Physiological Constraints and Comparative Economic Development*

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Abstract. It is a well known fact that economic development and distance to the equator are positively correlated variables in the world today. It is perhaps less well known that as recently as 1500 C.E. it was the other way around. The present paper provides a theory of why the "latitude gradient" seemingly changed sign in the course of the last half millennium. In particular, we develop a dynamic model of economic and physiological development in which households decide upon the number and nutrition of their offspring. In this setting we demonstrate that relatively high metabolic costs of fertility, which may have emerged due to positive selection towards greater cold tolerance in locations away from the equator, would work to stifle economic development during pre-industrial times, yet allow for an early onset of sustained growth. As a result, the theory suggests a reversal of fortune whereby economic activity gradually shifts away from the equator in the process of long-term economic development.

Keywords: long-run growth, evolution, nutrition, fertility, education, comparative development.

JEL: O11, I12, J13.

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1. Introduction

It is a well known regularity that economic development tends to increase as one moves away from the equator. Figure 1 provides one particular illustration, which employs the urbanization rate as a proxy for development, but similar patterns emerge if one were to consider other indicators such as GDP per capita. The strong "latitude gradient" emerges across the world at large, and even within Europe.

Strikingly, however, this state of affairs is of relatively recent origin as evidenced by Figure 2. As is visually obvious, economic development (measured by population density, for the standard Malthusian reasons; Acemoglu et al., 2002; Ashraf and Galor, 2011) was negatively correlated with absolute latitude at the eve of the Age of Discovery. Again, this association is found both across the world at large and within Europe. The fundamental objective of the present paper is to provide a theory, which can account for this remarkable "reversal of fortune".[1]

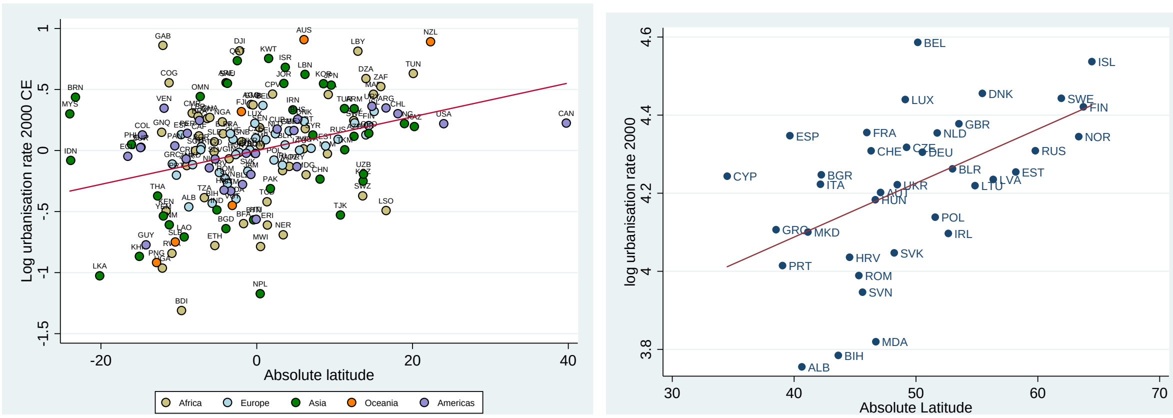
This paper proposes that the intertemporally shifting latitude gradient is a consequence of differences in the physiological constraints faced by individuals at different geographical locations. The argument is anchored in an important fact from the fields of biology and physical anthropology: Individuals are inherently physically bigger (measured in kg) in locations further away from the equator.[2] This regularity is very likely a consequence of positive selection towards greater cold tolerance in the aftermath of the exodus from Africa some 50,000 years ago, as discussed below. The substantive implication of this "latitude gradient in body mass" is that individuals living in colder climate zones would end up facing higher metabolic costs of fertility, on purely physiological grounds, since these costs are increasing in the body mass of individuals. As a consequence, during pre-industrial times one would expect to see progressively lower levels of population density as one moves away from the equator (see Dalgaard and Strulik, 2012). Moreover, if, in the pre-industrial era, technological change was positively influenced by population size, societies where citizens were larger but less numerous would tend to be less technologically sophisticated, reinforcing the physiologically founded reason for low economic

[1]The picture depicted in Figure 2 carries over if the urbanization rate in 1500 is used instead of population density (see the Appendix, Table A1). As far as we know, the negative link between absolute latitude and early development was noticed first in Ashraf and Galor (2011).

