very slowly as the sample sizes grow large. Additionally, they show the rate of convergence *r* to be of order $\mathcal{O}(n^{\frac{-2}{p+q+1}})$, *p* being the number of inputs and *q* the number of outputs. Even for a small model with 3 inputs and 2 outputs the rate is $r = n^{-1/3}$, and it decreases with more variables being added. As a consequence, standard approaches to inference are invalid.

To deal with this problem, Simar and Wilson suggest a special form of the parametric bootstrap that allows for a consistent inference in this two-stage approach. The steps of their method are the following:

1. Using the original data compute $\widehat{\delta}_i(x_i, y_i)$ for $i = 1, \ldots, n$.

2. Use the method of maximum likelihood to obtain an estimate $\widehat{\beta}$ of β as well as an estimate $\widehat{\sigma_\varepsilon}$ of σ_ε in the truncated regression of $\widehat{\delta}_i$ on z_i in (2) using the $m < n$ observations where $\widehat{\delta}_i > 1$.

3. Loop over the next three steps (3.1 to 3.3) L times to obtain a set of bootstrap estimates $\mathscr{A} = \{(\widehat{\beta^*}, \widehat{\sigma_\varepsilon^*})_b\}_{b=1}^{L}$:

   3.1) For each $i = 1, \ldots, m$ draw ε_i from the $N(0, \widehat{\sigma_\varepsilon})$ distribution with left-truncation at $(1 - z_i'\widehat{\beta})$

   3.2) Again for each $i = 1, \ldots, m$ compute $\delta_i^* = z_i'\widehat{\beta} + \varepsilon_i$

   3.3) Estimate the truncated regression of δ_i^* on z_i to get the estimates $(\widehat{\beta^*}, \widehat{\sigma_\varepsilon^*})$

4. Use the bootstrap values in $\mathscr{A}$ and the original estimates $\widehat{\beta}, \widehat{\sigma_\varepsilon}$ to construct estimated confidence intervals for each element of β and for σ_ε.

Appendix C.1: Reliability of the capital stock estimates

This appendix serves as a comparison of different capital stock datasets in order to check their suitability for used in the analysis. The most important difference between existing estimations are the different estimation strategies and the assumptions, particularly the underlying depreciation rates, they are based on.

The largest comparable dataset on physical capital stock estimations in existence was compiled by Baier, Dwyer and Tamura (henceforth BDT 2006). They use the perpetual inventory method which sums up net investments.[37] By applying this method, they are able to provide physical capital stock estimates for up to 143 countries on a decadal basis between the 1840s and 2000 (see Table 3.2). This data set has already been used by several economic historians and international economists (see for instance Huberman and Minns 2007, Bergstrand and Egger 2007, O'Rourke and Taylor 2006).

The same method is also used by other scholars, but with a narrower focus regarding time and space. Maddison (1994) generates capital stock estimates for six large countries. His series go back until the 1820s in the case of the UK, but others start quite late, as in the case of the Netherlands in the 1950s. Madsen (2007, 2010) and Madsen and Davis (2006; henceforth 'Madsen') used data for 22 countries from the 1870s to the 2000s for TFP estimations. For the period after 1950 more comprehensive datasets are available. The most prominent data can be found in the Penn World Tables (Summer and Heston 1994). They cover the period from the year 1965 to 1992 for a panel of 62 countries. Alternative estimates for the period after 1967 were compiled by Larson, Butzer, Mundlak and Crego (2000), covering 62 countries.

[37] Scholars who use this method have to make an assumption about the depreciation rate. However, there is no consensus on the appropriate level. Therefore, scholars get different estimates based on this method. Some scholars assume a uniform rate for the whole capital stock (Maddison 2001 as well as Nehru and Dhareshwar 1993 use 4%), while others differentiate between machinery and equipment on the one hand and non-residential building on the other (Madsen 2006, 2010 uses 17.6% and 3%, respectively).

Table 3.2: Number of countries per decade for which capital data are available in the BDT-data.

Year	Number of Countries
1840	1
1850	6
1860	9
1870	13
1880	17
1890	20
1900	23
1910	28
1920	33
1930	37
1940	46
1950	66
1960	114
1970	122
1980	127
1990	143
2000	143

Baten and Enflo (2007) base their estimates on energy consumption, which is highly correlated with physical capital. By estimating this relationship for 1965 (using the PENN World Tables as a reference) and using this estimate to project physical capital stock backwards in time they can estimate capital stock data for four data points between 1925 and 1965 for up to 77 countries.

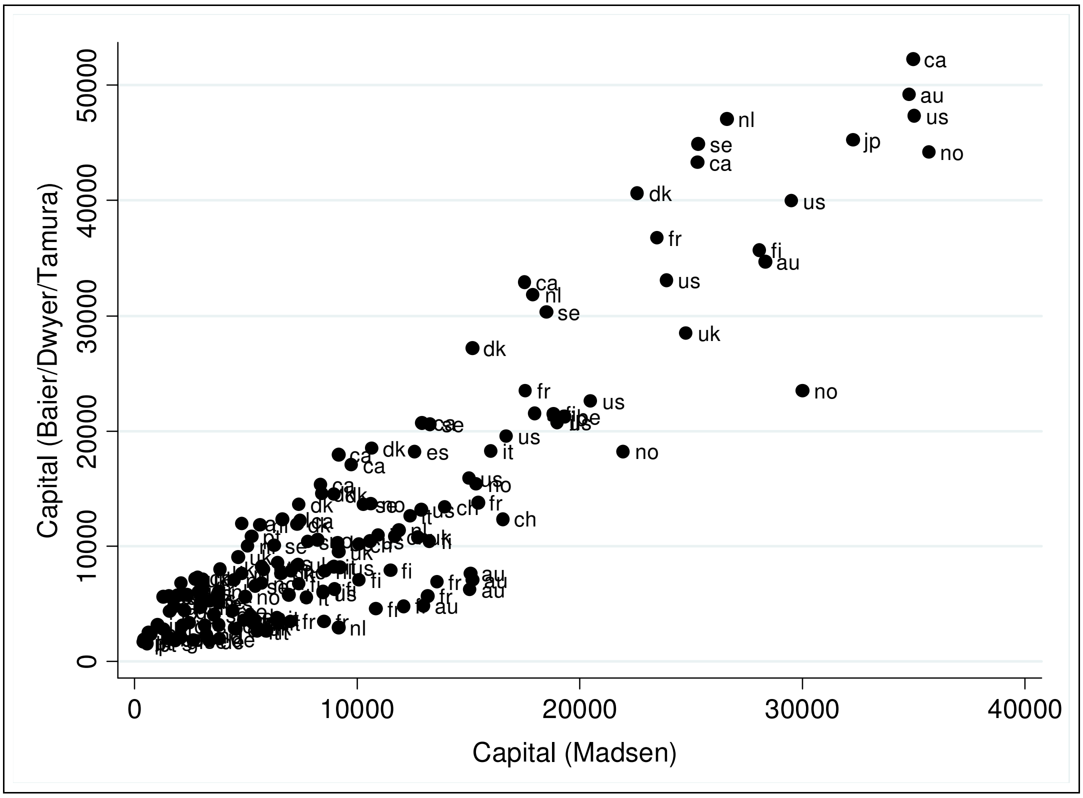
Here we assemble various alternative capital stock series and compare the data (see notes for sources). Table 3.3 shows that the results of the different estimation methodologies are highly correlated, suggesting that the different estimation strategies employed lead to similar results. In addition, Figure 3.13 shows the correlation between the capital estimates of BDT and Madsen in the form of a scatter plot. It reveals that both estimation strategies come to similar results, particularly for low capital stock levels.

Table 3.3: Correlation between various estimation of physical capital

	BDT	BE	PWT	Maddison	LBMC	Madsen
BDT	1					
BE	0.9094	1				
PWT	0.9089	0.9948	1			
Maddison	0.9133	0.8570	0.8485	1		
LBMC	0.7502	0.7486	0.7474	0.8886	1	
Madsen	0.9396	0.9163	0.8851	0.9588	0.8961	1

Notes: The table contains Pearson correlation coefficients. 'BDT' are the data from Baier, Dwyer and Tamura (2006). 'BE' refers to Baten/Enflo (2007), which are supplemented with the Penn World Table data for the periods after 1965. 'PWT' are the Penn World Table data (Summers and Heston 1994). 'Maddison' refers to his 1994 estimates. 'LBMC' are data from Larson, Butzer, Mundlak and Crego (2000). 'Madsen' refers to the dataset used in Madsen (2007, 2010) and Madsen and Davis (2006).

Figure 3.13: Scatterplot of the Capital estimations from BDT and Madsen



Notes: We included only those observations which were used to calculate the efficiency values.

In a second step we look at capital-output ratios, as this measure allows ignoring a great deal of trend correlation in many countries and periods compared to the capital series (Nehru and Dhareshwar 1993; also according to Fisher tests, see Maddala and Wu 1999). This yardstick is a measure of capital productivity. It has several weaknesses, such as the fact that productivity of capital is not only a function of investment, but, for example, also of technical progress and the interaction of physical capital with other characteristics of an economy, like the growth of the labor force (Reddaway 1959).

Table 3.4: Descriptive statistics of capital-output ratios

	Mean	CV
BDT	2.56	0.38
BE & PWT	1.76	0.38
Maddison	1.70	0.48
LBMC	2.43	0.31
Madsen	2.08	0.51

Notes: Abbreviations see Table 3.3. GDP-Data come from Maddison (2001). The sample here is restricted to the countries and time periods for which Madsen provides data to ensure comparability.

Table 3.5: Correlation between several measures of capital-output series

	BDT	BE	PWT	Maddison	LBMC	Madsen
BDT	1					
BE	0.2878	1				
PWT	0.3357	0.8374	1			
Maddison	0.5852	-0.1018	0.4847	1		
LBMC	0.5093	0.1366	0.1451	0.7763	1	
Madsen	0.3616	0.2907	0.6501	0.8958	0.6685	1

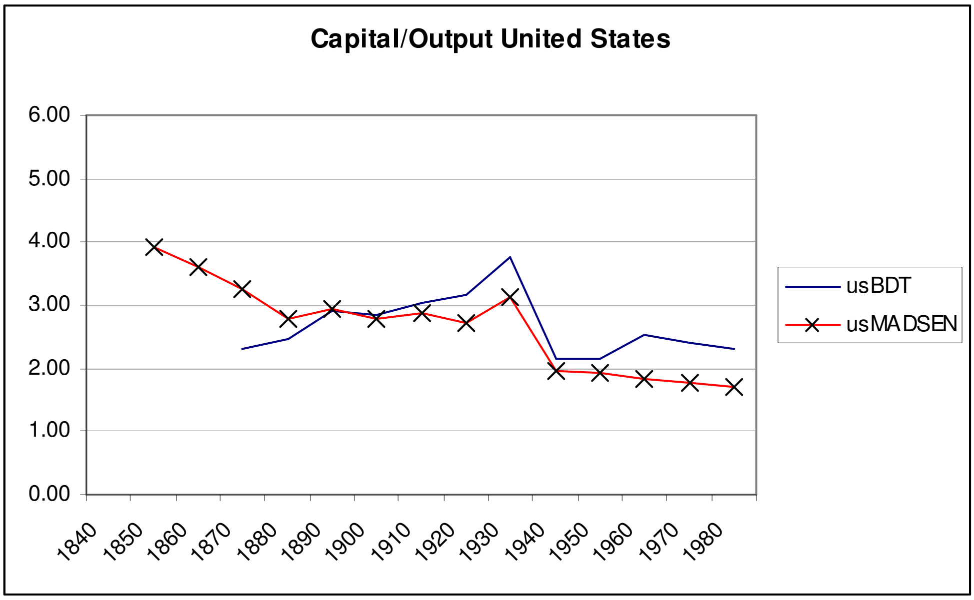
Notes: Abbreviations see Table 3.3. GDP-Data come from Maddison (2001).

Another problem is its susceptibility to variation over time. We calculate both the mean and the coefficient of variation of alternative capital-output measures of the above described measures of physical capital in order to get a first idea of the quality of the data sets. The descriptive statistics in Table 3.4 show that, although the mean of the BDT series is somewhat higher, the coefficients of variation (CV) have comparable magnitudes.

Table 3.5 shows that the capital-output series are less correlated than the capital series. The coefficient between the BDT data and the alternative estimations fit into the general picture. The correlations are of medium strength, but neither significantly lower nor higher compared to other correlation coefficients.

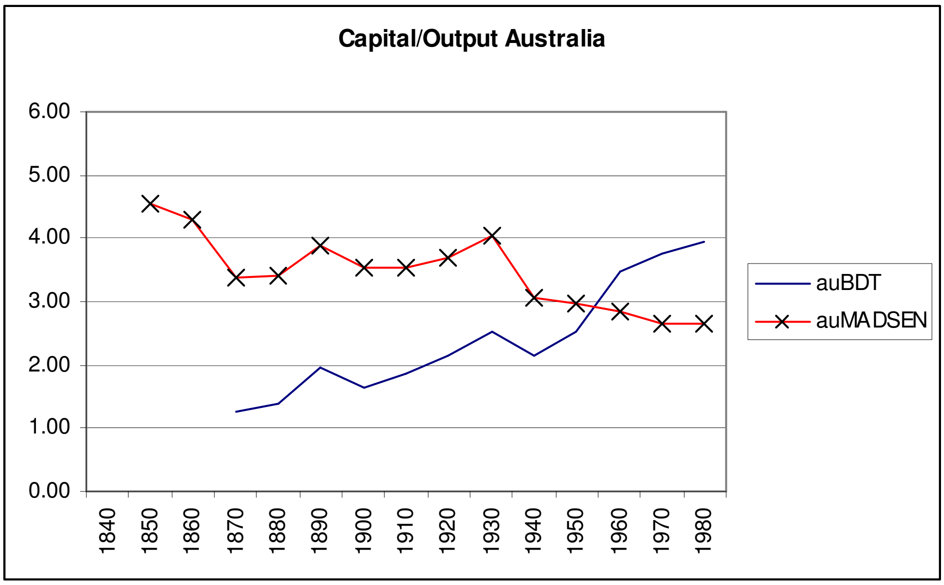
Figures 3.14 to 3.19 show the development of capital-output ratios for selected countries, each graph comparing the series based on the BDT data and the data from Madsen. In most series, the same pattern is found although slight deviations are observed. Nevertheless, none of the datasets can be favored since the courses of the graphs lead to the conclusion that both datasets are of similar quality.

Figure 3.14: Capital-output ratio, United States



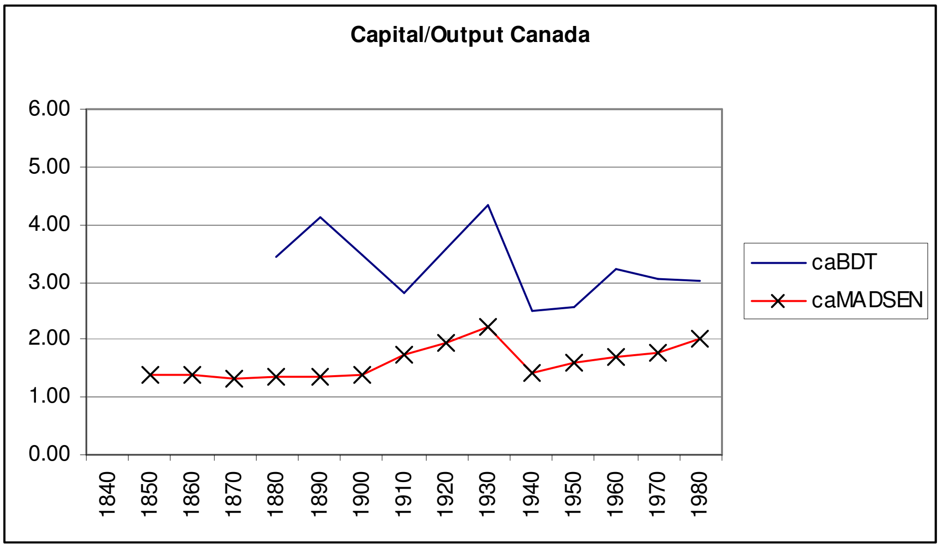
Note: Abbreviations see Table 3.3

Figure 3.15: Capital-output ratio, Australia



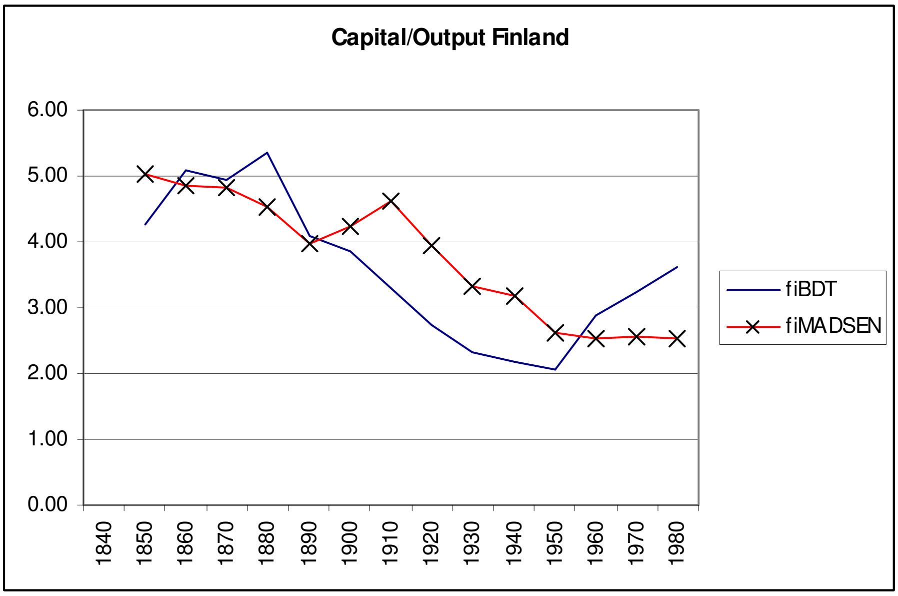
Note: Abbreviations see Table 3.3

Figure 3.16: Capital-output ratio, Canada



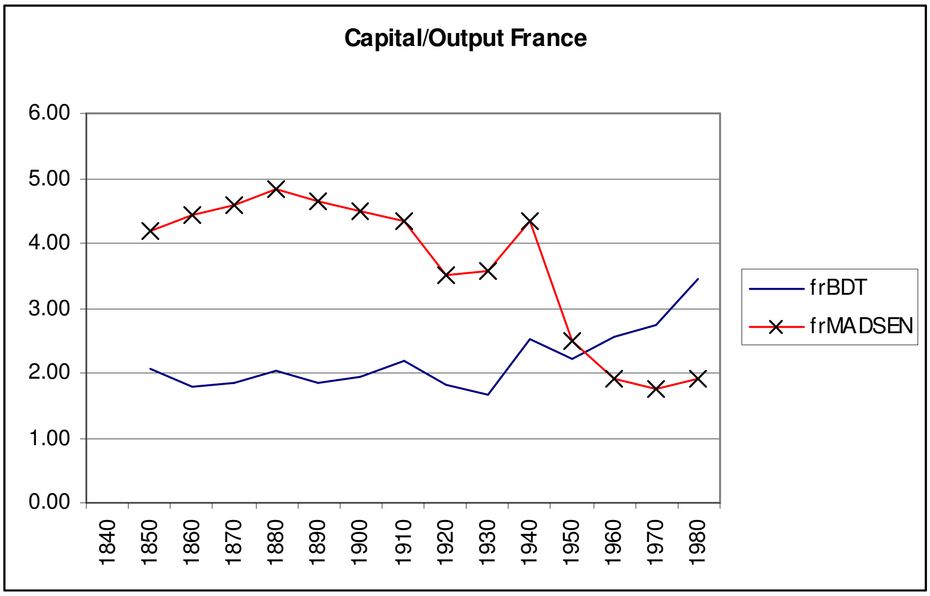
Note: Abbreviations see Table 3.3

Figure 3.17: Capital-output ratio, Finland



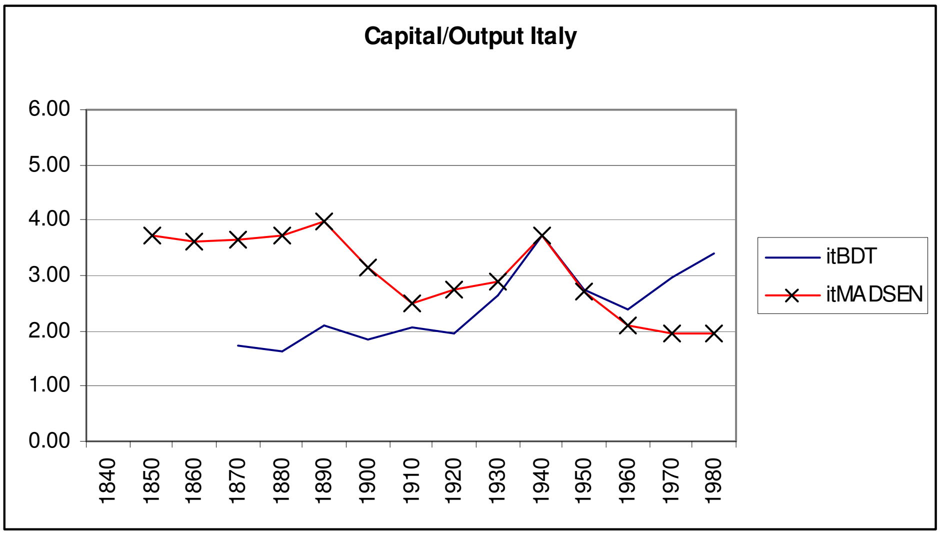
Note: Abbreviations see Table 3.3

Figure 3.18: Capital-output ratio, France



Note: Abbreviations see Table 3.3

Figure 3.19: Capital-output ratio, Italy



Note: Abbreviations see Table 3.3

We conclude that the dataset compiled by Baier, Dwyer and Tamura (2006) is as reliable as alternative estimations. In addition, it is the only data set that allows us to follow governmental efficiency for up to 130 years in a panel of 60 countries. BDT is the most suitable dataset in the prevailing context, since the other ones do not offer improvements in terms of quality or quantity.

Appendix C.2: Reliability of the efficiency estimates

Table 3.6 shows the correlation coefficients between alternative estimations of governmental efficiency. BDT, for instance, stands for the efficiency estimation based on the measure of physical capital – the other in- and outputs are hold constant - provided by Baier, Dwyer and Tamura (2006) as it is described above. The correlation matrix suggests that altering the measure of physical capital does not change the estimates of government performance significantly. The correlation coefficients between the DEA values based on BDT and its alternatives lie in the range of 0.68 and 0.95. None of our conclusions depend on the choice of the capital measure.

Figures 3.20 to 3.23 show the efficiency trends for selected countries based on the capital data from BDT and Madsen, respectively. Although the detailed forms differ, the general conclusions to be drawn from the series are similar. We therefore conclude that our results do not depend on the choice of the capital measure.

Table 3.6: Correlation between different efficiency estimations, each based on alternative estimation of physical capital

	BDT	BE	PWT	Maddison	LBMC	Madsen
BDT	1					
BE	0.81	1				
PWT	0.74	0.95	1			
Maddison	0.96	0.85	0.89	1		
LBMC	0.68	0.77	0.82	1	1	
Madsen	0.75	0.78	0.94	0.99	0.91	1

Notes: Abbreviations see Table 3.3

Figure 3.20: DEA Scores Canada

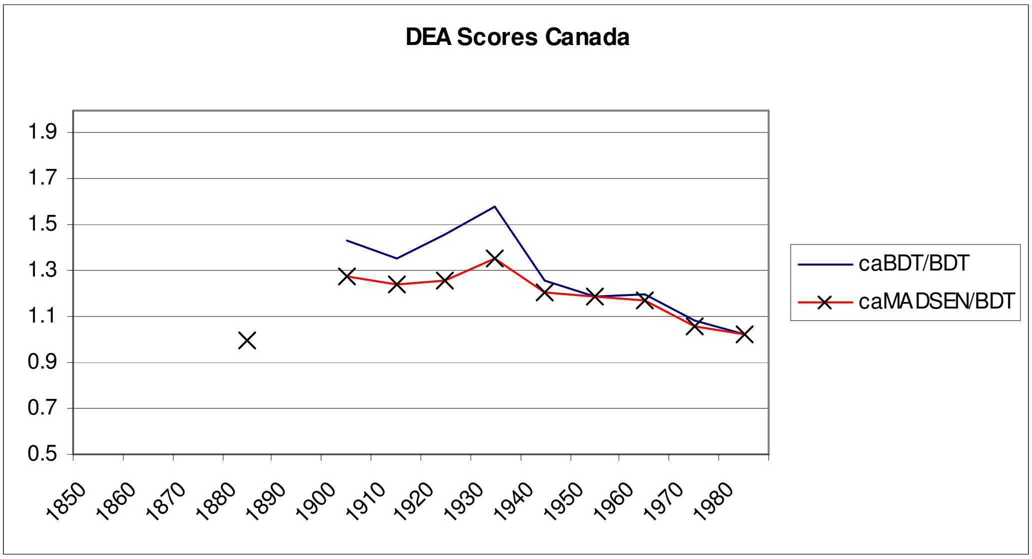


Figure 3.21: DEA Scores Denmark

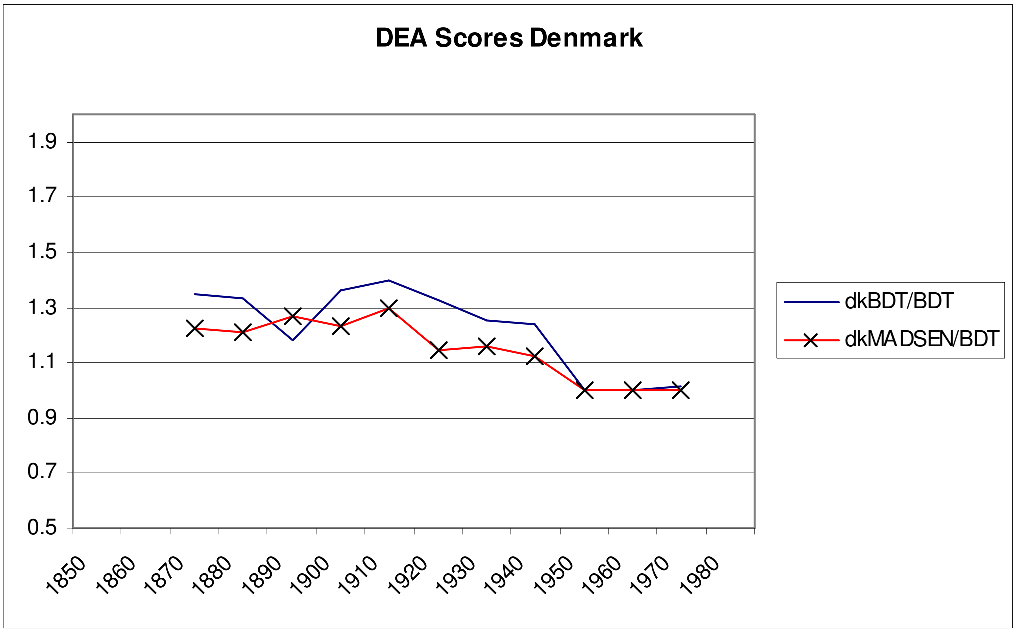


Figure 3.22: DEA Scores Netherlands

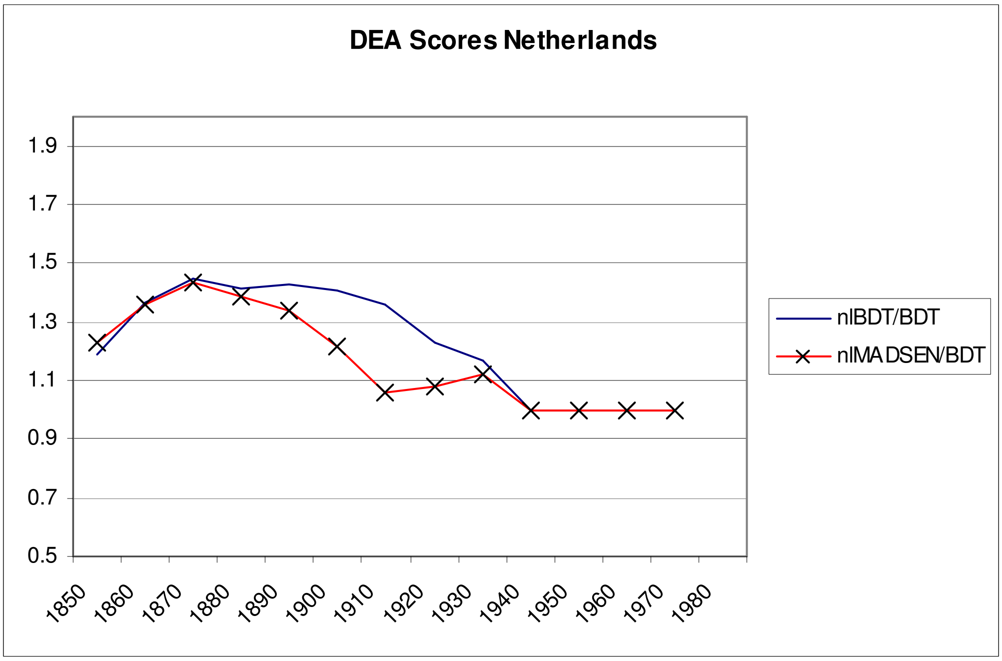
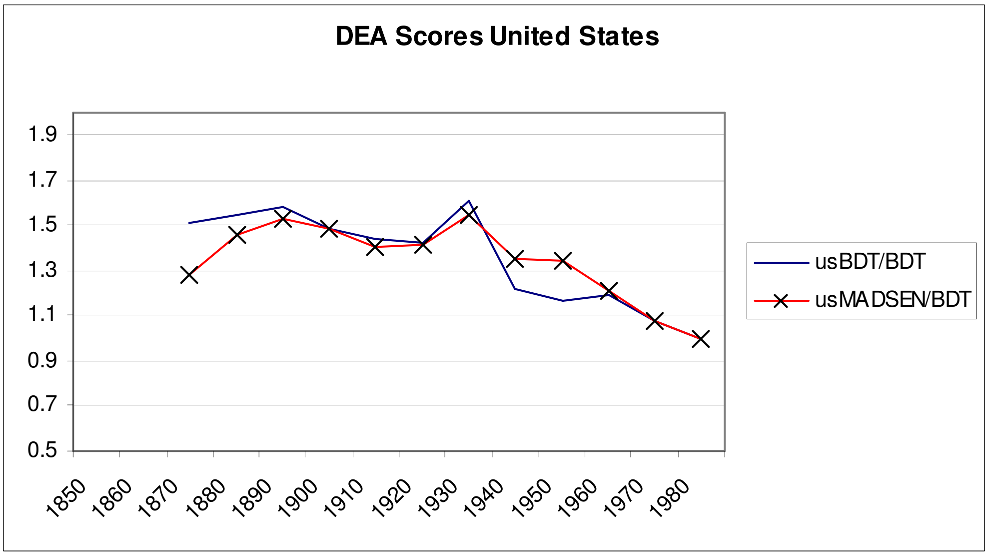


Figure 3.23: DEA Scores United States



Appendix C.3: Reliability of the human capital stock estimates

Several global long-run datasets on human capital are available. In general, we can discern two different types. First, there are data such as school enrollment, signature ability, literacy or numeracy, which have an upper bound, as they reach values of 100 percent during the course of development. Second, there are measures such as average years of schooling which do not face such a boundary. For our analysis it would be unreasonable to use datasets with an upper bound since they reach high values already during early stages of economic development. Both Baier, Dwyer and Tamura (2006) and Morrisson and Murtin (2009) provide estimates of human capital on a global scale. These authors offer a good compromise, as they construct series without an upper bound during the twentieth century and their data incorporate more than only basic skills.

Moreover, in the underlying context relying on data that is arranged by birth decades of the people holding the human capital is undesirable. In order to use human capital as an input in an economic process, all people in the labor force have to be taken into consideration. Data arranged by birth decades rather indicate the quality of the time one particular cohort is schooled. This is not exactly what is in demand in this paper. In contrast, BDT estimate the stock of human capital in the way we prefer, since they look at the population in general. They provide estimations of the human capital stock available for the economy on a decadal basis.

Their values on human capital are calculated by combining average years of schooling, which were calculated by including enrollment ratios (including primary, secondary and college education), the age distribution of the population and the average working experience. They are able to show that human capital was strongly increasing during the 19th and 20th century.

We compare the BDT dataset with the Morrison and Murtin (2009, 2010) one. The Morrison and Murtin dataset offers estimations of comparable quantity and quality. The estimates are closely correlated; the correlation coefficient is 0.9068. This shows that both sets are useful sources to describe human capital development. Here, we use the BDT data as they incorporate working experience as well as education and therefore capture more information than the Morrisson and Murtin data.

4. THE INFLUENCE OF INEQUALITY ON THE STANDARD OF LIVING

WORLDWIDE EVIDENCE FROM THE 19th AND 20th CENTURIES

4.1 Introduction

In 1854, Hermann Heinrich Gossen published his ideas on how individual consumption leads to individual welfare. He demonstrates how the marginal return of consumption diminishes the more units are consumed. Therefore, he claimed, resources should be spent in a way that in the end the marginal returns of all consumed goods equal each other. Today, his findings are known as the *'Gossen's Laws'* and belong to the fundamentals of welfare economics.

Dalton (1920) goes one step further and argues that in a population the marginal product of income is lower among the rich compared with poor strata, just because the rich have already reached a higher standard of living than the poor. This implies that redistribution from rich to poor strata can increase aggregate welfare because the extra gain of the poor outweighs the loss of the rich. Therefore, in a static and theoretical world, aggregate welfare is - ceteris paribus - expected to be maximized when redistribution has equalized the income of all individuals. Although this situation is far away from reality, it offers interesting insights into the determinants of a nation's welfare.

There is a long tradition of studies that try to investigate this relationship between inequality and welfare. Preston (1975), for instance, found that, among poor countries, increases in purchasing power go along with strong improvements in health. Among rich countries this effect is weaker or even absent. Rich countries require more additional income for the same increase in terms of health compared to poor countries due to diminishing marginal returns to income. He remarks that if this mechanism is also at work within countries, redistribution from rich to poor social strata can increase average health.

Sawyer (1976) argues in a similar way. He finds a strong negative correlation among OECD countries between life expectancy and the Gini values of their income. Wilkinson (1992, 1996) shows a positive relation among several developed countries between the income received by the least well off 50% of the population and life expectancy. Therefore, he states, the lower half of the income distribution is the most sensitive to income inequality. Similarly, Leigh and Jencks (2007) find a weak increasing impact of the top 10% income share on infant mortality and a negative one on life expectancy. However, after summarizing decades of research in this field, Deaton (2003, p.151) concludes that income inequality itself is no major determinant of population health because, among others, nobody has provided a robust correlation so far.

The present study follows an alternative approach to address this lacuna. Unlike the studies mentioned above, this paper uses anthropometric measures, namely adult male height and the coefficient of height variation (henceforth 'CV') as indicators of well-being and economic inequality, respectively. This methodology offers several advantages. The biggest benefit is its output-oriented character, since it combines several sources of income and does not only rely on inequality of purchasing power.[38] In addition, we can rule out many other influences that sometimes come along with inequality. Steckel (1983, 1995) and Carson (2009) take advantage of this by using height as the dependent variable in a similar analysis. Unfortunately, their main explanatory variable is not measured in the same way, but as a Gini coefficient of income. In contrast, the underlying data set provides corresponding values for average height and height inequality. This provides the opportunity to perfectly link those two yardsticks and analyze if they are correlated.

This study provides information both on the (biological) standard of living, measured as average male height, and the corresponding (biological) inequality, measured in height CVs, during the 19th and 20th centuries. We argue that inequality is an important influencing factor of the standard of living. We include Lindert's (1994, 1998, 2004) data on redistribution into our analysis in order to test Preston's (1975) hypothesis that

[38] On this account, when the term 'income' is applied, the authors refer to several sources – monetary and non-monetary - of income.

redistribution increases aggregate welfare. Our results support this hypothesis, since our regression results indicate a positive influence.

Our results indicate that the negative influence of inequality on average height has existed throughout the past two centuries; it still does and has even been strengthening during the second half of the 20th century. The results are unambiguous with just one exception: Eastern European countries in the 20th century show no correlation between these two variables, although the effect in the 19th century is obvious.

The paper is structured as follows: The second section deals with the methodology, while section 3 discusses the characteristics of the data. In section 4, the paper's strategy is described and in section 5 the results are presented. Section 6 concerns potential biases and doubts of the analysis, section 7 concludes.

4.2 Methodology

Conventional monetary welfare measures such as real wages or GDP per capita are normally based on official statistics. Therefore, they are often limited to taxpayers although a comprehensive picture of the society - including other sources of income - is required for an analysis (Deininger and Squire 1998). Closing this important gap primarily requires finding a way to include self-employed people, like peasants practicing subsistence farming, unemployed people and people working in service industries or participating in black markets into the data. Moreover, development economist and economic historians often face the problem that reliable conventional measures tend to be limited to urban areas and modern times. In less developed countries conventional data are distorted by measurement errors (Barro 2000) or are simply not available. In socialist countries this problem occurs because reliable and comparable data do not exist due to an entirely different economic system (Pak 2004, Komlos and Kriwy 2004, Schwekendiek 2009).

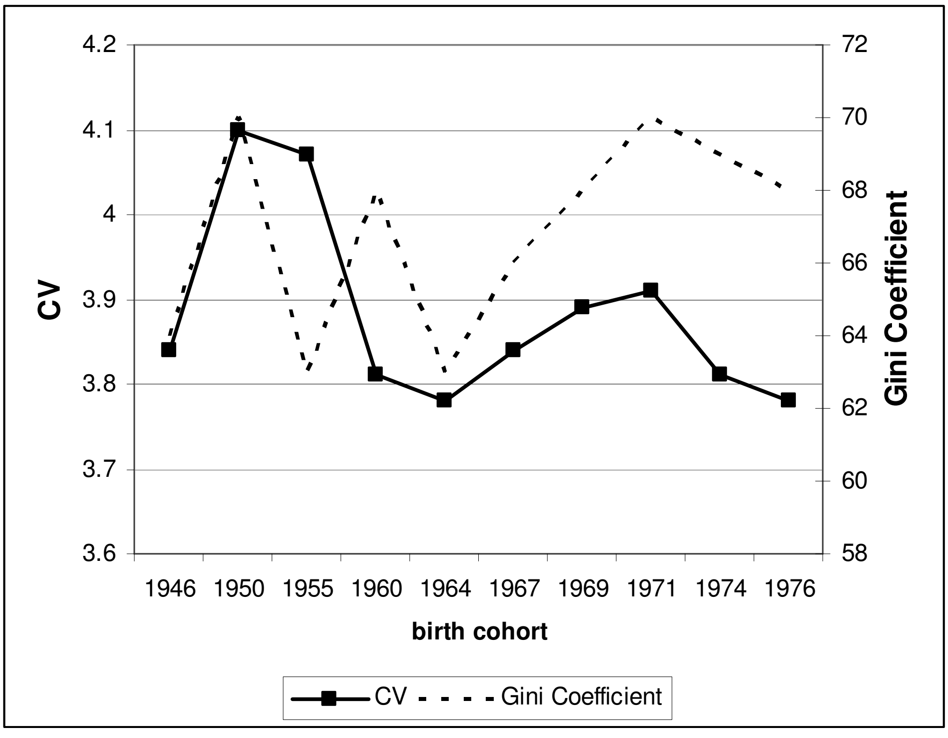
The measure applied in this study, the biological standard of living, combines several sources of income due to its output-oriented character and allows us to counter the problems described above. Measures based upon purchasing power certainly capture one important source of income. Anthropometric ones, however, include public goods such as public health care or education, income from moonlighting, subsistence farming, and intra-family transfers as well.

Another advantage adult height offers is the time of its determination. We can rule out some influences which may disturb the analysis of the correlation between inequality and height. Fuchs (1993), for example, argues that differences in time preference rates may lead to unequal investments in health and eventually to unequal health. Wilkinson (1994) and Frank (2000) emphasize the role of relative deprivation (particularly the stress it causes) and its negative psychological effects on health. Relative deprivation, however, comes along with the awareness of economic inequality, which is a common phenomenon among adults. In addition, some scholars state that reverse causality (Haddad and Bouis 1991, Haas et al. 1995) might play a role, since good health and good nutrition can lead to higher productivity. Therefore, unequal health can lead to unequal incomes and not exclusively the other way around. Although these phenomena undoubtedly exist, they do not bias our analysis because height and its distribution in a society are determined *simultaneously* mainly during the early years (about three) in life.[39] It is reasonable to assume that children at this age do not suffer from relative deprivation or benefit from a superior physical condition in terms of earnings. Nor do they choose between current and future consumption.

[39] On this account, all variables (including social spending and per-capita income) refer to the corresponding birth decade.

This kind of inequality measure, which was introduced by Baten (1999, 2000), has been used in many other studies as an informative alternative to conventional inequality measures (Baten and Fraunholz 2004, Moradi and Baten 2005, Komlos 2007, Baltzer and Baten 2008, Blum and Baten 2010). There are several studies that convincingly make a case for the use of biological inequality. Alter, Neven and Oris (2004) find that in 19th-century Belgium there were differences in height between occupations, and especially between rich and poor strata. The authors report that the gap between the wealthiest and the poorest was about 8 centimeters, and these differences can be explained by economic conditions during childhood. Komlos (2007) reports that at the same time in England, height differences among 16-year olds were about 22 centimeters. Komlos et al. (2003) argue that height inequality in early-modern France led to major dissatisfaction and finally to the French Revolution.