[2]This phenomenon is labeled "Bergmann's rule" in the relevant literatures, after Bergmann (1847). For empirical evidence, see e.g. Roberts (1978), Ruff (1994), Katzmarzyk and Leonard (1998) and Gustavson & Lindenfors (2009).

Figure 1: Contemporaneous Latitude Gradient

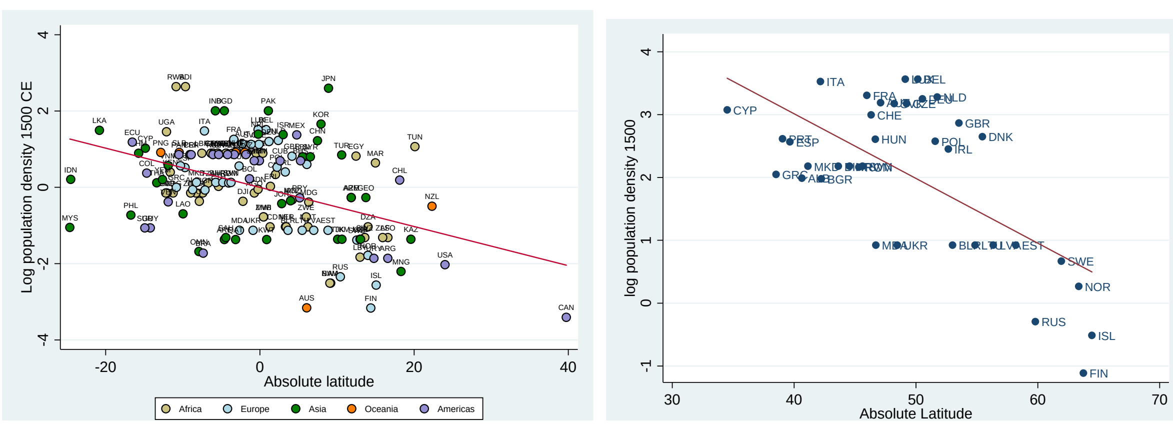
A: World B: Europe



The figures show the correlation between absolute latitude and urbanization rates in the year 2000 across the world and in Europe. Continental fixed effects have been partialled out in Panel A. The depicted line is estimated by OLS.

Figure 2: Pre-Industrial Latitude Gradient

A: World B: Europe



The figures show the correlation between absolute latitude and population density in 1500 C.E. across the world and in Europe. Continental fixed effects have been partialled out in Panel A. The depicted line is estimated by OLS.

development.[3]

However, as technological change makes formal education more attractive it is likely to be adopted sooner in societies where the (relative) cost of child quantity are greater; places inhabited by bigger individuals, further away from the equator. This is where the latitude-productivity nexus gradually begins its turnaround: as educational investments are undertaken, fertility declines and economic growth takes off. Consequently, the currently observed positive correlation between absolute latitude and development outcomes may be the product of a differentiated

[3]For a formal discussion of the link between population density and technological change in a pre-industrial environment, see Aiyar et al. (2008) and Ashraf and Galor (2011).

timing of the take-off, which has provided places further away from the equator with a developmental head start in the modern growth regime.

Accordingly, we argue that the pre-industrial latitude gradient arose in essence for physiological reasons: physiologically bigger people face higher metabolic costs of fertility, which works to lower average population density. A positive scale effect in technological change from population size provides a reinforcing mechanism yielding relatively poor development outcomes early on, in locations where people on average are heavier. The contemporary latitude gradient, we would argue, arose more recently due to the differentiated timing of the take-off; societies inhabited by (on average) bigger individuals managed the transition earlier, propelling them to relatively higher levels of prosperity. The differentiated time of take-off would not only lead to economic divergence, but also physiological divergence as rising income permits greater nutritional investments per child implying that pre-existing differences in body mass are enhanced.

In support of this hypothesis we develop a unified growth model. The model features overlapping generations of children and adults. Adults are the economically active agents and decide on family size, the level of nutrition and schooling of the offspring as well as own (luxury) consumption. Following Dalgaard and Strulik (2012, 2014) parents are subject to the physiological constraint that they have to cover their basal metabolic needs, which depend on their own body mass as well as the level of fertility. Moreover, body mass is transmitted via an intergenerational law of motion. Finally, a unique output good is produced using body size augmented labor, human capital, land, and technology.

Aside from these features the theory builds on three key elements. First, utility of parents is increasing in the quality and quantity of offspring as well as own consumption. There are two dimensions to child quality, which are assumed to be imperfect substitutes: nutrition and skill formation. Moreover, preferences are assumed to fulfill a "hierarchy of needs" principle: in a time of crisis parents will tend to adjust own (luxury) consumption more strongly than child quantity and quality. Second, the return to skill formation is increasing in the level of technological sophistication and human capital production features a non-convexity. The latter element involves the assumption that parents costlessly transmit a minimum amount of skills to the next generation, which permits a corner solution in terms of skill investments when the level of technology is sufficiently low. Third, technology evolves endogenously and depends on human capital augmented population size.

These elements interact in the following way. At early stages of development the economy finds itself in a "subsistence regime" featuring low income and a relatively poor state of technology. Consequently, parents only invest in child quantity and the nutrition-based quality component. As technology slowly advances, however, income rises gradually despite the resource diluting influence from population. Eventually, the economy transits into a "pre-modern regime". The higher level of income entices the parents to start spending resources on themselves; i.e. above and beyond subsistence requirements. In addition, parents choose to increase the size of the family further. Nutritional investments also rise, but not on a per child basis. Consequently average body mass is not increasing despite a higher level of income. Yet as technology continues to advance, now at a higher speed, the economy ultimately moves into the "modern growth regime", where human capital investments are deemed optimal. As quality investments are intensified, individuals respond by lowering fertility, which also allows nutritional spending per child to increase. Consequently, growth takes off: economically, and physiologically in the sense of increasing body mass. In the long-run the economy converges to a steady state where fertility is at replacement level, average body mass and human capital investments are constant, and economic growth occurs at a constant exponential rate.

With this model in hand we conduct experiments in order to examine the origins of the shifting latitude gradient, described above. Specifically, we compare societies where the body of the citizens allows for different degrees of heat loss. In colder locations, further away from the equator, individuals are likely to be more cold tolerant as a result of natural selection. Due to our microfounded intergenerational law of motion for body mass we can capture this outcome parametrically. Our model predicts that, at the steady state, if people are more cold tolerant they also grow bigger in terms of body mass. The question is then whether societies in cold locations are likely to take off sooner, yet be less developed early on.

We consider several scenarios. The simplest scenario, which we can deal with analytically, assumes instantaneous diffusion of ideas across societies. That is, all societies share the same pool of knowledge. In this setting the result is unambiguous: societies inhabited by relatively cold tolerant people will feature relatively larger individuals, and relatively lower population densities early on, but will transit to the modern growth regime relatively sooner. The intuition is simple. Biologically, the metabolic costs of fertility is increasing in the body mass of the parent, which implies that bigger people have a comparative advantage in providing quality investments. Consequently, in early stages of development they produce bigger, but less plentiful offspring; population density will therefore be comparatively low in colder environments. Yet, the comparative advantage in quality investments also implies that human capital investments will become attractive at a lower level of technological sophistication, which ensures an earlier take-off. The model thus rationalizes the regularities depicted in Figure 1 and 2.

The assumption of instantaneous knowledge sharing is admittedly extreme and tends to bias the results in favor of an earlier transition for societies inhabited by larger individuals. If bigger populations produce more ideas it is possible that the "small but many" society, close to equator, could transit to modern growth earlier despite being somewhat more reluctant to invest in quality, on physiological grounds.

We therefore further scrutinize the predictions of the model, by way of numerical experiments, in more realistic settings where knowledge diffusion is gradual and possibly incomplete. We show, for instance, that if societies asymptotically share all knowledge, then places further away from the equator (featuring bigger people) will transit to the modern growth regime relatively earlier unless the diffusion lag in the transmission of ideas is more than 12 generations, which in our calibrations means 720 years. We examine other scenarios as well, some of which involve imperfect knowledge sharing (i.e., some ideas are *never* diffused). Overall, we find for a range of settings, featuring both gradual diffusion and imperfect sharing of ideas, that societies featuring citizens of larger body mass are predicted to take off sooner. Hence, our analytical results, which require instantaneous and perfect knowledge sharing, are fairly robust.