Figure 4.1: Development of income and female height inequality in Kenya during the 20th century



Source: Moradi and Baten (2005)

Although height inequality and income inequality are not perfectly correlated, they follow a similar pattern. Moradi and Baten (2005) find a positive correlation between these two measures in different regression specifications and therefore conclude that the height CV is a valuable measure of economic inequality. Figure 4.1 shows the development of both the female height inequality (CV) and the income Gini in Kenya during the 20th century. The two trends are not perfectly synchronized, but the inequality development is shown in a similar way both by the anthropometric and the monetary measure. A very recent study even goes so far as to estimates Gini coefficients using CVs (van Zanden et al. 2010).

4.3 Data

We apply an extended version of the data set on height inequality used by van Zanden et al. (2010). A great deal of the height data was published in anthropological journals (from the mid 19th century to about 1930) or medical and economic ones (from then on). By far the best sources were samples calculated from individual data, mainly because those researchers collected height data with the intention to use it as an anthropometric welfare indicator. To a certain extent we were able to collect individual data ourselves, but the contributions of individual data sets from other authors have also been a great assistance.[40]

We included a variety of dummy-variables into the analysis in order to be able to identify observations with special characteristics. To give an example, observations are

[40] I thank Jörg Baten, Dorothee Crayen, Robert Fogel, Nadine Frerot, Ricardo Godoy, Laurent Heyberger, Michał Kopczyński, Kerstin Manzel, Sunyoung Pak, Valeria Prayon, Inas Rashad, Daniel Schwekendiek, Mojgan Stegl, Yvonne Stolz and Linda Twrdek for contributing their data. We also want to thank Jörg Baten, Dominic Behle (the 'Ghost of *Research* Present'), Herman de Jong, Ralph Hippe, Pedro Lains, Kerstin Manzel, Eóin McLaughlin, Cormac Ó Gráda, Valeria Prayon, Jaime Reis, Mojgan Stegl, Linda Twrdek, the participants of the 'Economic and Social History Workshop' in Oxford and the 'Centre for the Study of Wider Europe's Workshop' at NUI, Maynooth for valuable comments on earlier drafts of this paper.

based on students or sportsmen and hence might suffer from an upward bias, since individuals in those groups underwent different kinds of selection. Students often come from upper class families and enjoyed better nutrition and medical resources during their childhood than the average child.

A small fraction of our sample is based on migrant data. Migrants often undergo several stages of selection. Twrdek and Baten (2010) find that migrants moving to Argentina between the 1900s and 1930s are mostly positively selected in comparison to the population in their home country. Their results indicate that particularly immigration policy, poverty constraints, and chain migration played an important role in determining the selectivity of migrants. During the compilation of the dataset we tried to avoid observations calculated from migrant data but chose unselected individuals. We can identify the selection effect among the remaining migrant observations by including another dummy variable for migrant observations.

Several scholars have investigated the reliability of self-reported height and some find that self-reported height measurements tend to be upward biased. There are several potential sources of this bias. Niedhammer et al. (2000) find that among others age, educational level, and occupation can play a role regarding the accuracy of the individual statement. Spencer et al. (2001) find that the overestimation increases with age, low actual height and obesity. Strauss (1999), however, compared the self-reported height and the actual height of young adolescents and finds no systematic bias. In the underlying study, a bias due to old age can be ruled out since we include only individuals under the age of 50. Nevertheless, a dummy variable controls for self-reported heights in the regression models because for some of the observations we do not have information on biasing characteristics correlated with self-reported body measures.

Since armed forces frequently introduced a minimum-height-requirement, data drawn from military records may suffer from a special shortfall. Figure 4.2 (appendix) shows the distribution of 175,436 Bulgarian conscripts born in the 1880s. Since no conscripts were drafted below the stature of 153 cm, this selected population implies an upward biased mean height value. We carefully checked individual data samples for this shortcoming and applied truncation regression techniques to correct the corresponding observations for this shortcoming (A'Hearn 2004, Heintel 1996, Komlos 2004).

The final panel data set contains 528 observations from 105 modern countries during the 19th and 20th centuries. Table 4.1 (appendix) gives an overview of the data characteristics. It shows that more than half of the observations come from Industrialized Countries and Transitional Countries of Eastern Europe and Central Asia. Latin America, Asia, and Sub-Saharan Africa contribute a smaller fraction; for the Middle East and North Africa only 29 observations are available. Table 4.1 also provides information on the number of observations with special characteristics. 32 out of 528 observations are either drawn from students' heights or were self-reported. 36 observations were derived from migrants; 45 observations had to be corrected by truncation techniques.

4.4 Analysis

In order to investigate the correlation between average height and height inequality several regression models are performed. In generally, we expect the correlation between inequality and height to be negative since – according to *Gossen's Laws* and the theory of diminishing marginal returns to income (Dalton 1920) – economic inequality implies an inefficient distribution of resources. The total share of resources spent on redistribution, however, is expected to be positive. To test this hypothesis, an empirical analysis using human stature on a macroeconomic level is performed.

The basic model is:

$$Stature = \alpha + \beta_1(\textit{Coefficient of Height Variation}) + \beta_2(\textit{GDP per Capita}) + \beta_3(\textit{Social Spending in \% of GDP}) + \gamma(\textit{Vector of Dummies}) + \varepsilon$$

Since the main focus lies on the interaction between inequality and average height and not only the determinants of height, the basic regression model is varied in several ways. One model specification, for example, controls for per-capita income, provided by Maddison (2001), in order to have a benchmark of a country's economic development. This can be useful since Preston (2007) states that medical improvements like vaccination, sulfonamide drugs and antibiotics are fairly cost-intensive and usually come along with economic development. Hence, we expect per-capita income to exert a positive influence on average height and, in addition, function as a robustness test. Another model uses an interaction variable to test for an interaction effect of per-capita income and inequality.

The same technique is applied in order to test for the hypothesis that the total amount of social spending interacts with the prevailing level of inequality. Lindert (1994, 1998, 2004) provides historical data on redistribution activities (% of GDP). Apart from transaction costs, the nature of redistribution is a zero-sum game. Usually, money is taken away from rich individuals by taxation and is transferred to people in need or in situations being worth funding. Speaking in terms of marginal returns to income, money is redistributed from low returns to higher ones and is therefore expected to increase average height. It is important to include the total amount of social spending and not only one component since anthropometric indicators are able to capture intra-household transfers, no matter whether resources are provided by pensions, child benefit, or unemployment benefits.

Since it is not clear if inequality has the same impact on height throughout the world, we use interaction variables as described by Brambor, Clark and Golder (2006). To do this, we replace the variable CV with interaction variables combining world regions like Industrial Countries, Latin America, Middle East / North Africa, Sub-Saharan Africa and Eastern Europe and the Coefficient of Height Variation, respectively.[41] In another model we replaced the CV with interaction variables which combine time and inequality. By performing this variation, we are able to trace the influence of inequality on height throughout the 19th and 20th centuries.[42]

4.5 Results

The results of the regression models are shown in Table 4.2. Inequality, measured as the Coefficient of Height Variation, is negatively correlated with average height and is statistically significant. Model 1 suggests that a one unit increase of the CV goes along with a height decrease of more than 2 cm. Model 2 uses the same specification as model 1. This time, however, all observations which might suffer from any of the above described biases were excluded. In addition, 2% of all height and CV extreme values (1% of the upper and the lower extremes each) were excluded. The results suggest that the negative effect of height inequality is neither driven by observations with shortfalls nor by extreme values.

According to the theory of diminishing returns to income, the correlation between inequality and height is supposed to be negative *and* concave. Table 4.2 (model 3) and

[41] The classification of countries into world regions is explained in Table 7 (appendix)

[42] All models control for the above mentioned characteristics, such as students, truncation, self-reported heights, and migrational background. We also included time dummies to capture any time trends.

Table 4.2: Determinants of male height (cm)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inequality (CV)	-2.24*** (0.00)	-1.23** (0.04)	2.03 (0.31)	-2.43*** (0.00)	-3.03*** (0.00)	-2.62*** (0.00)	8.05 (0.11)
Inequality (CV squared)			-0.52** (0.04)				
Social Spending (as % of GDP)				0.55 (0.20)	-6.78* (0.08)		
Interaction Social Spending x CV					1.99* (0.06)		
Income/c (log)						1.41** (0.02)	6.44*** (0.01)
Interaction Income x CV							-1.40** (0.03)
Truncated (yes/ no)	-1.37*** (0.00)		-1.41*** (0.00)	-0.92 (0.11)	-1.01* (0.10)	-0.49 (0.32)	-0.51 (0.31)
Migrants (yes/ no)	1.08* (0.07)		1.05* (0.08)	-1.12 (0.29)	-0.90 (0.36)	2.29*** (0.01)	2.45*** (0.00)
Students (yes/ no)	2.21*** (0.00)		2.35*** (0.00)	1.45 (0.13)	1.18 (0.20)	1.22** (0.04)	0.83 (0.26)
Self-Reported (yes/ no)	-0.23 (0.80)		-0.09 (0.92)	0.95 (0.42)	3.19** (0.03)	-1.54 (0.13)	-0.96 (0.29)
Constant	174.18*** (0.00)	169.69*** (0.00)	165.65*** (0.00)	173.956*** (0.00)	173.51*** (0.00)	173.57*** (0.00)	135.72*** (0.00)
No. of Observations	528	401	528	97	97	238	238
Number of Countries	105	98	105	23	23	40	40
R-squared (overall)	0.32	0.26	0.33	0.29	0.28	0.50	0.47

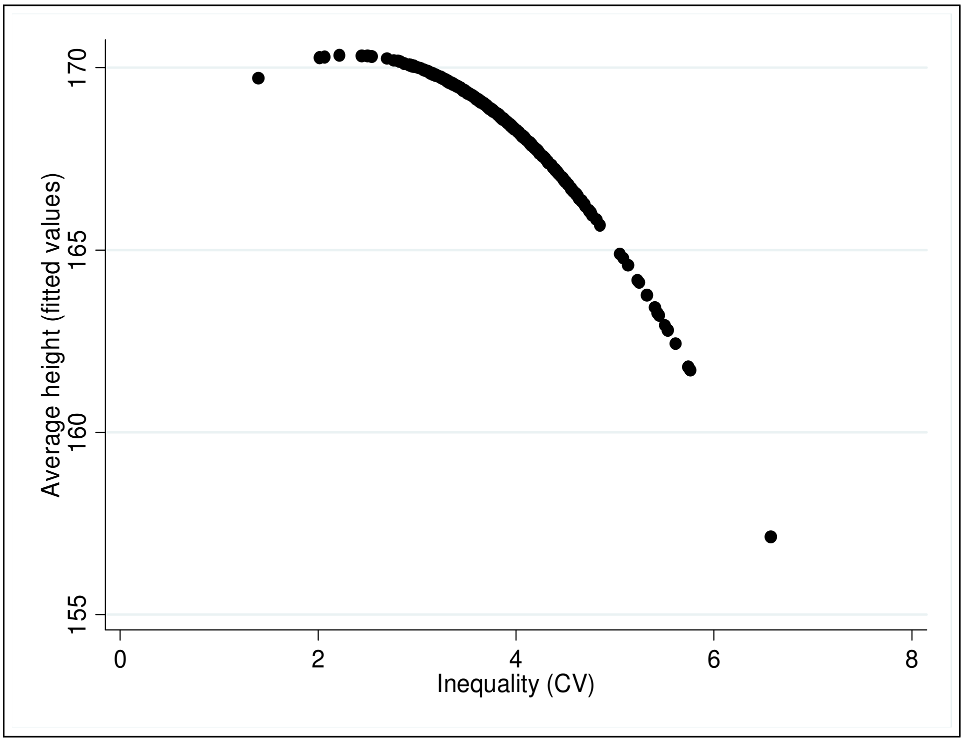
Note: * significant at 10%; ** significant at 5%; *** significant at 1%. All models control for country-specific fixed effects and use robust standard errors. Data source: see References II

Figure 4.3 show this relationship.[43] The combination of inequality and its squared term indicates a concave relationship between height inequality and average height. On a concave (and negative) shaped function, the part of the function with high inequality

[43] Concavity *per se* does not prove a negative relationship, but after calculating the maximum of this CV-parabola it turns out that the overwhelming majority of the observations exceed the global maximum.

values shows a steep slope indicating that a reduction of inequality or a rise of redistribution increases average height considerably. In such a situation, the marginal returns to income of the lower and the upper height distribution differ enormously and redistribution shifts money to places (and individuals) with high beneficial effects. With decreasing inequality values, the slope becomes flatter until it tends to zero.

Figure 4.3: Concave correlation between inequality (CV) and height (fitted values)



Data source: see References II

At the other extreme, marginal returns to income of upper and lower strata are similar since height differences between the social classes are only small. This systematic indicates that the more unequal a society's income distribution, the more welfare potential is left for the lower strata because of the low (high) marginal returns to income of the rich (poor) part of the society. Inequality could work as a leverage: the more unequal the society, the more potential for improvement is left and the higher is the expected welfare increase of redistribution. In models 4 and 5 Lindert's data on public social spending (as % of GDP) are included. The results indicate that redistributing money from rich to poor strata increases average height. Although the said coefficient is statistically insignificant in Model 4, it suggests that average height can be increased by increasing social spending.[44] In Model 5 an interaction term combining social spending and height inequality is applied. When the average CV value of 3.79 (see descriptive statistics; Table 4.1) is entered into the estimation formula, the resulting effect of social spending is positive (.7621) and statistically significant.[45] When calculating the total effect of height inequality on average height the coefficient is -1.74 compared to -2.24 in model 1.[46] The comparison of those coefficients reveals that social spending weakens the negative influence of inequality slightly.

Models 6 and 7 include (log) per-capital income as a benchmark for the stage of a country's economic development. High values of GDP represent achievements of economically successful states, e.g. low infant mortality rates and high quality nutrition (Baten and Blum 2010). This variable is also an indicator of a nation's possibility to offer public goods and the diffusion of advanced technology, such as medical care or pharmaceutics. Model 6 is designed as a simple multiple regression analysis that reveals a negative influence of height inequality and a positive one of per-capita income on the dependent variable. In Model 7, once again, an interaction term is applied which combines per-capita income and inequality. The results indicate that – given a certain level of inequality – the higher the stage of development the greater the inequality effect. In other words: In developed countries there is the opportunity to satisfy everybody's needs, including the lower end of the height distribution without considerable losses at the

[44] Since the nature of redistribution is a transfer of resources from rich to poor classes, an interaction of height inequality and social spending comes to mind. The comparison of models 1 and ¾ suggests that collinearity is no danger to the relevant regression models.
[45] Total effect of social spending = 3.79*1.99 + (- 6.78) = 0.7621.
[46] Total effect of height inequality = 0.65*1.99 + (- 3.03) = 1.7365.

other end of the distribution (losses in terms of money certainly exist due to redistribution, but height losses are barely conceivable). In this situation, individuals belonging to the upper end of the height distribution already enjoy high incomes and their marginal returns to income are low. The marginal returns of the lower strata, however, are higher and leave space for improvement.[47] This systematic implies that it is important to look on the ratio of the upper *and* the lower classes' marginal returns in order to get a comprehensive picture of the effect of inequality and redistribution.

Since the explanatory variables height inequality, social spending and per-capita income are measured in different units, the comparison of their effect on average height is problematic. A possible solution are standardized coefficients. Table 4.3 shows the regression results of models 1, 3, and 5 and the standardized beta coefficients of the explanatory variables. Their values are directly comparable and can be interpreted similarly. The comparison of beta values reveals that the influence of inequality is almost as strong as the influence of per-capita income. A one standard deviation increase of height inequality causes a change of average height of -.21 standard deviations. The corresponding values for per-capita income and social spending are .23 and .12, respectively.

Furthermore, we included several dichotomous variables to control for observations that might have undergone some kind of selection. Table 4.2 partially confirms the above described concern. Observations drawn from students show a significantly higher stature.[48] The positive coefficient of migrants confirms Twrdek and Baten's (2010) results, who find that migrants arriving in Argentina were positively selected compared to their home population.

[47] When entering the mean value for log income (7.73) into the estimation formula, the overall effect of inequality becomes negative: total effect of CV = 8.05 - 1.4 * 7.73 = - 2.772

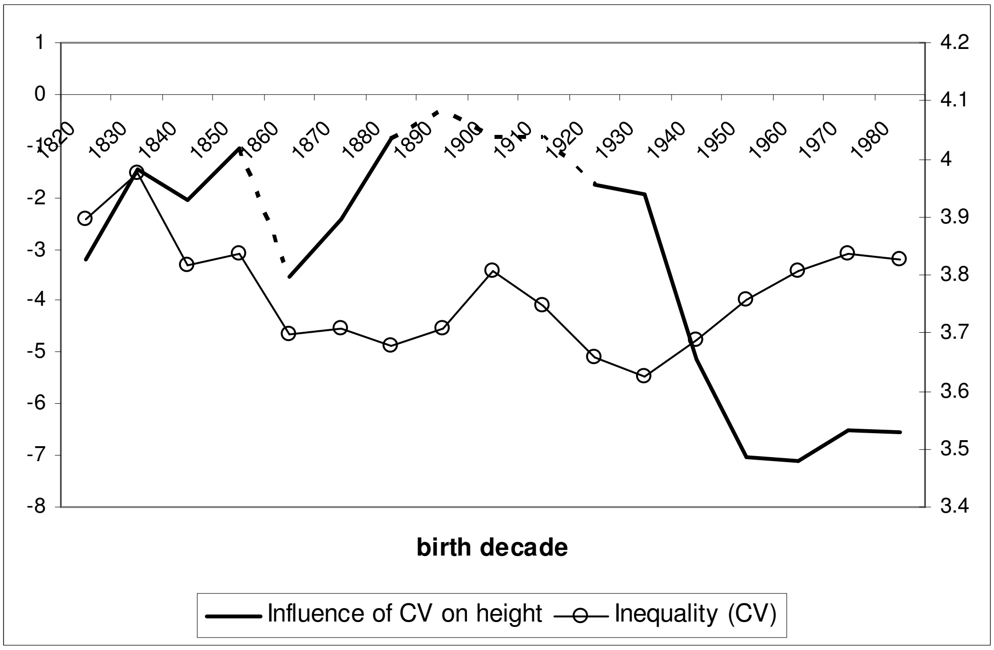
[48] The reference category are those variables with no shortcomings.

Table 4.3: Determinants of male height (cm) and its standardized coefficients (models 1, 3, 5):

	(1)	beta	(3)	beta	(5)	beta
Inequality (CV)	-2.24*** (0.00)	***-0.21***	-2.43*** (0.00)	***-0.21***	-2.62*** (0.00)	***-0.20***
Social Spending			0.55 (0.20)	***0.12***		
Income/c (log)					1.41** (0.02)	***0.23***
Truncated (yes/ no)	-1.37*** (0.00)		-0.92 (0.11)		-0.49 (0.32)	
Migrants (yes/ no)	1.08* (0.07)		-1.12 (0.29)		2.29*** (0.01)	
Students (yes/ no)	2.21*** (0.00)		1.45 (0.13)		1.22** (0.04)	
Self-Reported (yes/ no)	-0.23 (0.80)		0.95 (0.42)		-1.54 (0.13)	
Constant	174.18*** (0.00)		173.956*** (0.00)		173.57*** (0.00)	
No. of Observations	528		97		238	
Number of Countries	105		23		40	
R-squared (overall)	0.32		0.29		0.50	

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. All models control for country-specific fixed effects and use robust standard errors. Data source: see References II

Figure 4.4: The influence of inequality (CV) on height by birth decade



Note: For every birth decade the hypothesis is tested that the influence of inequality is different from 0. Therefore, values on the ordinate indicate the total influence of inequality on height by birth decade. Values not significant at least on the 10% level are indicated by the dashed part of the line. Data source: see References II

Figure 4.4 and Table 4.5 (appendix) also describe the influence of inequality on average height. In contrast to the basic regression models, Table 4.5 reports one coefficient for every single birth decade between the 1810s and 1980s using interaction variables as described in Brambor, Clark and Golder (2006).[49]

The trend shown in Figure 4.4 indicates that the influence of inequality on height has always been negative, but not constant over time. In fact, the coefficients representing the influence of inequality in early periods (until the 1940s) suggest that the negative influence was rather modest, but started to increase during the second half of the 20th century. This finding is consistent with the results of regression model 7 in Table 4.2, which finds that the strength of the negative influence increases with economic development. Figure 4.4 also shows that mean (within-country) inequality was increasing permanently in the post-WWII period. In order to put this result in perspective the average height trend (Figure 4.5) has to be applied. Beginning in the 1940s the growth of average height accelerates as a result of rising living standards in general. The combination of this information suggests that – unlike in preceding, rather static periods – the massive increase of average height went along with increasing inequality values. This scenario looks similar to the one described by Kuznets (1955), where some individuals in a society benefit from rising wealth while others do not. Moreover, increasing average height entails the *possibility* to redistribute without major height losses for rich strata since those individuals have already become very close to their growth potential. Speaking in terms of utility theory, during economic development the marginal returns to income decrease faster among rich individuals compared to poor ones. Therefore, the increasing negative influence of inequality can be considered as the result of the

[49] The interaction variables between CV and world regions/ birth decades report the total influence of inequality on height.

concentration of wealth on a high level of economic development where it does not result in considerable height growth.

Table 4.6: The influence of inequality on welfare by world region

	Height (cm)
*CV * Industrial Countries*	-2.10***
*CV * Latin America*	-1.97***
*CV * Asia*	-2.85***
*CV * Middle East/ North Africa*	-2.98***
*CV * Sub-Saharan Africa*	-2.47**
*CV * Eastern Europe*	-1.40
Migrants (yes/ no)	1.13*
Students (yes/ no)	2.32***
Self-Reported (yes/ no)	-0.27
Truncated (yes/ no)	-1.37***
Constant	171.67***
Country Fixed Effects?	YES
Time Dummies included?	YES
Observations	528
Number of Countries	105
R-squared	0.35

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. All models control for country-specific fixed effects and use robust standard errors. For every world region the hypothesis is tested whether the influence of inequality is different from 0. Therefore, the interaction variables between CV and the various world regions are the total influence of inequality on height by world region. Data source: see References II

The same technique is applied to differentiate between world regions. Interaction variables help to distinguish the influence of inequality within Industrial Countries, Latin America, Asia, Middle East/ North Africa, Sub-Saharan Africa and Eastern Europe, respectively. The fact that these regions are different in terms of institutions, economic systems, culture and religion suggests a separate investigation. Table 4.6 shows the result of this regression model. Globally we find a significant negative relationship between inequality and average height; however there is one notable example, Eastern Europe. The result for Eastern Europe – especially in the 20th century – raises the question why the underlying mechanism is not observed in this world region. To take a closer look on this world region, we separate the Eastern European observations into two halves; the 19th and 20th century. Figures 4.8 and 4.9 (appendix) show the results of this measure. In the 19th century the correlation between inequality and height is negative, as expected. However, the scatter plot of the 20th century reveals that the negative correlation turned into almost no correlation. It is not possible to identify a clear slope in the scatter plot. When thinking of this world region in the 20th century, immediately the introduction of communism comes to mind. However, the theory of diminishing marginal returns to income is independent of the type of regime. The variation of height, however, might be less in a communist world. As a matter of fact, one feature of Eastern Europe after 1900 is that average inequality decreases slightly from 3.69 to 3.62 (according to the observations included in regression model 1), the standard deviation of the CV values decreases from .36 in the 19th to .30 in the 20th century.

4.6 Econometric issues and other doubts

One potential source of estimation problems is endogeneity caused by reverse causality. Is it possible that average height influences inequality? Meeker (1974), for instance, calculates the gain of the reduction of disease-caused time loss and the rise in life expectancy by the installation of elementary health-protecting equipment between 1880 and 1910 in the US. Therefore, in some scenarios it might be easier for rich societies to reduce inequality by supporting the poor, the old and the sick systematically. We consider this possibility and control for social spending and the national per capita income in several model specifications and find that modifying the basic regression model does not change the results considerably.

In addition, does the fact that average height is present on both sides of the equation – as the dependent variable and as part of the CV – cause a negative correlation between height and CV? Assuming that inequality is constant (and mean height is not) between countries and over time might lead the reader to the conclusion that regressing height on something that is divided by height inevitably causes a negative correlation. In order to investigate if our results are the product of a statistical phenomenon, we show the distribution of inequality and run the regressions of section 5 one more time. This time we use the standard deviation of heights as a measure of inequality instead of the CV and obtain almost the same results.

Since Schmitt and Harrison (1988) express doubts that the standard deviation of heights are reliable throughout all income levels due to a natural increase of height variation during economic development, we decided to follow Baten's (1999, 2000) example and use the CV in the first place. The following formula is applied:

$$CV_{it} = \frac{\sigma_{it}}{\mu_{it}} \cdot 100$$

By using the standard deviation of height as a robustness check we certainly forego the CV as a hedge for the naturally increasing standard deviation during economic development, but the experiment conducted above makes sure that the negative coefficients in Table 4.5 are not statistical artefacts. Table 4.4 shows the results. The use of the standard deviation instead of the CV as a measure of inequality has only minor impact on the regression results and therefore indicates the robustness of the results. The comparison of Tables 4.2 and 4.3 reveals that the R-squared decreases by 2 and 8 per cent when the standard deviation is applied. Apart from that, inequality in Table 4.4 shows a slightly lower t-value compared to the one in Table 4.2. The coefficients describing the impact of social spending, per-capita income and the control variables, however, remain almost unchanged.

Moreover, Figures 4.6 and 4.7 (appendix) suggest that inequality is not constant, in fact, the distribution looks almost perfectly normally distributed. The comparison of Figure 4.6 and 4.7 reveals that the transformation of standard deviation values into CVs does not change the character of the distribution, it only becomes tighter.

People being unfamiliar with anthropometrics are often concerned by the idea that genetic and cultural differences could cause some kind of measurement error. However, the law of large numbers makes sure that individual genetic determinants cancel each other out, when large populations are being observed. Furthermore, we control for systematic differences *between* countries, such as culture, religion, dietary patterns and genetics by including country fixed-effects into the regression models.

4.7 Conclusion

This study offers insights into the influence of inequality on welfare, measured by average height. While a great deal of the literature dealing with this issue makes use of monetary measures, such as the gini coefficient of income, this study applies alternative measures of income and its distribution, namely average adult (male) height and the coefficient of height variation. This measure does not entail biases like relative deprivation, different time preference rates or reverse causality, since the final adult height as well as the distribution of height is determined *simultaneously* during the early years in life.

The results indicate that inequality is negatively correlated with average height. Rich individuals tend to have lower marginal returns to income, while for poor individuals the opposite is true. An unequal income distribution goes along with unequal returns to income, so that a reduction of inequality could lead to increasing living standards. Accordingly, redistributing income from upper to lower strata also leads to increasing average height – although rich individuals lose. However, the gains of the poor outweigh the losses of the rich. This result is even more noticeable because the bureaucracy necessary for operating a redistribution system requires considerable resources which cannot be used directly to create welfare and have to be considered as 'sunk' for the use in any other welfare producing process.

The negative influence of inequality on living standards is neither restricted to one exceptional world region nor is it restricted to a certain period in time. In fact, starting in the 1940s the negative influence of inequality – simultaneously with within-country inequality itself – increases. Although the negative impact does not to seem to be constant, it can be traced throughout the past two centuries.

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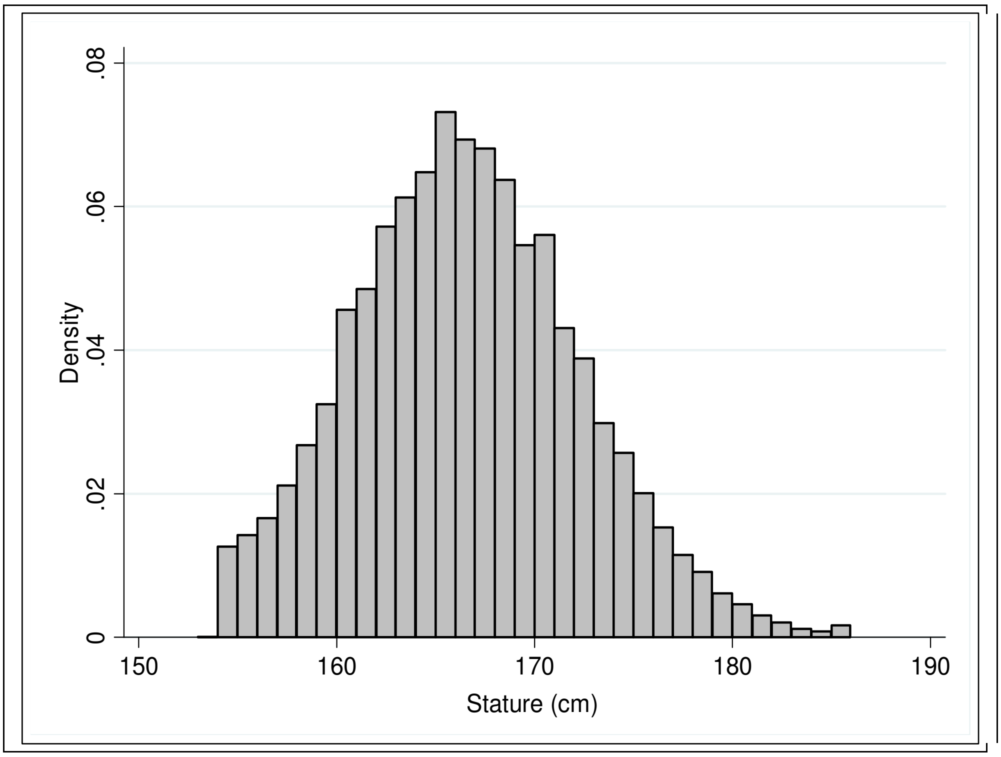
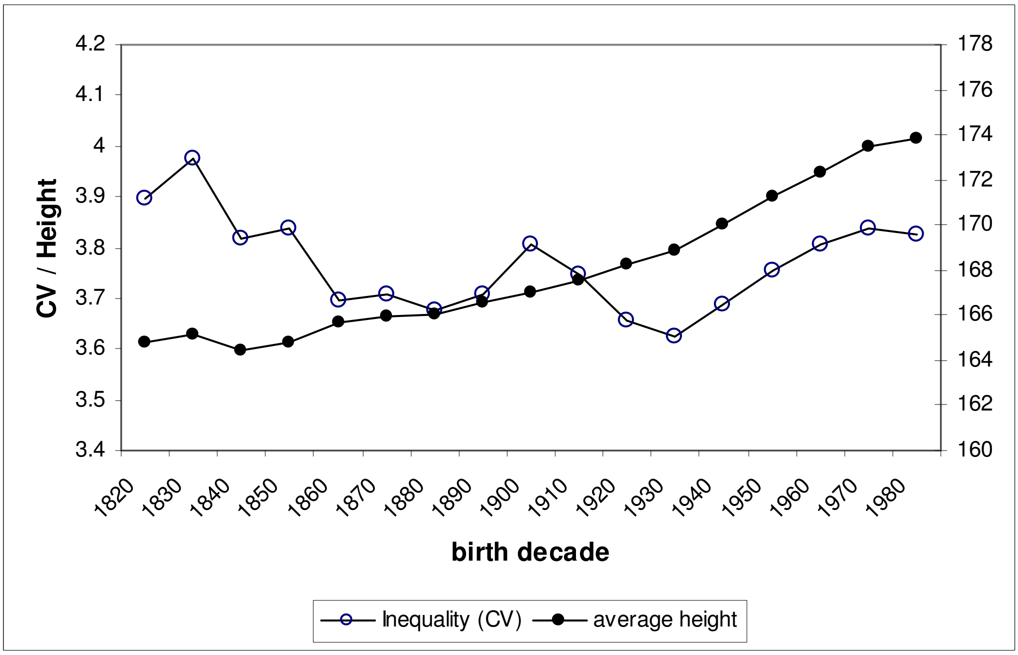
Appendix

Figure 4.2: Bulgarian conscripts born in 1880



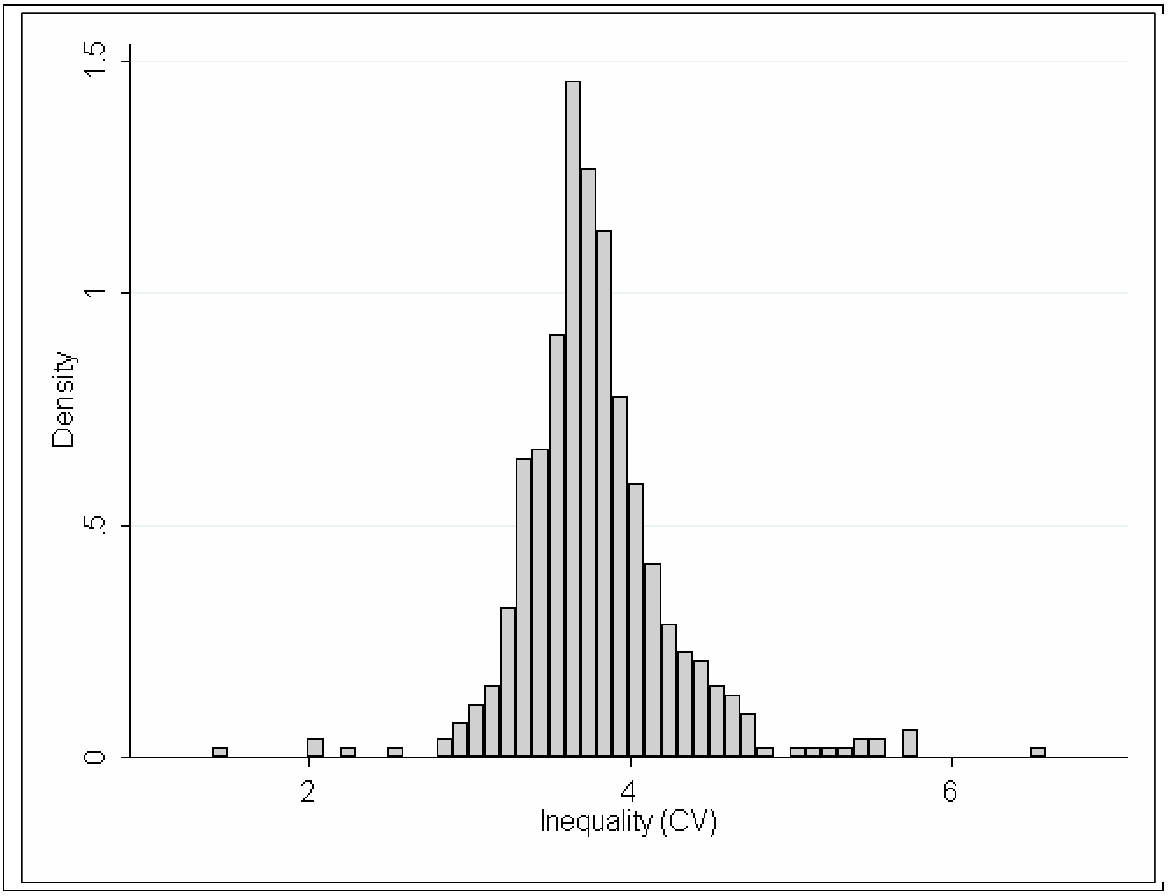
Source: Drontschilow 1916

Figure 4.5: Inequality (CV) and average height during the 19th and 20th centuries



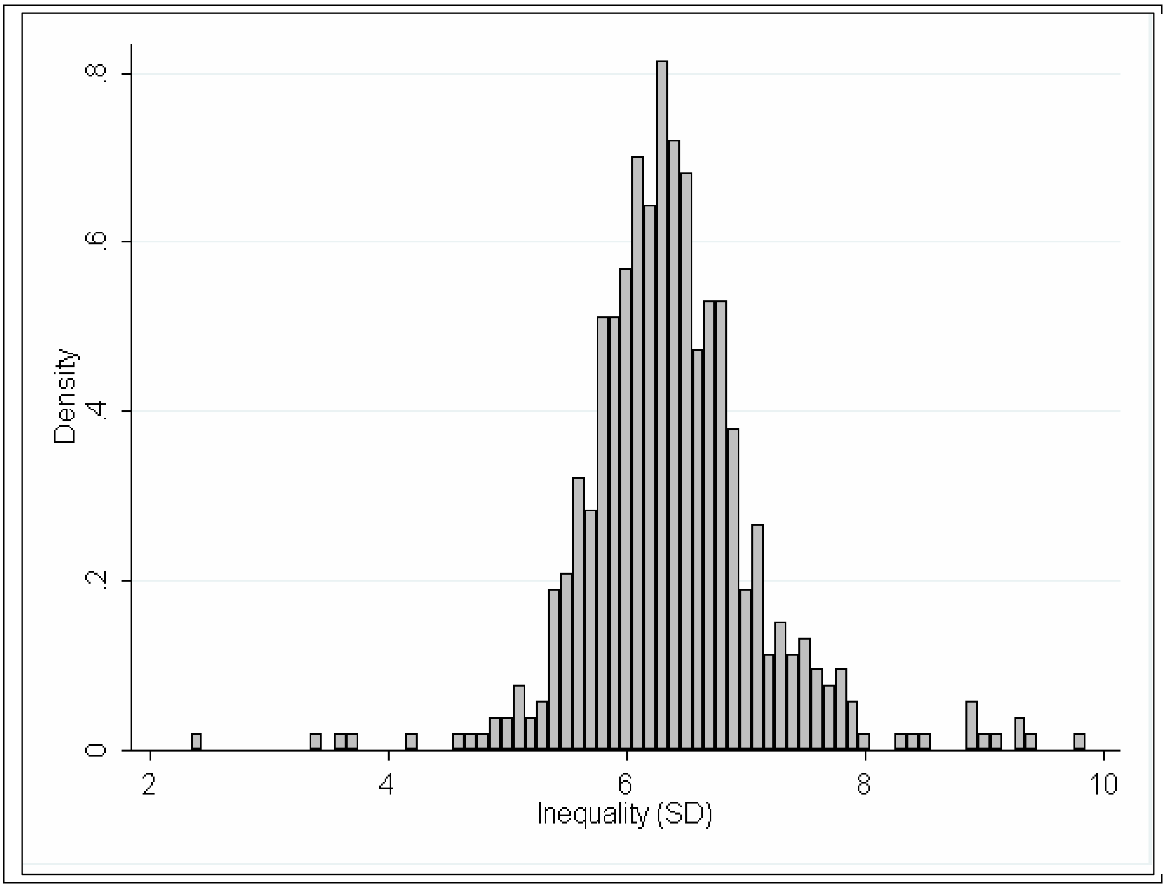
Data source: see References II

Figure 4.6: Frequency distribution of CV values (cases included as in Model 1)



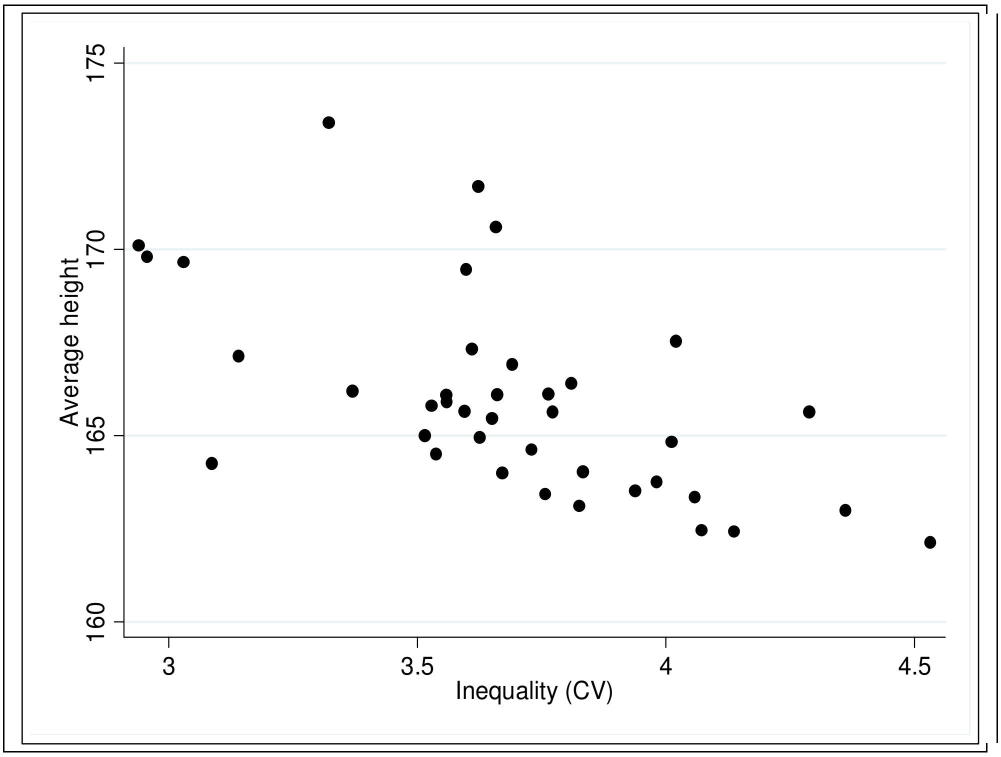
Data source: see References II

Figure 4.7: Frequency distribution of Standard Deviation values (cases included as in Model 1)



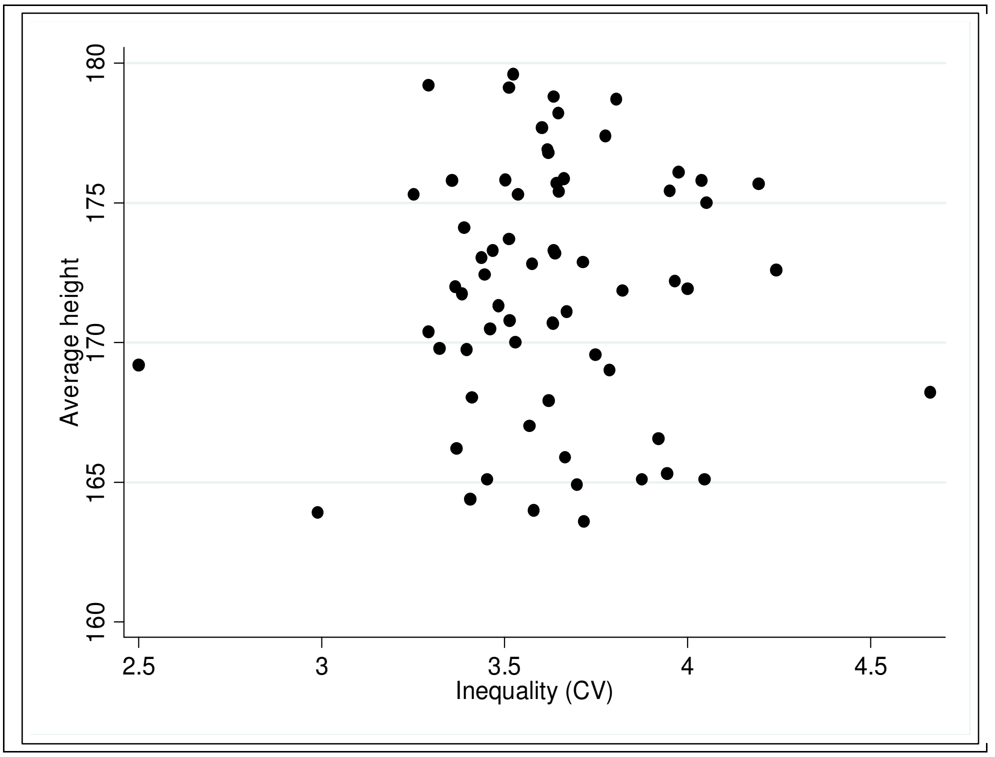
Data source: see References II

Figure 4.8: Correlation between Inequality (CV) and Welfare in Eastern Europe, 19th century



Data source: see References II

Figure 4.9: Correlation between Inequality (CV) and Welfare in Eastern Europe, 20th century



Data source: see References II

Table 4.1: Descriptive statistics (cases included as in Model 1, except income/c and Social Spending)

	N	mean	sd	min	max
Height	528	168.61	5.06	148.66	184
CV	528	3.79	0.47	1.39	6.58
Income/c (log)	294	7.73	0.84	5.81	9.85
Social Spending (as % of GDP)	97	0.65	0.88	0	4.96
Migrants	36			0	1
Truncated obs.	45			0	1
Students	17			0	1
Self Reported heights	15			0	1
Industrial Countries	203			0	1
Latin America	60			0	1
Asia	56			0	1
Middle East & North Africa	29			0	1
Sub-Saharan Africa	74			0	1
Eastern Europe	106			0	1

Table 4.4: Determinants of male height (cm)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inequality (SD)	-0.80***	0.12	2.66	-1.18**	-1.70***	-1.08**	2.73
	(0.01)	(0.78)	(0.11)	(0.02)	(0.00)	(0.01)	(0.36)
Inequality (SD squared)			-0.26**				
			(0.04)				
Social Spending (as % of GDP)				0.54	-8.94		
				(0.22)	(0.02)		
Interaction Social Spending x SD					1.48***		
					(0.01)		
Income/c (log)						1.43**	4.54*
						(0.02)	(0.06)
Interaction Income x SD							-0.49
							(0.19)
Truncated (yes/ no)	-1.50***		-1.53***	-0.97	-1.15*	-0.72	-0.32
	(0.00)		(0.00)	(0.11)	(0.08)	(0.17)	(0.21)
Migrants (yes/ no)	1.44**		1.36**	-0.99	-0.68	2.64***	1.02**
	(0.02)		(0.03)	(0.38)	(0.50)	(0.01)	(0.02)
Students (yes/ no)	2.56***		2.66***	1.79*	1.34	1.58***	-0.25
	(0.00)		(0.00)	(0.07)	(0.16)	(0.01)	(0.74)
Self-Reported (yes/ no)	-0.32		-0.09	1.22	3.98***	-1.79	0.85**
	(0.73)		(0.92)	(0.33)	(0.00)	(0.11)	(0.03)
Constant	170.29***	163.74***	158.99***	171.83***	172.83***	170.42***	65.98***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
No. of Observations	528	401	528	97	97	238	238
Number of Countries	105	98	105	23	23	40	40
R-squared (overall)	0.26	0.24	0.28	0.22	0.20	0.43	0.42

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. All models control for country-specific fixed effects and use robust standard errors. Data source: see References II

Table 4.5: The influence of inequality on welfare by birth decade

	Height (cm)
*CV * 1810*	-2.61***
*CV * 1820*	-3.22***
*CV * 1830*	-1.47**
*CV * 1840*	-2.05***
*CV * 1850*	-1.05
*CV * 1860*	-3.53**
*CV * 1870*	-2.41*
*CV * 1880*	-0.85
*CV * 1890*	-0.30
*CV * 1900*	-0.81
*CV * 1910*	-0.84
*CV * 1920*	-1.76***
*CV * 1930*	-1.92**
*CV * 1940*	-5.14***
*CV * 1950*	-7.04***
*CV * 1960*	-7.09***
*CV * 1970*	-6.52***
*CV * 1980*	-6.54***
Migrants (yes/ no)	1.03**
Students (yes/ no)	1.46**
Self-Reported (yes/ no)	-0.5
Truncated (yes/ no)	-1.05**
Constant	174.04***
Country Fixed Effects?	YES
Time Dummies included?	YES
Observations	465
Number of Countries	96
R-squared (overall)	0.35

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. All models control for country-specific fixed effects and use robust standard errors. For every birth decade the hypothesis is tested that the influence of inequality is different from 0. Therefore, the interaction variables between CV and the various birth decades indicate the total influence of inequality on height by birth decade. Data source: see References II

Table 4.7: Classification of countries

Eastern Europe (EEU): Albania, Armenia, Azerbaijan, Bulgaria, Croatia (Hrvatska), Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Macedonia, Poland, Romania, Russian Federation, Serbia and Montenegro, Slovakia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan Industrial Countries (IC): Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States Latin America (LA): Argentina, Bolivia, Brazil, Chile, Colombia, Guatemala, Mexico, Peru Middle East/ North Africa (MEN): Afghanistan, Algeria, Egypt, Iran, Iraq, Israel, Lebanon, Libya, Morocco, Syria, Turkey, Yemen Sub-Saharan Africa (SSA): Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Congo, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Madagascar Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zimbabwe Asia: Indonesia, Malaysia, Myanmar, Papua New Guinea, Philippines, Thailand, Viet Nam, Bangladesh, India, Nepal, Pakistan, China, Korea (North), Korea (South), Taiwan

5. ANTHROPOMETRIC WITHIN-COUNTRY INEQUALITY AND THE ESTIMATION OF SKILL PREMIA WITH ANTHROPOMETRIC INDICATORS

This Chapter is based on a working paper with the same title written by Prof. Dr. Jörg Baten and myself. The paper has been accepted for publication by the *Review of Economics*. The idea was developed jointly. Both the analysis and the writing were done together in equal shares.

5.1 Introduction[50]

Recently, a method to measure inequality has been proposed that is based on anthropometric indicators. Baten (1999, 2000) argued that the coefficient of variation of human stature (henceforth 'CV') is correlated with overall inequality in a society, and that it can be used as indicator, especially where income inequality measures are lacking. This correlation has been confirmed in further analyses, for example by Pradhan et al. (2003), Moradi and Baten (2005)[51], Sunder (2003), Guntupalli and Baten (2006), Blum (2010a), van Zanden et al. (2010). The idea is that average height reflects nutritional conditions during early childhood and youth. Since wealthier people have better access to food, shelter and medical resources, they tend to be taller than the poorer part of the population. Hence, the variation of height of a certain cohort may be indicative of income distribution during the decade of their birth.

The aim of this study is firstly to provide an overview of different forms of within-country height inequality. Previous studies on the aspects of height inequality are reviewed. Inequalities between ethnic groups, gender, inhabitants of different regions and income groups are discussed. In the two final sections, we compare height CVs of anthropological inequality with another indicator of inequality, namely skill premia. We also present estimates of skill premia for a set of countries and decades for which 'height CVs', as they will be called in the following, are available.

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[50] I thank Dorothee Crayen, Robert Fogel, Nadine Frerot, Ricardo Godoy, Laurent Heyberger, John Komlos, Michał Kopczyński, Kerstin Manzel, Stephen Nicholas, Sunyoung Pak, Valeria Prayon, Inas Rashad, Daniel Schwekendiek, Mojgan Stegl, Yvonne Stolz, Linda Twrdek and Greg Whitwell for contributing their data. Marianne Hock improved the language.

[51] Moradi and Baten's (2005) results are shown as an example in Figure 5.1 and Table 5.1 (appendix)

5.2 Advantages of anthropometric inequality measures

What are the advantages and disadvantages of anthropometric inequality measures? Heights offer a good complement to conventional inequality indicators and constitute perhaps an even better indicator in some respect (see Moradi and Baten (2005) on the following). If the distribution of food and medical goods in an economy becomes more unequal, heights should also become more unequal. Yet while a correlation with income does exist, this correlation is only partial. Some important inputs are not traded on markets but are provided as public goods, such as public health measures or food supplements for schoolchildren. Public goods lead to modest deviations between purchasing power-based and height-based inequality measures.

Moreover, income neglects transfers within households. If there is, for example, only one income earner in the household, it cannot be assumed that transfers to other household members reach the same degree everywhere. Deaton (2001) and Pradhan et al. (2003) have argued convincingly that measures of health inequality are important in their own right, not only in relation to income. Heights do capture important biological aspects of the standard of living (Komlos 1985, Steckel 1995), irrespective of the fact that some problems regarding the stature variable may exist.

Anthropometric methods are even more advantageous for studying developing countries of the 20th and the generally poorer countries of the 19th century. To date, the development of inequality within LDCs could not be sufficiently explored because reliable data were lacking. The well-known Deininger and Squire data set (1996), for example, provides only eight gini coefficients of income for Sub-Saharan Africa for the period before 1980, labelled as ‘acceptable’. Atkinson and Brandolini (2001) convincingly pointed to serious flaws in the income inequality data collected by Deininger and Squire, arising from insufficient consistency across countries and over time.

For those countries, height inequality measures can provide important additional insights. We certainly do not claim that height is the only accurate measure of inequality, but argue that it generates new insights on inequality while serving as a useful countercheck for other indicators, thereby leading to more meaningful results overall.

5.3 Different forms of within-country inequality

The following chapters discuss the literature on inequality between social classes, urban-rural differences, differences between ethnic groups, economic systems, and among regions within the same country. In reality, however, several of those issues occur at the same time. Hence, the estimation of height inequality is a complex process. For example, differences in stature between ethnicities are often linked to differences in social affiliation while it is not unusual that urbanization processes are connected to certain regions of a country. In the literature reported below, height inequality is often studied in a multidimensional way. Therefore, this article can be considered as an introduction to the economics of the forces behind inequality and a guide to their investigation.

5.3.1 Differences between ethnicities

Steckel (1979) as well as Margo and Steckel (1982) are considered as pioneer works on the living standards of Afro-American slaves. Both studies are based on data from so called ‘slave manifests’, containing records of tens of thousands of slaves, mainly shipped via the ports of Baltimore, Charleston, Mobile, New Orleans, Norfolk and Richmond. The data used in those studies employ growth and final height of the shipped slaves in order to gain information on their biological living standard.

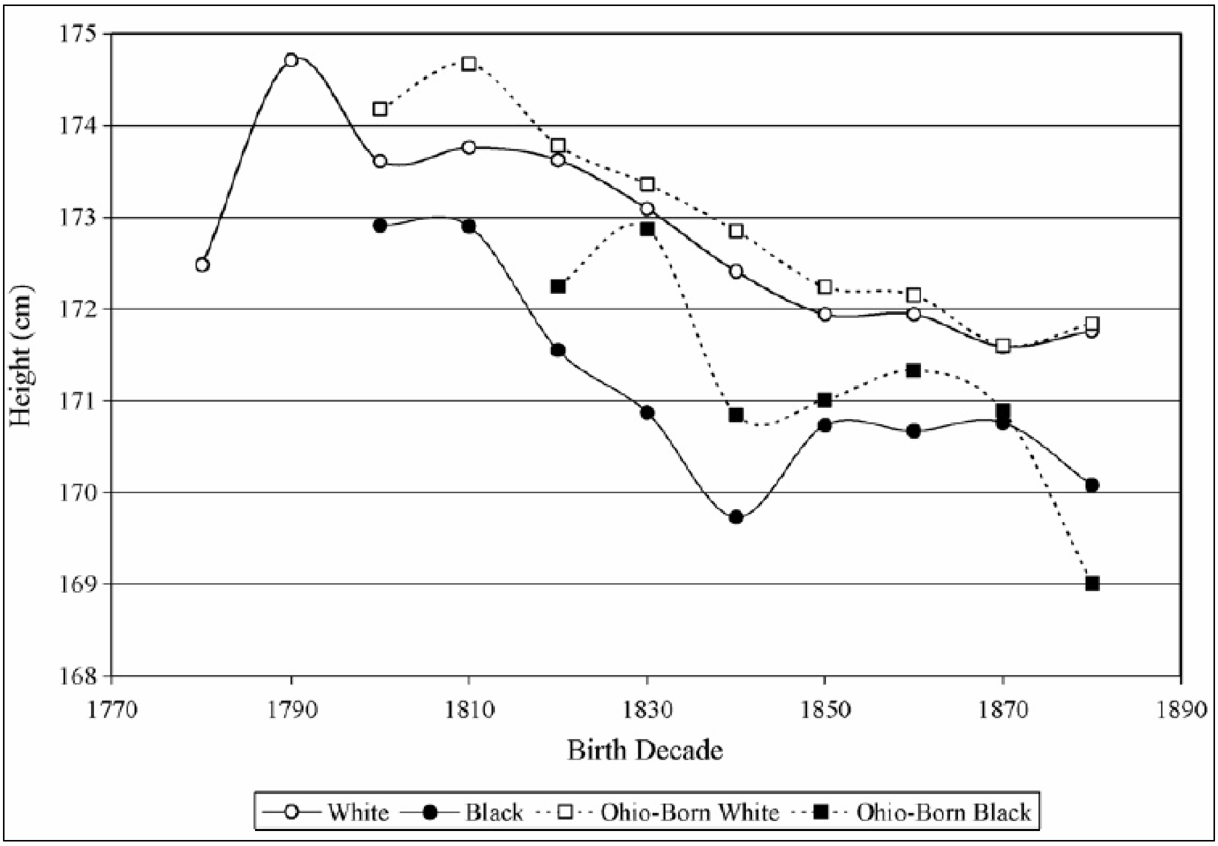
They report that contemporary African Americans ended up being shorter compared to the white Americans. On the other hand, their height indicates that slaves were even taller than Whites born in Europe. Therefore, they conclude that the nutritional status of African Americans was worse compared to white Americans but superior to European levels.

Furthermore, light-colored slaves were taller than their dark-colored counterparts (Steckel 1979, Margo and Steckel 1982). Bodenhorn (2002) confirms this by analyzing free rural Blacks in Virginia. Both male and female light-colored African Americans were taller mainly due to economic and behavioral reasons. Since Mulattos were often wealthier than Blacks, they had better access to nutrition. Furthermore, a contemporary attitude might have helped the light-colored female black slaves, because slave owners tended to prefer them over darker Blacks as household servants and for sexual reasons.

In addition, height varied significantly among occupations, regions and birth cohorts. Particularly plantation size, crop-mix and food supply were major determinants of slave heights (Margo and Steckel 1982). Bodenhorn (1999) reports that although free African Americans experienced discrimination, such as restricted occupational choices, education and even property rights, they did surprisingly well. They reached almost the same height as white Americans and enjoyed an even higher biological welfare compared to many Europeans.

Maloney and Carson (2008) not only confirm the height gap between African Americans and Whites during the 19th century, but using prison data from Ohio, they also report that both height trends follow a similar path (see Figure 5.2). At the end of the 18th century both Blacks and Whites started on a high level, but lost height between the 1820s and the 1840s. This might indicate that both trends were influenced by the same economic process. However, the height of African Americans declined earlier than the one of their white contemporaries, as their lower living standards were more vulnerable to income shocks.[52]

Figure 5.2: Mean height by race and year of birth of 19th century American inmates



Source: Maloney and Carson (2008)

Komlos (2010) investigates the period between the 1920s and the 1980s using adult height data collected for the NHANES (National Health and Nutrition Examination) surveys. He reports that height differences between white and black Americans are still prevalent. In the course of the 20th century the male height gap was on average one

[52] Komlos and Coclanis (1997) suggest that Georgia's black population was less integrated into the commercialized food production because they were either living on subsistence farming or because their owners wanted to maintain their economic value.

centimeter. He also observes a height gap between black and white females. The average gap of about two centimeters was mainly caused by differences of the low and middle strata. In contrast, height differences between rich Whites and rich Blacks were only modest, indicating that primarily differences in purchasing power lead to differences in the biological standard of living.

There are studies which deal with ethnic minorities in other parts of the world. Twrdek and Manzel (2010), for example, apply prison records to gain information about the individual's height, ethnicity, age, place of birth, occupation and religion of convicts in 19th century Peru. They find that particularly Whites benefited from the earnings generated by the guano exports. In contrast, Mestizos and Peru's native inhabitants were suffering due to increasing prices. Blacks were the tallest population group during the entire period under observation. Twrdek and Manzel conclude that Blacks were considered as an investment which had to be kept vital and strong in order to be productive.[53]

Cameron (2003) reports that after the abolition of Apartheid in South Africa, the political, social and economic transition did not lead to short-term improvements of the nutritional status of non-white children in the 1990s. Differences in growth exist at the time of birth as well as during the growth process. Another kind of transition is investigated by Mironov (2007). In his study on mothers and infants in Russia he reports that the length at birth in St. Petersburg between 1980 and 2005 depended to some extent on the mother's ethnicity. Russians, Ukrainians and Byelorussians had significantly taller babies compared to the reference category (Azerbaijanians). On the other hand, the newborn babies of Jewish mothers were shorter by over one centimeter. Correspondingly, Aschoff and Hiermeyer (2009) find that in the beginning of the 19th century the stature of

[53] Twrdek (2010) concludes that freed blacks on the isle of Cuba grew even taller than the Cubans of European descent.

Jews in the German Principality of Salm were more than 7 cm shorter compared to the non-Jewish population. This finding suggests that during this time German Jews suffered from extreme nutritional deprivation.

For the Taiwanese case Olds (2003) reports that the economic upswing just after the beginning of Japanese rule also resulted in a stature increase. Olds distinguishes between Taiwanese aborigines and Chinese Taiwanese and finds that both groups benefited from the improved nutritional status and better disease environment. However, native Taiwanese height increased only by 3 cm, while Chinese Taiwanese gained additional 6 cm between the 1920s and the 1970s.

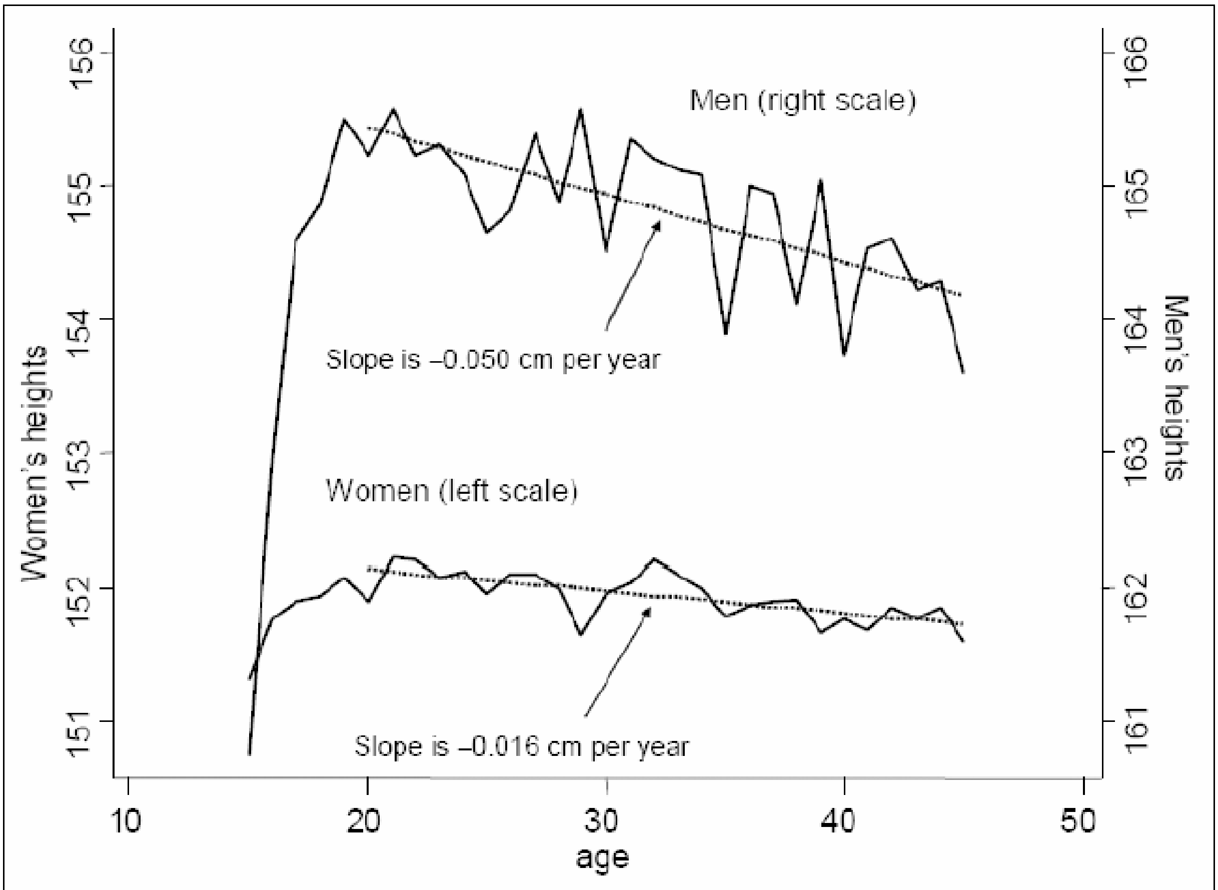
5.3.2 Gender differences

An entirely different field is gender inequality measured by different biological living standards. Besides the natural differences in growth and final stature, there are socio-economic factors which determine a deviation of the gender dimorphism of a population from the natural norm. The overwhelming majority of such deviations are caused by discrimination. In this regard, Osmani and Sen (2003) show that maternal deprivation is not only a matter of maternal health. In fact, health and nutrition of mothers are a crucial factor of a nation's health since it influences the long-term health risks. They argue convincingly that the determination of adult health starts with the determination of fetal health and birth weight.

Dangour, Farmer, Hill and Ismail (2003) use data of four-year-olds from Kazakhstan in the 1990s to investigate the influences of the transition from a centrally-planned economy to a market economy. Their results suggest that the anthropometric status among boys remained unchanged. However, Kazakh girls experienced an average height decline of 0.25 cm per annum between 1992 and 2000. In addition, the authors present data on nutritional intake of girls and boys in 1994 and conclude that girls were facing discrimination in terms of intra-household food allocation (for a Spanish study on the topic, see Costa-Font and Gil 2008).

Deaton (2008) uses the NFH (National Family Health) Survey in order to obtain information about gender-specific well-being in India. He reports that sexual height dimorphism in the 1960-65 period was 7.8 percent, increasing to 8.2 percent in only 15 years. The trend lines in Figure 5.3 suggest a growing height gap between male and female height, since height gaps of elderly generations were smaller compared to younger birth cohorts. Deaton concludes that this is a result of unequal access to the rising availability of nutrition and health care during the period under observation. He also

Figure 5.3: Heights by age and gender in India



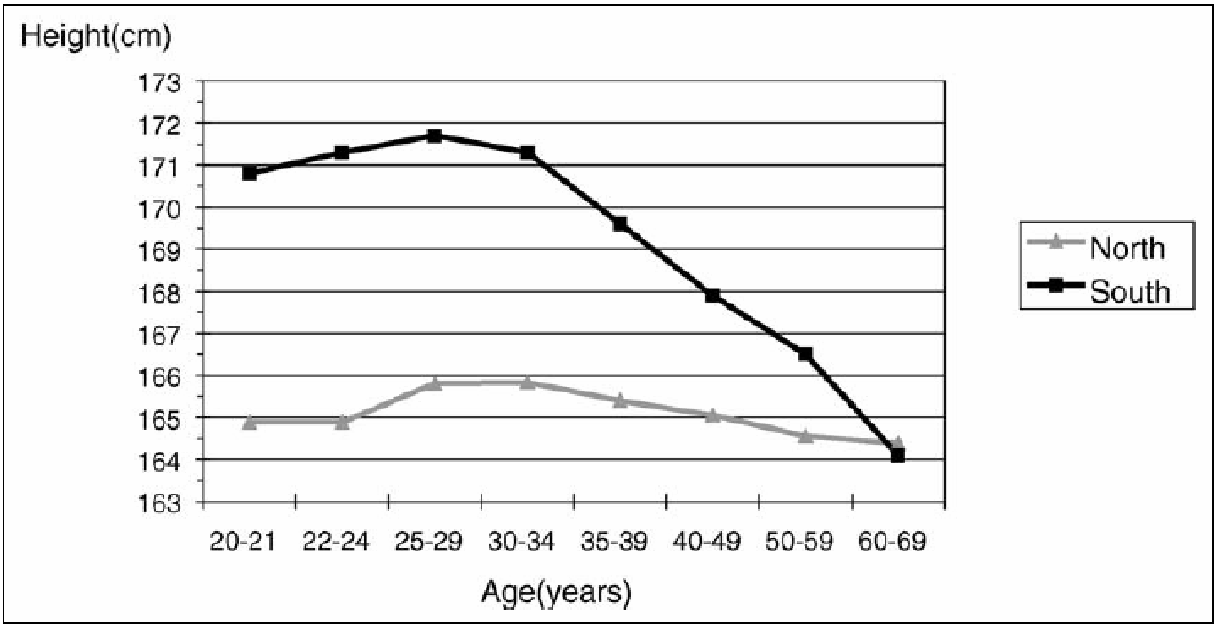
Source: Deaton (2008)

argues that this is just the continuation of the trend that had been in existence during the entire 20th century. However, if Delhi – where the natural gender ratio is massively disturbed by uneven migration – is excluded from the sample, it turns out that migration also seems to have played a role, aside the discrimination. Koepke and Baten (2005) as well as Guntupalli and Baten (2009) discuss and review other studies on gender inequality.

5.3.3 Differences caused by institutional systems

History has provided some huge institutional experiments regarding the wealth of nations. Changes of political and economic systems belong to the most dramatic ones, particularly if the two parts undergo different types of institutional transition, such as in Korea or postwar Germany.

Figure 5.4: Mean male height of North Korean escapees (1999.2003) and South Koreans (1997)



Source: Pak (2004)

Pak (2004) compared heights of Koreans from the North and the South and reveals that by the end of the 1940s Korean heights were quite homogenous (Figure 5.4). The divergence began in the late 1940s. Pak concludes that this divergence reflects the unequal economic, medical and nutritional development of the two Koreas. The advantage of the Republic of Korea in terms of biological well-being over the communist North grew steadily and was on average about 6 cm in the 1980s. Schwekendiek (2008a, 2008b, 2009) significantly extends those Korean studies by identifying the forces beyond living standards in North Korea.

Komlos and Kriwy (2003) come to a similar conclusion in their study on the two Germanies. Although differences were not nearly as severe as in the case of Korea, the authors report that height differences existed throughout the entire period of separation. In addition, height differences started to diminish just after reunification, implicating the improvement of the socioeconomic and environmental circumstances. Heineck (2006) confirms the general picture and his results suggest that the height gap was larger among males than among females.

Furthermore, the different features of the two economic systems also caused different dimensions of economic inequality within the two parts of Germany. The German Democratic Republic had a significantly smaller service sector causing difficulties regarding the distribution of nutritional resources (Komlos and Kriwy 2003). In contrast, Hiermeyer (2008) reports that the inequality of heights in the West was higher compared to the East. However, he concludes that this might be caused by the geographic diffusion of the Western population and the greater diversity rather than a system-driven inequality.

Quite a different clash of systems was investigated by Steckel and Prince (2001). Their comparison of living standards in the expansion- and productivity-oriented Anglo-

American economy and the Native American subsistence economy of the 19th century reveals surprising results. Despite their technological and institutional advantages, European-Americans were about 1-2 cm shorter than the Native inhabitants. The authors explain these differences by the low population density and the fact that Native American tribes used to move several times per year. Therefore, sanitary and hygienic problems known in large cities were here unknown. In addition, the common practice of sharing and caring about other tribesmen in need worked as a social insurance. The combination of those factors led to a superior biological living standard and made Native Americans the *'tallest of the world'* during the mid-nineteenth century (Steckel and Prince 2001). Komlos (2003) argues that populations living near the North American frontier were generally taller compared to urban centers due to abundant productive land, low population density, a great deal of protein availability (bisons) and a better disease environment although they might have been poor in monetary terms. In the case of New Zealand, however, Inwood, Oxley and Roberts (2010) do not find evidence for differences in height between Maori and New Zealanders of European descent.

In their analysis of the native Tsimane people in Bolivia, Godoy et al. (2006) find that individual characteristics such as being fluent in Spanish and indicators of human capital go along with higher stature of both mothers and daughters. In general, however, the height development of the Tsimane does not show a secular trend during the 20th century. These results indicate that the majority of the Tsimane were living in autarchy with only sporadic contact with the market economy. Women being in contact with the Spanish speaking, market-oriented part of the population were significantly taller than the women living in the traditional subsistence sector. Particularly modern medical technologies helped to improve the disease environment of the people being open to Western influences.

5.3.4 'Urban penalty'

A phenomenon that has frequently been observed during the industrial revolution is the lower living standard of urban areas. On the one hand, the organizational structure of cities should have allowed low transaction costs, and public facilities such as schools, universities and hospitals that can be run with economies of scale. Cities and their suburbs were generally a hotspot of economic activity. After the era of medical and sanitary advancements of 1900, cities could use their superior purchasing power to acquire medical care and superior nutrition. Over the course of the development process cities benefited from urban development, purification of water supply, sanitation, less child labor and the accessibility of medical services (Martínez-Carrión and Moreno-Lázaro 2007).

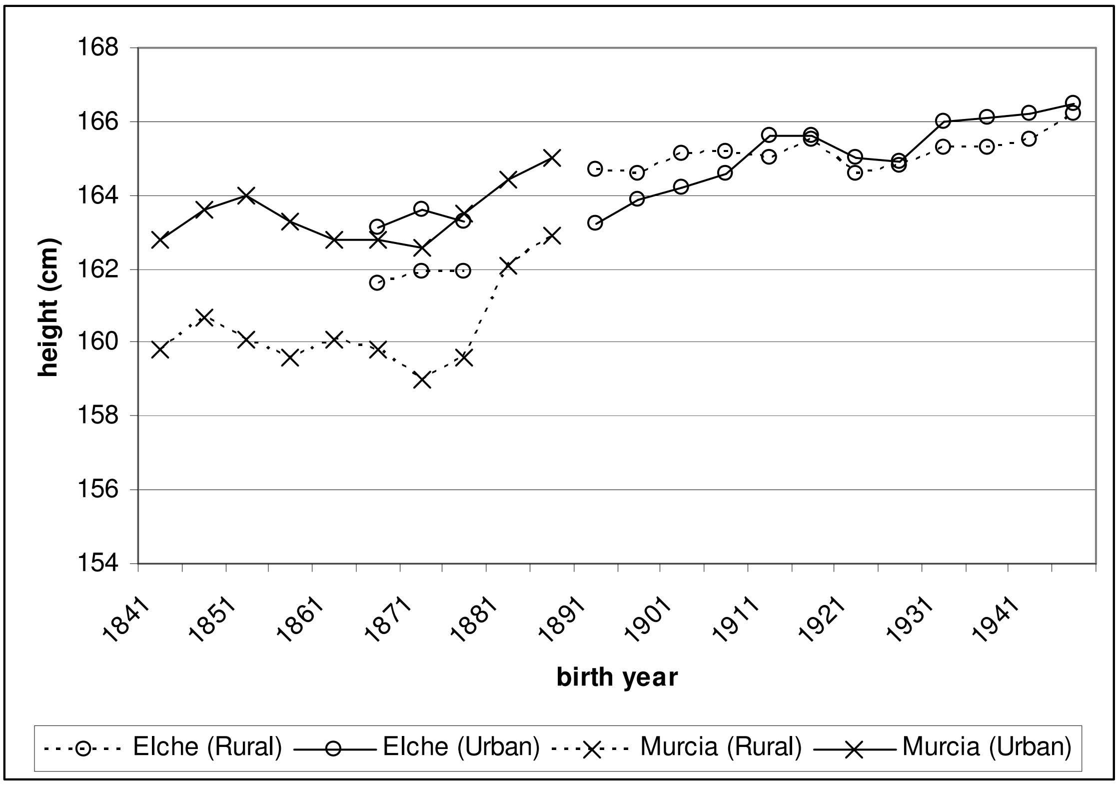
On the other hand, the early years of urbanization were characterized by overcrowded housing and insufficient sanitary conditions, particularly compared to modern standards. Srzeter and Mooney (1998) argued that cities during the 19th century did not invest significantly in their infrastructure. As a result, diseases occurred more often, causing more severe epidemics and therefore often created a worse disease environment compared to rural places. Furthermore, the nutritional status of cities largely depended on the supply from surrounding rural areas. The higher the transportation costs the more difficult it was to supply the urban citizens. Needless to say, transaction costs increased dramatically with distance, particularly the costs to transport animal products before the invention of refrigerators, pasteurization and the integration of rural areas into the railroad network (Baten 1999). Hence, it is possible that heights are declining although the economy is growing in conventional measures (Komlos 1998, Cuff 2005). Margo and Steckel (1983) analyze the height of soldiers who served during the American Civil War and find that individuals born in places with more than 10.000 inhabitants were significantly shorter than those born in smaller places. Floud, Wachter and Gregory (1990) address the issue for the United Kingdom.

It is the trade-off of advantages and disadvantages of the above described kind that determined the living standards in cities and rural areas, yet every single case study has to investigate the prevailing conditions carefully and evaluate their influences on a case-to-case basis. Baten's (2009) analysis of Bavaria, France and Prussia, for example, revealed that the nutritional status in the 19th century was low in areas *near* towns, since their agricultural economy was targeted towards close urban markets, but high in some of the administrative cities. Therefore, especially the city of Munich benefited from a very special situation because the urban and rural advances occurred at the same time. Urban structures combined with the nutritional supply from the nearby rural places near the Alps allowed a high living standard in the 19th century. The height in more remote regions, however, was mainly shaped by their agricultural strategies. Areas specialized in milk and meat production enjoyed higher biological living standards compared to areas whose focus lay on the production of carbohydrates (mainly grain and potatoes).

For the case of 19th century Spain, Martínez-Carrion and Pérez-Castejón (1998), Quiroga (2002) and Martínez-Carrion and Moreno-Lázaro (2007) report a rural disadvantage. The latter, however, report only slight height differences and conclude that underdeveloped regions suffer from typical disadvantages to a limited extent since the transformation into an industrial society was not completed yet.

In modern times, cities tend to provide superior biological living standards since low transportation costs and high productivity allow fresh and cheap foodstuffs to be sold on urban markets. The disease environment is also generally better. This, combined with other benefits of cities, often lead to taller heights in cities compared to towns and villages. Accordingly, Komlos and Kriwy (2003) find that German males living in cities both in the Eastern and Western part were significantly taller than those living in towns and villages.

Figure 5.5: Rural and Urban heights in two Spanish municipal districts



Source: Martínez-Carrión and Pérez-Castejón (1998)

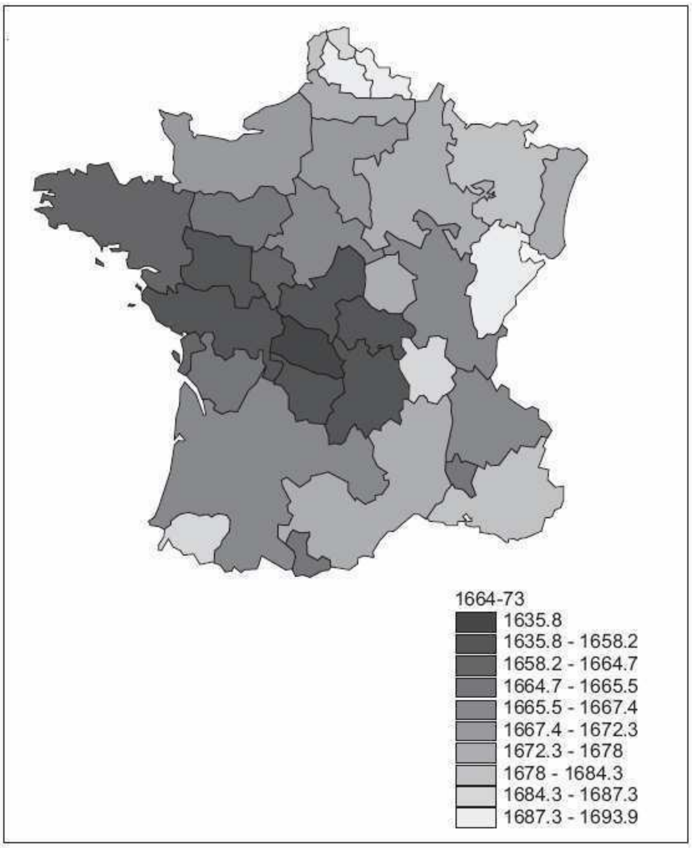
The same seems to be true among transitional and developing countries. Eiben and Mascie-Taylor (2004), for instance, find that Hungarian boys born between 1960s and the 1980s were taller in larger cities. The tallest ones lived in the capital. Sahn and Stifel (2003) confirm this finding for several Sub-Saharan countries during the second half of the 20th century. Both of their measures, child stunting and adult malnutrition, reveal that the nutritional status in rural areas lags far behind those in urban centers.

5.3.5 Differences between regions

Probably the most intuitive case of within-country inequality is the divergence of living standards between regions. Regions are characterized by particular properties because often each of them was shaped by a unique, history although being an integral part of the same state.

Therefore, among others, population density, urbanization, industrialization, infrastructure, religion, geography, climate, soil quality, the social, cultural and economic history as well as the interaction of the latter give every region a unique character in terms of economic performance and well-being. As a result, the living standards across regions in a country might differ depending on the economic activity they develop. Figure 5.6 shows the geographical height distribution in France during the 17th and 18th century.

Figure 5.6: Adult male height in France during 1664-1763



Source: Komlos (2003)

One of the pioneer studies in this field compares biological living standards across several regions of the Habsburg Monarchy (Komlos 1985). Komlos applies conscript data from four provinces between the 1740s and the 1830s and finds significant differences in stature. His results indicate that Bohemia and Lower Austria, two early industrialized regions, could improve their income because of increasing productivity of labor. But the industrialization process went along with decreasing average heights, as observed in many other places.

A recent study on Russian children revealed that there are significant differences between provinces of the Russian Federation (Fedorov and Sahn 2005). A striking result of their study is the dramatic height difference between the civil war affected regions of the Northern Caucasus and other provinces.

Alter, Neven and Oris (2004) conduct a study on 19th century Belgium finding significant regional differences even in a relatively small area in eastern Belgium. At the same time in Ireland, people in Connaught and Munster had the worst living standards, measured as the height of Irish-born female convicts in Australia. In contrast, Ulster benefited from a very special situation since the industrialization in the northern part of the Irish isle was not followed by its usual disadvantages (Oxley 2004). Sandberg and Steckel (1987) draw a similar conclusion for the Swedish case. In 18th and 19th century northern Italy heights in Lombardy were among the lowest while the Venetian provinces of Vicenza and Verona enjoyed relatively good living standards (A'Hearn 2003). This finding is confirmed by Arcaleni (2006), who investigates the whole of Italy between 1854 and 1980. In addition, she finds a strong North-South divide in heights as well as in illiteracy, per-capita income, unemployment and mortality. The divergence is persisting but decreased in the course of economic development. In a comparison of Puerto Rico and the American mainland between the late 19th century and the mid-20th century, Godoy et al. (2007) find that differences in adult stature exceeded 8 centimeters.

Accordingly, Chinese living standards also greatly differed in the 19th and early 20th century. Individuals from the northern parts were almost three (two) centimeters taller than their counterparts from the center (south) due to different nutritional endowments (Morgan 2004). Bassino (2006) studies the regional convergence of 47 Japanese provinces between 1842 and 1941. He finds that income and height are highly correlated and regional convergence of heights occurred before World War I. These findings suggest that the main driving force of regional differences in well-being is predominantly a result of unequal economic development and its nutritional consequences. A similar conclusion was drawn for Argentinean, Mexican and Indian cases (Salvatore 2004, López-Alonso and Condey 2003, Guntupalli and Baten 2006). In their investigation of colonial Burma, Bassino and Coclanis (2008) find that regional height developments do not correlate with the development of economic power. Although lower Burma experienced a rapid economic development due to the expansion of rice production, average heights were stagnating because tropical diseases were able to spread more easily. Hence, stature in Lower Burma was higher than in Upper Burma. Furthermore, height variation within Upper and Lower Burma can be explained partly by the nutritional status and the development of rice prices.

5.3.6 Differences by social group

Reasons for differences in well-being between social strata are manifold. The most profound one is the difference in purchasing power. On the one hand, high quality foodstuffs, particularly foodstuffs containing animal protein such as meat and milk, are more expensive than carbohydrates because livestock breeding requires more input in terms of fertile farmland and time. On the other hand, animal based nutrition is often considered as superior to a vegetarian diet – at least in times when it is scarcely available – and wealthy individuals consume animal products as long as it is affordable. As a consequence, the quality of one's nutrition is linked to the supply and demand mechanisms. This usually leads to a situation in which high social strata enjoy a high quality diet. The lower strata's diet, however, is rather based on carbohydrates, due to the fact that it offers more energy per monetary unit compared to meat. Since meat and milk are driving forces in the growth process, the high social strata mostly end up being significantly taller.

In addition, lower income groups tend to have more children compared to upper ones after the early 19th century (Clark 2007). When their limited purchasing power has to be allocated among a higher number of children, the negative influences associated with poverty are multiplied. As a result, children growing up in large (small) families tend to be shorter (taller). This phenomenon is known under the *Quantity-Quality tradeoff* and has been found for several countries and periods (Becker, Cinnirella and Woessmann 2010).

Another link exists between education and health. Human capital, particularly the ability to read, enables parents to gain information about how to provide their children with a clean and hygienic environment. Since families from upper social classes tend to be more educated, their children tend to be ill less often and the course of disease in those strata is less severe. The human body has to invest energy in order to fight diseases. Hence, illness may delay growth less often in upper class families.

There is a great deal of empirical evidence on growth differences among social classes coming from entirely different societies and periods. The picture that is drawn, however, is often the same. Komlos (1987), for instance, reports that population growth and urbanization in Antebellum America induced increasing demand for foodstuffs. As a result, the nutritional status declined in some parts of the population. Particularly, children of blue-collar workers and surprisingly farmers showed declining heights (see Table 5.2).

Table 5.2: Index of stature by occupation of father and decade of birth of West Point cadets

Birth Decade	Farmer		Blue Collar		Merchant		Profes-sional		Govern-ment		Total		Harvard Students		
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	Index	cm	N
1820s	50	101.3	17	100.1	29	99.7	35	99.6	14	100.5	78	98.8			
1830s	169	101.0	70	99.7	132	99.6	144	99.7	62	100.0	338	99.7	100.0	172.5	550
1840s	88	100.0	57	98.9	93	100.4	106	100.1	50	100.4	249	100.3	100.5	173.3	1089
1850s	107	99.5	98	98.7	114	99.2	143	99.8	48	99.9	305	99.6	100.2	172.9	335
1860s	198	100.0	169	99.2	226	100.0	233	99.5	91	100.0	550	99.8	101.1	174.4	506
1870s	35	100.0	26	99.9	60	100.7	41	100.2	20	101.7	121	100.7	101.8	175.6	307
Average	647	100.3	437	99.2	654	99.9	702	99.7	284	100.2	640	99.9			

Source: Komlos (1987)

While the blue-collar workers' wages did not keep up with rising food prices, farmers had the incentives to sell high quality food instead of consuming it themselves. He also reports (Komlos 1990) that in mid-18th century Germany the biological standards of living diverged considerably between the social classes. Students of an elite school in Stuttgart displayed height differences of 12 centimeters compared to the lower class and their counterparts of the upper aristocracy. In the case of early-modern France, Komlos (2003) reports that social differences in well-being were one driving force on the way to the French Revolution. Cardoso and Caninas (2010) find that in Portugal between 1910 and 2000 socioeconomic differences have diminished but are generally persistent.

In a study on 19th century Belgium Alter and Oris (2008) find that the stature of brothers from wealthier families was stronger correlated than that of brothers from lower class families. They conclude that upper class families were more successful in dealing with socioeconomic challenges due to higher purchasing power. Salvatore (2004) finds that differences in biological well-being in Argentina during the first half of the 20^{th} century were determined by differences in education, skills, and social standing. He reports that individuals with secondary education were on average 2-3 centimeter taller than the average while illiterates were significantly shorter.

This systematic pattern persists up to modern times. As observed by Cvrcek (2009), even in communist Czechoslovakia between 1946 and 1966 sons of clerks and other professionals are generally taller than sons of blue-collar workers and farmers. Mironov (2007) comes to the same conclusion for the Russian case between 1980 and 2005. Smith et al. (2003) study the height of children from Guatemalan Maya immigrants in the United States. Low- and middle-class Mayas are significantly shorter than white Americans of the same age (except in the upper tail of the height distribution). In addition, Mayan Americans measured in 2000 are still shorter than the reference standard for American children, but they are, on average, 10.2 cm taller than Maya children in Guatemala. This reflects the successive socioeconomic integration of Mayan Americans and underlines the environmental factors that determine growth.

5.4 A guide to deal with shortcomings and limitations when analyzing height inequality

Some of the above discussed determinants of economic inequality are also a source of biases and shortfalls when comparing different height measurements that experienced dissimilar selections. For example, if national averages are not calculated from a representative mix of urban and rural height the result might be biased. The same is true if values are calculated from selective samples, such as heights of only low or high social classes, of workers, illiterates, students, sportsmen, or elite-troops, respectively. Special cases are migrants who often tend to be upward biased compared to the average height in their source country (Twrdek and Baten 2010, Humphries and Leunig 2009).

Furthermore, samples based on soldiers often show a shortfall on the lower end of the height distributions. Since many armed forces introduced a *Minimum Height Requirement*, estimates based on soldiers should be adjusted with appropriate methods. If a shortfall exists and is overlooked, average height (height inequality) is upward (downward) biased. Several strategies have been developed in order to estimate the true distribution of height (Komlos and Kim 1990, Komlos 2004, A'Hearn 2004).[54] In general, measurements of conscripts are mostly unbiased when general conscription was applied. However, it might be worth looking at the recruitment strategies of the recruiters and medical officers in order to check if the general physical condition or education played a role in the recruitment process.

A further quite obvious bias is the measurement of not fully-grown populations.[55] However, it is not that easy to precisely identify that point in time when a group of individuals stop growing. It is difficult to estimate whether growth potential is left among late teenagers and early twens; future catch-up growth causes a downward biased mean. In borderline cases, some individuals might be already fully grown while others expect to have some catch-up growth left. This situation may indicate a higher variation of height than the final adult height distribution would have. Baten and Komlos (1998) use Mackeprang's (1907-11) reports of repeatedly measured Danish conscripts born in the mid-19th century in order to correct this kind of bias. Mackeprang reports that even 19-year-olds were approximately 1.9 cm shorter than their full grown compatriots. In general, the growth potential is reached earlier the better the net nutrition of a population.

[54] An older method, the Quantile Bend Estimator, has been replaced by more effective methods (see Wachter and Trussell 1982).

[55] Needless to mention another important age-related bias. Individuals over a certain age start to become smaller due to age-related shrinking. Therefore, most height studies have to be restricted on individuals under the age of 50.

A rather modern phenomenon is the use of self-reported heights. Several studies have investigated the determinants of a self-reporting bias and find that among others, gender, age, educational level, occupation (Niedhammer et al. 2000), low actual height, and obesity (Spencer et al. 2002) play a significant role in the severity of the bias. Strauss (1999), however, compared the self-reported height and the actual height of young adolescents and finds no differences in the accuracy of self-reported heights, whereas Hatton and Bray (2010) adjust self-reported height measurements downward by 0.8 centimeter.

One question to be addressed is whether the distribution of heights is vulnerable to survivor bias, as only survivors could be included. However, considering the gini coefficients of income inequality, it is important to mention that the inequality measures only include survivors. In order to be an income earner in any inequality measure, one must at least survive to the age in which people earn incomes. In other words, also the gini coefficient relates to the living population and does not reflect inequality of newborn babies who might have died during their first year of life. Moradi and Baten (2005) actually tested whether countries with higher infant and child mortality might have had a systematically different height CV. They actually found the expected negative effect. However, only a very small part of the CV's variance was able to be explained by mortality differences between the countries.

The retrospective height CV measure might suffer from an additional bias, namely the mortality between age 20 and 49 (heights are typically restricted to those ages, in order to exclude young and growing, as well as very old and shrinking persons). When comparing the development of height and income inequality in Kenya, Moradi and Baten (2005) found that this measure was not biased towards the expected direction. This might have been caused by offsetting factors, and by the fact that selective mortality between ages 20 and 49 was too small to influence the measurement.

On the behalf of completeness one should bear in mind that subgroups of the same population might differ in their nutritional habits (Blum 2010b). The reasons can be related to biological, religious, and cultural factors. In particular, some populations in Asia and Sub-Saharan Africa suffer from lactose intolerance which deprives them from the positive benefits of cow milk (Sahi 1994). Furthermore, religious beliefs sometimes hinder people from the consumption of meat, such as the taboo of pork among Muslims and Jews (Harris 1986). Finally, also genetic height potentials can play a role, although literature has reduced the potential for genetic maxima at the population level to a small amount (Moradi and Baten 2005).

5.5 Applications of anthropometric income measures and the estimation of Skill Premia

5.5.1 Literature review

Besides the investigation of inequality between special groups, there is another field of research that uses overall measures of within-country inequality. In those cases, the CV of individual data is applied as a proxy indicator, comparable to the gini coefficient of income (Baten 1999).

Moradi and Baten (2005), for example, find that specialized cash cropping in Sub-Saharan Africa increases within-country inequality, measured by the CV of heights. Diversified cash cropping, however, has the opposite effect. They also compare gini values and the corresponding CV measures and provide a formula to estimate gini coefficients. They suggest the following formula to estimate gini values with CVs:

(1) $$Gini = 33.5 + 20.5 * CV$$

Van Zanden et al. (2010) use height gini values calculated with this formula to provide a global picture on the development of world inequality during the 19th and 20th centuries.

Baten and Fraunholz (2004) investigate the influence of globalization on inequality in the Latin American periphery. They find openness to increase inequality (at first) and vice versa. However, inward looking development strategies did not cause less inequality. On the other hand, inequality motivated countries to cause protectionist policies (Baltzer and Baten 2008).

Blum (2010a) argues that a further determinant of biological well-being is the inequality of resources, which are distributed inefficiently, since marginal returns to income differ between individuals and social classes. His results suggest that the reduction of inequality and the increase of redistribution from rich to poor classes increase average height, since the losses of the rich are outweighed by the gains of the poor.

5.5.2 Methodological background of height CVs

What is the idea of height CVs (or their linear transformation, the height ginis)? The effects of inequality on heights are best understood by comparing the likely outcomes of a hypothetical situation, in which a population is exposed to two alternative allocations of resources A and B after birth (Moradi and Baten 2005):

(A) All individuals receive the same quantity and quality of resources (nutritional and health inputs). This case refers to a situation of perfect equality.

(B) Available resources are allocated unequally (but independently of the genetic height potential of the individuals).

In the case of A, the height distribution should only reflect genetic factors. Despite perfect equality, we observe a *biological variance* of (normally distributed) heights in this case. Yet, how does the height distribution respond to an increase in inequality (B)? The unequal allocation of nutritional, medical and shelter resources allows some individuals to gain and grow taller, while others lose and suffer from decreasing nutritional status. In comparison to the situation of perfect equality, the individual height of the rich strata shift therefore to the right, the heights of the poor strata shift to the left. Thus rising monetary inequality should lead to higher height inequality, although this effect is weakened by the fact that the genetic height variation accounts for the largest share of height variation. Even a bimodal height distribution could result if the resource endowment differed extremely between groups. In practice, since the biological variance continues to contribute a large share to the total variance, most height distributions are normally distributed or very close to normal, but with a much higher standard deviation than the rather theoretical situation of perfect income equality.

The standard deviation is not a satisfactory measure of inequality, since anthropologists argue that the *biological v*ariance increases with average height (Schmitt and Harrison 1988). The coefficient of variation (CV) takes this effect into account and is a consistent and robust estimate of inequality. For a country i and a birth decade t, the CV is defined as:

(2) $$CV_{it} = \frac{\sigma_{it}}{\mu_{it}} \cdot 100$$

Thus, the standard deviation σ is expressed as a percentage of the mean μ.

5.5.3 The estimation of Skill Premia with anthropometric indicators

Skill premia are here defined as the wage ratio between a skilled worker in the building trades, and an unskilled one. This measure is available for a number of countries since the 19th and early 20th century, whereas the amount of other inequality indicators (such as the gini coefficient of income) is quite limited and sometimes of low accuracy before the 1970s and 1980s. Clearly, the skill premium as a measure of inequality does not cover the entire economy and the assumption that inequalities between skilled and unskilled building workers reflects skill premia in other sectors of the economy might not always hold. On the one hand, sources of income like subsistence farming, household production, public goods and black market economies are not captured by skill premia. Those latter parts of the economy, however, can be covered quite well with anthropometric measures. On the other hand, wage differences are expected to result in differences in biological living standards. Hence, we consider height CVs as valuable basis for the estimation of skill premia. This means that if we find a significant correlation between skill premia, which is one of the most abundant income-based inequality indicators, and height CVs, both measures together will allow to trace inequalities within countries considerably well for the past two centuries.

We collected the available evidence of unskilled and skilled building workers that was compiled by Robert Allen for the 19th century, and the League of Nations and International Labor Organization Statistics for the early 20th century.[56] This evidence yielded a panel of 166 observations between the 1800s and 1950s. In most cases, around

[56] We collected the ILO data from Bureau International de Travail: Annuaire des Statistiques du Travail 1949/1950, 11eme edition. BIT Publisher, Geneve 1951, pp. 212-227. Where more than one city was available, we took the city with an average unskilled wage. Where wages for 1950 were not available, we took the ones for 1949. For the 1920s to 1940s, we took the data from the internet page 'Prices and Wages' at the University of Utrecht, accessed on May 2nd, 2010, http://www.iisg.nl/hpw/data.php. The earlier data comes from the internet page documented in Allen (2001), lastly accessed on June 3rd, 2009. Further details in appendix available from the authors.

10 observations were available per decade (mostly from the Allen compilation), but in 1950 there were 33 observations, because the International Labor Organization extended the coverage to a number of poor countries. This is also the reason why the variation of inequality is slightly higher in this decade.

As noted above, Moradi and Baten (2005) have argued that the coefficient of variation can also be expressed as a 'height gini' with a simple linear transformation derived from a regression analysis. When we compare the dataset of skill premia with overlapping evidence on height inequality expressed in these gini units, the positive correlation between the both indicates a general correspondence (Tables 5.4 and 5.5). For example, Spain in the 1850s-1890s, Mexico in the 1950s and the U.S. had relatively high inequality, whereas inequality was rather low in Denmark and Switzerland in the 1920s. Testing this more systematically, we examine in three different regression specifications whether the relationship between anthropometric inequality measures and skill premia is

Table 5.4: Regressions of skill premia on height ginis

Model	(1)	(2)	(3)
Estimation technique	Fixed Effects	Random Effects	OLS
Height gini	2.13*	1.99***	2.49***
	(0.059)	(0.003)	(0.000)
Time fixed effects included?	No	Yes	No
Constant	0.69	0.92***	0.53**
	(0.160)	(0.006)	(0.025)
Observations	50	50	50
R-square within	0.18	0.33	
R-square overall	0.23	0.34	0.23

Notes: Robust p-values in parentheses, ***, **, * indicates significance at 0.01, 0.05, 0.10 levels. The results of the Hausman test between model 1 and 2 were Chisq(1)= 0.03, Prob>chi2 = 0.8663, hence the fixed effects effects model would be preferred. Descriptive statistics can be found in Table 5.3.

significant (Table 5.4). The overlap between our database on height ginis and skill premia yields 50 observations, and each observation reflects one country and birth decade. Given the panel nature, we estimated both fixed and random effects models in order to study the robustness of the relationship (and also simple OLS in column 3). The relationship is statistically significant and positive. The explanatory power of these models is reasonably high, although a lot of random fluctuation cannot be explained.

Table 5.5: Regressions of skill premia on height ginis (continued)

Model	(1)	(2)	(3)	(4)	(5)
Estimation technique	Random Effects	Fixed Effects	Fixed Effects	OLS	OLS
Which years	All	All	All	All	Until 1910
Height gini	1.04*	1.04*	1.35**	2.53***	1.51***
	(0.09)	(0.09)	(0.02)	(0.00)	(0.00)
Time fixed effects	Yes	Yes	No	No	No
Country fixed effects	Yes	No	No	No	No
Constant	1.08***	1.28***	1.06***	0.52***	1.06***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	125	125	125	125	101
R-square within	0.36	0.36	0.08		
R-square overall	0.83	0.27	0.23	0.23	0.09

Notes: Robust p-values in parentheses, ***, **, * indicates significance at 0.01, 0.05, 0.10 levels. The results of the Hausman test between model 1 and 2 were Chisq(1)= 2.36, Prob>chi2 = 0.1243, hence the fixed effects effects model would be preferred. We used the changes in height gini of the following countries as reference countries in case interpolations were necessary for individual decades of countries in brackets: Brazil (for Argentina, Columbia, Guatemala, Mexico), Columbia (Nicaragua, Peru), China (North Korea, South Korea, Japan), Czech Republic (Poland), Germany (Austria, Switzerland), France (Belgium, Germany, Netherlands), Indonesia (Myanmar, Thailand), India (Bangladesh, Pakistan), North Korea (China), Poland (Czech Republic, Estonia, Hungary, Latvia, Russia), Portugal (Cyprus, Spain, Greece, Italy), Sweden (Denmark, Finland, Norway), United Kingdom (Ireland), United States (Australia). In the cases of missing Canadian values, both the US and the UK were used as reference countries.

In order to assess the robustness, we repeated the test with a slightly larger sample of height ginis, for which we used some conservative interpolation for Europe, America and Asia (for which the amount of data allows some interpolation). This brought the number of observations to 125 for the whole period and 101 for the 'long' 19th century (until the 1910s). Adding these values reduces the size of the coefficient somewhat (which can partly be explained by the fact that the constant is now estimated to be around 1, whereas it was below 1 in Table 5.4 and the Col. 4 of Table 5.5). In general, the relationship between anthropometric inequality and skill premia remains robust. Neither is it affected by the inclusion of decadal or country dummy variables.

Finally, we have also studied the experience of the period until 1910 separately, which might be different from the 1920s to 1950s period, in which a number of parameters changed in the world economy (column 5 in Table 5.5). Once again, the estimation results are relatively robust.[57] The height ginis and the resulting skill premia are reported in Tables 5.6 and 5.7.

5.6 Conclusion

In this study, several facets of inequality are analyzed and described, such as differences between ethnicities, genders, regions, social groups, differences caused by unequal institutional systems, and rural-urban differences. In addition, this article gives advice on how to (and how not to) study anthropometric within-country inequality.

A direct comparison with skill premia has not been introduced in the previous literature. We found the relationship between the two inequality indicators to be relatively strong and robust in different estimation procedures. We developed a model to estimate skill premia based on those height-based measures. This allows extending the study of inequalities in general and skill premia in particular by more than a century.

[57] The constant and coefficients of column 5 suggest that skill premia for the 19th century can be estimated as 1.05995 +.0151313 * height gini. This can be done with the height ginis that we reconstructed from the large amount of anthropometric inequality values based on anthropological and anthropometric publications; see notes to Table 5.6.

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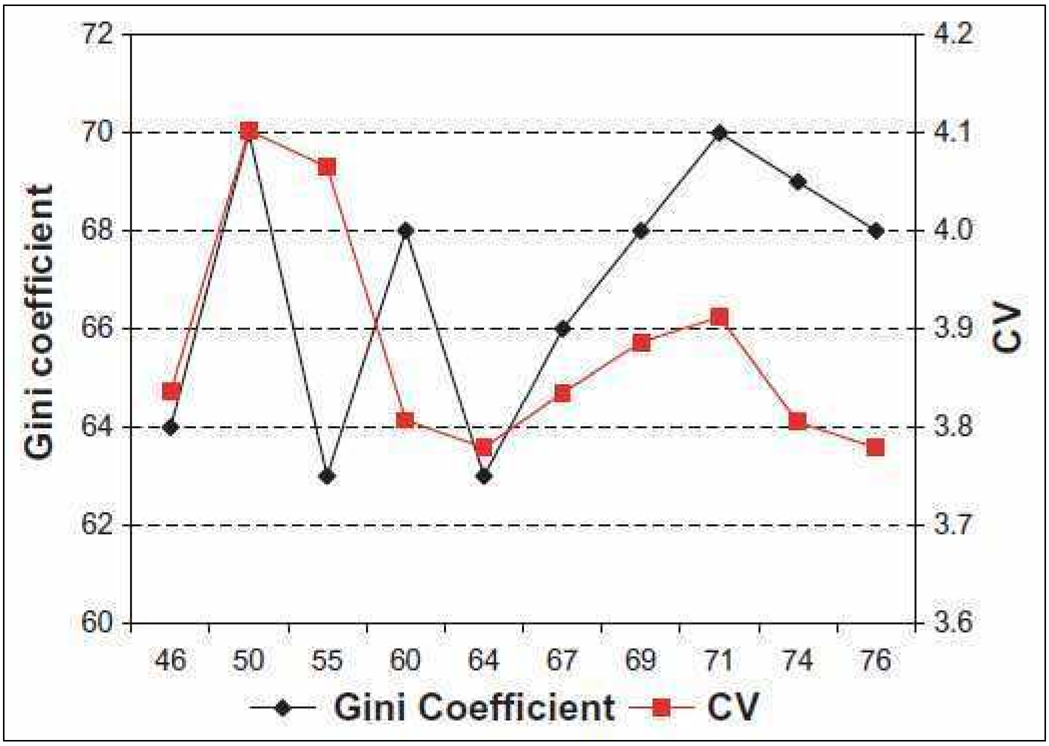
Figure 5.1: Development of income and nutritional inequality in Kenya



Source: Moradi and Baten (2005). Notes: The gini coefficients are from Bigsten (1985) with a national coverage but based on national accounts of income groups, although Deininger and Squire (1996) label them as being based on taxpayers. Bigsten (1985) admits that his estimation technique overestimates the gini coefficients by about 20 percentage points. Birth cohorts were averaged from Kenya II and Kenya III, weighted by the coverage of female population.

Moradi and Baten argued that an excellent case for comparing the development of both income and height-based inequality measures is Kenya, for which the estimates by Bigsten (1985) offer a consistent source with a sufficient number of data points. They conclude that the development of CVs over time serves as a promising measure of inequality, even more so because in periods and countries in which other data on inequality are either non-existent or unreliable.

Table 5.1: Relationship between income (gini) and height inequality (CV)

Gini-coefficient of income	(1)	(2)	(3)	(4)
Constant	-23.429 (-0.80)	-65.912 (-2.06)	19.235 (0.23)	-33.557 (-0.70)
CV	13.182 (1.72)	20.932 (2.87)	8.988 (0.42)	20.547 (1.67)
Coverage of female population (in %)	0.016 (0.20)		0.024 (0.13)	
Age group 20-24 (1=yes, 0=no)	-2.073 (-0.85)			
Age group 45-49 (1=yes, 0=no)	-2.343 (-0.60)			
Gabon		19.582 (4.22)		21.167 (3.01)
Country fixed-effects [p-value]	[0.000]		[0.387]	
Fixed effects for population coverage and income definition [p-value]	[0.000]	[0.000]	[0.810]	[0.026]
Fixed effects for primary source [p-value]	[0.000]	[0.052]		
Weighted by	share of female population		multiple country-periods	
R^2-adj.	0.812	0.521	0.324	0.436
N	78	78	29	29
Degrees of freedom	42	58	6	19

Source: Moradi and Baten (2005). Notes: Gini coefficients which were not based on a national coverage were excluded; t-values in circular parentheses. Number of countries: 14. The reference category represents a gini based on gross income, which covers the total population and persons as reference units. When dummies for countries and the source of gini are included, the reference category additionally represents Kenya and Bigsten (1986). The population coverage controlled for refers to households, economically active population, income recipients and taxpayers, with the income definitions referring to expenditure, net income and income not nearer specified. In cases where two DHS-surveys offer information on the same birth cohort, we took the average weighted by the female population they cover. The gini coefficients were derived from twelve primary sources listed in Deininger and Squire (1996). Coverage/Age: Additionally, we would have expected a negative coefficient for the percentage of the female population measured, correcting for the somewhat higher CV when based on more women. Obviously, however, the impact is almost zero. Similarly, age effects have the expected negative sign but do not introduce a significant bias.

Table 5.3: Descriptives for the skill premia data set

Decade	Observ.	Mean	Std. Dev.	Min	Max
1800	9	1.66	0.26	1.30	2.00
1810	9	1.73	0.32	1.32	2.42
1820	11	1.82	0.29	1.32	2.32
1830	11	1.86	0.37	1.32	2.60
1840	11	1.80	0.35	1.32	2.43
1850	11	1.80	0.37	1.32	2.65
1860	11	1.75	0.31	1.32	2.48
1870	10	1.77	0.31	1.32	2.13
1880	9	1.69	0.22	1.32	2.00
1890	8	1.67	0.27	1.32	2.10
1900	10	1.67	0.29	1.32	2.16
1910	10	1.69	0.25	1.32	2.11
1920	4	1.31	0.08	1.24	1.42
1930	5	1.34	0.16	1.20	1.61
1940	4	1.22	0.04	1.17	1.26
1950	33	1.64	0.48	1.08	3.00
Total Sum/Mean	166	1.65	0.27	1.28	2.17

Source: see text

Table 5.6: Estimated Height ginis (based on anthropometric inequality values)

Light grey color indicates interpolation based on growth rates of similar countries (see notes to Table 5.5), in the first column it is explained which country. Dark grey color indicates linear interpolation.

Sources: internet address of literature list: http://www.wiwi.uni-tuebingen.de/cms/fileadmin/Uploads/Schulung/Schulung5/Joerg/ref_anth.pdf

Co	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980
dr														46	49	47	50	
gy										46								
ht															49	49	49	44
cn		38	37	35	35	34	34	33	33	40	41	37	51	45	41	46	42	
hk		38	37	35	35	34	34	33	33	40	41	37	51	45	41	46	42	
kp		31	30	28	28	28	28	27	26	33	34	31	44	38	35	39	36	
kr		31	30	28	28	28	28	27	26	33	34	31	44	32	33	35	31	35
tw		38	37	35	35	34	34	33	33	40	41	37	51	28				
al								27	27	18								
am									36	35								
bg								39										
cz	33	35	36	33	35	32	54	50	51	41	39	41	41	41	40	38	40	43
ee	40	42	43	40	42	39	38	34	35	33	36	37	36	34	38	36	39	
ge									30	35								
hr													48					
hu	38	41	48	48	51	47	46	42	43	44	41	44	42	41	41	41	41	
kg									45	37	46	36		39	42	40	41	
kz									56		28		36	36	45	45	48	
lv	48	49	51	48	50	46	46	41	41	42	39	42	40	39	42	40	42	
mk												43						
pl	45	47	48	45	47	44	43	39	39	40	38	40	39	37	41	39	41	44
ru	51	52	54	51	53	49	49	45	45	62	42	40	36	34	38	36	38	41
si						31						38			35		34	
sk													38	40				
tj										47	49							
tm									29		41							
ua		38	42	36														
uz									42	40	42			39	45	47	43	
at	54	53	46	47	52	48	50	44	47	46	45	45	48	47	48	42	42	
au	47	47	45	44	47	45	45	42	42	39	42	33	35	37	39	46		
be	47	57	59	54	53	50	47	46	47	45	44	44	47	43	48	47	50	
ca	38	37	37	42	29	32	37	38	44	47	42	45	42	45	47	40	39	
ch	45	44	45	42	47	44	45	43	37	36	37	37	40	39	40	39	41	
cy	52	59	48	41	45	45	50	31	38	40							43	
de	45	45	46	43	48	45	46	41	44	43	41	41	44	44	44	43	45	
dk	42	33	42	40	42	41	41	41	40	37	41	33	33					
es	62	70	58	51	53	51	65	53	59	61								
fi	46	36	46	44	46	45	45	45	43	38	42	42	42	40	36	43		
fr	43	53	55	50	49	46	43	41	43	41	40	40	43	39	44	43	46	
gr	46	53	42	35	39	39	44	37	33	39			37		35	40		
ie	51	36	37	35	33	29	35	35	41	45	40	42	39	40	42	41		
it	34	41	44	37	41	41	45	41	46	48			41		38	44		

jp		37	36	34	34	33	33	32	45	43	44	43		36	40			32
nl	43	42	44	41	46	43	44	39	42	40	39	39	42	41				
no	37	28	38	36	38	36	36	36	35	32	42			36				
pt	49	56	45	38	42	42	47	42	48	50							43	42
se	43	34	43	42	43	42	42	42	41	38	42			34	45			
uk		40	42	39	37	34	40	40	46	50	45	47	44	45	47	45		
us	42	42	40	39	42	51	38	45	50	44	46	44	47	48	51	54	57	
ar		49	48	45	42	43	46	45	43	47	47	41						
bo														36	34	41	35	33
br		59	57	54	52	50	50	47	53	55	58	70			49	49	49	
co		70	68	65	63	61	61	52	54	63	57	52	52	50	48	47	46	
gt		73	72	68	66	64	64	56	57	66	60	56	55	53	51	55	54	
mx		63	62	59	38	51	46	47	51						57	59	62	64
ni		68	67	64	62	60	60	51	53	62	56	51	51	49	49	45	47	44
pe		79	78	80	64	60	50	53						42	45	43	43	44
af													38					
dz											35	34	33					
eg										45			45		42	42	39	36
il													42					
iq									45	49								
ir																59	61	60
lb									44	48								
ma								41							44	44	43	41
sy									36									
tr								35					36		42	40	41	40
ye										49								
bd				42	48	40	44	48	45	46	48	51	50	50	41	43	42	41
in				46	52	45	40	44	41	42	44	47	46	46	44	42	45	
pk				43	49	42	37	49	54	55	57	60	59	59	57	55	57	
id				42	42	43	48	51	40	42	38							
mm				35	35	36	36	36	25	26	23							
pg													47					
th				35	36	37	41	45	34	35								
ao										39	43	58	42	63				
bf												37	42	42	43	42	42	42
bi												49						
bj	53														47	48	45	47
cd											46	41	41					
cf															56	51	58	
cg	48										40	32	46	41				
ci															43	44	45	
cm									36	30	46		37		45	46	47	45
et														48	50	50	51	
ga															49	48	46	56
gh								50	46	46	42	41			48	46	48	46
gn											44				49	49	46	
gw													43	48	42			
ke								37			57	57	45	51	49	48	47	48
km															39	44	47	

mg												43			42	44	42	
ml													47	53	50	52	45	43
mw												36	39	37	42	45	45	49
mz							41				34				48	46	50	47
na								49						44	49	50	46	
ne											48			45	41	45	43	
ng	54	56							44									
rw											38	48			54	51	50	48
sd												45	48					
sn	58											39		47	43	46	40	
so												44						
td							40						41	30	47	47	47	52
tg															42	45	46	
tz										45	38	38	37	45	49	50	49	
ug											43				53	49	48	50
za										46	40	51	43	43				
zm														51	46	46	46	49
zw										39					47	47	48	

Table 5.7: Estimated Skill Premia, 1810 - 1980

Co	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980
cu														1.62	1.71			
gy										1.72								
ht												1.48	1.63					
jm									1.74		1.60	1.59	1.63					
pr									1.63	1.70	1.68	1.69	1.84					
cn	1.68	1.59	1.58	1.55	1.51	1.61	1.54	1.52	1.52	1.63	1.64	1.59				1.74		
kp								1.42							1.55	1.62	1.56	1.51
kr														1.51	1.52	1.55	1.49	1.55
tw											1.27	1.14	1.20	1.45				
al								1.43	1.43	1.29								
am					1.53	1.96			1.56	1.67					1.57	1.64	1.75	1.70
az						2.14									1.56	1.58	1.83	1.58
bg								1.62					1.67	1.49				
cs					1.63		1.82	1.82	1.75							1.81		
cz	1.53	1.55	1.57	1.52	1.76	1.66	1.84	1.68	1.71	1.64	1.60	1.64	1.64	1.64	1.63			
ee							1.63	1.66	1.54	1.52	1.56					1.57	1.61	
ge									1.47	1.54								
hr					1.76				1.73	1.54			1.75		1.88	1.62		
hu	1.59	1.65	1.75	1.75	1.80	1.54	1.60								1.65	1.65	1.64	1.77
kg								1.56	1.70	1.59	1.72	1.56	1.53					
kz									1.87		1.44		1.57			1.69		
lv			1.54					1.65	1.64	1.65								
mk											1.58	1.68	1.58					
pl				1.70	1.74	1.68	1.67	1.61	1.62	1.73	1.71		1.61	1.59	1.64	1.61	1.64	1.69
ro				1.30	1.78		1.81			1.69								
ru				1.65	1.64	1.61		1.59	1.70	1.96	1.66	1.62	1.57	1.54	1.60			
si							1.49					1.60			1.56		1.54	
sk					1.77							1.74	1.59	1.62				
tj							1.60	1.55	1.74	1.74	1.77							
tm									1.45		1.64							
ua		1.59	1.66	1.56	1.92		1.62	1.74										
uz								1.68	1.65	1.62	1.65							
at		1.82	1.71	1.73	1.76											1.66	1.65	
au					1.73	1.71	1.70	1.65	1.66	1.61	1.65	1.52				1.71	1.66	
be														1.67		1.65		
ca	1.94	1.58	1.58	1.65	1.46	1.50						2.16	1.65	1.70	1.74	1.62	1.62	
ch		1.48	1.67				1.70	1.67		1.57	1.58							
cy						1.53	1.78	1.50	1.47									
de	1.71	1.70	1.71	1.68	1.75	1.70	1.72	1.64	1.68	1.59	1.55		1.69	1.68	1.69	1.68	1.71	
dk									1.62			1.52	1.53	1.44		1.69		
es				1.80	1.83	1.80	2.01	1.82	1.72	1.65	1.84					1.72		
fi								1.70		1.60			1.65	1.63	1.57	1.66		
fr	1.67	1.83	1.85	1.78	1.76	1.72	1.68	1.65	1.67	1.65	1.63	1.63	1.68	1.61	1.68	1.67	1.72	
gr							1.68	1.59					1.58		1.55	1.63		
ie	1.80	1.57	1.58	1.54			1.76	2.12	1.70	1.57	1.57					1.80		
it	1.82	1.64			2.19		1.39	1.64	1.79	1.69	1.70		1.65	1.74	1.60	1.68		
jp								1.51	1.71	1.67		1.67	1.61	1.56	1.62	1.61		1.50
nl							1.76	1.77						1.65		1.66		
no	1.72	1.54	1.50	1.59			1.57			1.51				1.56				
pt	1.76	1.87	1.70	1.59	1.66	1.65	1.73	1.66	1.75	1.78	1.66	1.69	1.52	1.71	1.67	1.70	1.67	1.66

se	1.67	1.53	1.68	1.65	1.68	1.66	1.58	1.66	1.64	1.60	1.66		1.52	1.54	1.71	1.68		
uk	1.86	1.62	1.65	1.62	1.59	1.54	1.62	1.63	1.71	1.77	1.70	1.73	1.69	1.70	1.73	1.71		
us	1.66	1.65	1.63	1.61	1.65	1.79	1.60	1.70	1.78	1.69	1.72	1.68	1.73	1.75	1.85	1.87	1.89	1.85
ar	2.29	2.22	2.30		1.66	1.67	1.72	1.70	1.67	1.73	1.73	1.64						
bo							1.50						1.43	1.41	1.37	1.54	1.39	1.35
br	1.76	1.91	1.89	1.84	1.81	1.78	1.78	1.73	1.83	1.86	1.90	2.08					1.74	
cl															1.50			
co							1.94	1.81	1.84	1.97	1.88	1.81	1.80	1.78	1.81	1.80	1.75	1.72
gt									1.63			1.50	1.50				1.74	
mx				1.91	1.60	1.79	1.72	1.74	1.79						1.89	1.92	1.96	1.98
pe		1.94	2.20	2.23	1.99	1.93	1.78	1.82				1.62						
af								1.67					1.59					
dz											1.55	1.53	1.52					
eg						1.99	1.16	1.45		1.70	1.66	1.77	1.69					
il							1.94						1.66					
iq								1.70	1.70	1.77	2.30							
ir							1.66	1.52	1.72	1.85	1.57					1.91	1.94	1.93
lb									1.69	1.75								
ly									1.57									
ma								1.64										
sy								1.95	1.56	1.83								
tr						1.64	1.67	1.55	1.54	1.68		1.56	1.56		1.63	1.78	1.70	1.62
ye										1.63								
bd					1.90	1.63	1.69	1.75	1.85	1.78	1.86							
in				1.71	1.81	1.70	1.63	1.68	1.64		1.69	1.73	1.72	1.71	1.80	1.76	1.78	1.81
lk																1.73		
np													1.55		1.96			
pk					1.52		1.58	1.76	1.65	1.86			1.58	1.64				
id				1.65	1.67	1.67	1.74	1.80	1.63	1.65	1.59							
mm					1.57	1.57	1.57	1.57										
pg						1.43		1.65					1.73					
ph						1.63	1.76	1.95	1.70	1.99	1.49							
th										1.55								
vn												1.66						
ao	1.93	1.69							1.45	1.61	1.67	1.90	1.66	1.97				
bf												1.58	1.66					
bi												1.76						
bj	1.82	1.66									1.69							
bw											1.52							
cd								2.25	2.09	2.55	1.71	1.65						
cg	1.75										1.63	1.50	1.72	1.65	1.65			
cm	1.90								1.57	1.47	1.72		1.58					
er								1.60										
eret							1.61											
et							1.62	1.42				1.87	1.47					
ga												1.82						
gh	2.11	1.50						1.43										
gn									1.56		1.69							
gw												1.93	1.67	1.75	1.66			
ke								1.57			1.88	1.88	1.70	1.70				
mg												1.68						
ml													1.73	1.82	1.87	1.95		

mr												1.53						
mw							1.56					1.57	1.61	1.61				
mz	1.58						1.65				1.54	0.95						
na							2.20	1.76					1.66			1.58		
ne											1.75							
ng	1.84	1.86							1.68									
rw							1.94				1.59	1.75						
sd							1.81				1.47	1.70	1.75					
sn	1.89	1.60									1.69	1.60			1.78			
so								1.71	1.68		1.65	1.69	1.42					
sz															1.81	1.72	1.73	1.82
td						2.02	1.63						1.64	1.47	1.75			
tz										1.70	1.60	1.60	1.58					
ug											1.68							
za									1.63	1.71	1.67	1.79	1.66	1.67				
zw										1.61								

6. Summary

In this thesis mainly anthropometric indicators are used to investigate several aspects of living standards and inequality in global and historical perspective. Chapter two uses anthropometric information as an indicator for human health and welfare in 156 countries spanning the period 1810-1989. The findings suggest that regional height levels around the world were fairly uniform throughout most of the 19th century, with two exceptions: above-average levels in Anglo-Saxon settlement regions and below-average levels in Southeast Asia. After 1880, substantial divergences began to differentiate other regions. In addition, the determinants of these divergences are assessed. The analysis suggests that protein availability was a core variable for human health and welfare as measured with anthropometric indices. Moreover, disease environment, lactose tolerance, and geography also played an important role. Those variables reduced the unobservable world differences in height by more than a half.

Chapter three also deals with the determination of living standards. In contrast to chapter two, however, it emphasizes the role of state efficiency. It evaluates the quality of a country's institutions by estimating the economic efficiency of their governments. We measure state efficiency by evaluating the process which transforms a given number of endowments, such as capital, labor power, and land, into welfare. Both an anthropometric yardstick, namely adult male height, and a monetary one (per-capita GDP) are applied to capture different kinds of human well-being. The Data Envelopment Analysis (DEA) is used in order to calculate efficiency values for 62 countries on a decadal basis between the 1850s and the 1980s.

In general, the results suggest that state efficiency increased among industrialized countries. Both Latin American (early 20th century) and African (post WWII) economies start on a relatively high level but show a systematic decline in the course of the 20th century. In Africa, former British colonies have done worse compared to their counterparts under French rule. In several countries we find wars, particularly occupation, violence and political instability to have a remarkable negative – sometimes even permanent – influence on state efficiency, as in the cases of Spain, Greece and Colombia. In this regard, typical characteristics of successful states seem to be agricultural specialization, redistribution and a homogeneous population.

Chapter four shows the interaction between inequality and living standards. It is argued that – according to the theory of diminishing returns to income – aggregate welfare is at its maximum if all resources are equally distributed among individuals in a society. In order to test this hypothesis the relationship between the Coefficient of Height Variation (CV) and average height is studied. The height CV is a measure of welfare inequality. It is an alternative to conventional yardsticks and it allows measuring inequality and economic development, both for countries and periods where conventional data are not available.

Using panel data on 105 countries during the past two centuries, the results indicate a systematic negative and concave relationship between inequality and average height, which can serve as a basis for the understanding of the consequences of economic inequality. An analysis of the correlates under study reveals that the influence of inequality has almost the same strength as per-capita income. After we distinguished between world regions and between birth decades the relationship still holds. An alarming finding is the increasing negative influence of inequality on average height during the post-WWII period.

Chapter five investigates anthropometric inequality in further detail. First, a literature review of anthropometric studies of within-country inequality is provided. Afterwards, the paper discusses the relationship between skill premia and inequality indicators based on height variation. Skill premia describe the wage gap between an unskilled and a skilled building worker, while height CVs display the variance in net nutrition. The results of this chapter indicate that the two measures are correlated and that CV values are suitable to estimate skill premia. We supplement the existing literature by an additional tool, namely the estimation of skill premia based on the coefficient of height variation (CV).