This paper is related to several strands of literature. On the theoretical side, the paper belongs to the literature on growth in the very long run (e.g. Galor and Weil, 2000; Galor and Moav, 2002; Lucas, 2002; Cervellati and Sunde, 2005; Strulik and Weisdorf, 2008; de la Croix and Licandro, 2013). In particular, the model developed below borrows elements from Dalgaard and Strulik (2012, 2014), in regards to the physiological constraints, and from Strulik and Weisdorf (2008) and Dalgaard and Strulik (2014) on the preference side. The contribution of the present paper lies in showing how differences in initial conditions with respect to underlying physiological constraints may have affected comparative development in general, and led to the reversal depicted in Figure 1 and 2 in particular.[4]

[4] On the potential predictive power of unified growth theory with respect to comparative development, see Galor (2010) and Cervellati and Sunde (2013).

The paper is also related to previous contributions that have aimed to explain observed "reversals of fortune". Acemoglu et al. (2002) provide an institutional theory of why former colonies may have experienced a "reversal of fortune", historically. The argument is that places that initially were successful (measured by population density or urbanization rates) were more likely to be "treated" by extractive institutions by the colonial powers, leading to a reversal in relative prosperity among former colonies. Naturally, this particular institution-based theory is not ideally suited to explain the reversal that seems to have occurred within Europe, cf Figure 1 and 2. Olsson and Paik (2014) have more recently argued that countries that underwent the Neolithic revolution relatively early developed extractive institutions and norms emphasizing obedience to the detriment of long-run growth. While an early Neolithic allowed for a developmental head start, the cultural and institutional side effects eventually stifled development, allowing latecomers to sedentary agriculture to overtake. In related research Litina (2013) documents that countries enjoying a geographical advantage in terms of agricultural productivity experienced high levels of economic development early on, but are relatively poor today. Moreover, Litina (2013) argues that this reversal can be explained by cultural change in favor of cooperative behavior in geographically "challenged" nations , eventually allowing them to industrialize comparatively early.[5] Finally, the so-called "temperate thrift hypothesis" asserts that a tropical locality may be have been advantageous early on, but a disadvantage since the emergence of agriculture. The reason being that agricultural techniques were predominantly developed for temperate locations that proved difficult to transfer into topical locations (e.g., Bloch, 1966; Lewis, 1978 and White, 1962).

In the Appendix we demonstrate that the latitude-reversal, documented in Figures 1 and 2, is robust to the control for the timing of the Neolithic revolution (Olsson and Paik) as well as land productivity (Litina), respectively (see Appendix Table A1). Accordingly, theories that account for reversals in these dimensions do not appear to be able to account for the reversal in terms of the "latitude gradient". The "temperate drift hypothesis", with its focus on the role of topical (and subtropical) climatic conditions and diffusion of agricultural techniques, is more difficult

[5]Matsuyama (1992) demonstrates theoretically that high agricultural productivity may stimulate productivity in a closed economy setting, while being detrimental to growth in an open economy setting. If the world economy in 1500 C.E. was, to a first approximation, characterized by autarky, in contrast to the current state of affairs, Matsuyama's theory predicts a reversal of fortune in terms of land productivity. See also Galor and Mountford (2008) who demonstrate, within an open economy unified growth model, that countries featuring a comparative advantage *outside* agriculture (more generally: in human capital intensive sectors) should experience a comparatively early fertility transition and thus transition to sustained growth.

to disentangle from the hypothesis advanced in the present paper. In Table A1, panel C, we are able to demonstrate that the "latitude reversal" remains visible when we simultaneously control for the fraction of a country's area that is located in the tropics and subtropics. But the statistical significance of the latitude reversal is diminished due to the high collinearity between absolute latitude and the fraction of a country's area in the tropical or sub-tropical climate zone. While it should be clear that the temperate drift hypothesis does not seem well suited to account for the change in the latitude-income gradient within Europe (cf. Figures 1 and 2) it seems reasonable to view the two hypothesis as complementary, from a world wide perspective.[6]

The paper proceeds as follows. In the next section we document a series of stylized facts, regarding the interrelationship between geography, body mass and economic activity, which we require the model to be able to account for. Section 3 develops the model, and Section 4 describes the development trajectory implied by the model. Section 5 discusses the model's predictions regarding comparative development whereas Section 6 concludes.

2. Motivating Evidence

This section falls in two subsections. We begin by examining the link between geography and physiology in Section 2.1 after which we turn, in Section 2.2., to the link between physiology and comparative development.

2.1. **Geography and Physiology.** In biology, Bergmann's rule (Bergmann, 1847) and Allen's rule (Allen, 1877) are two well established regularities with bearing on body mass and shape for (most) mammalian species. Bergmann's rule states that average body mass (kg) of individuals is increasing in the distance to the equator, whereas Allen's states that body limbs tend to grow relatively shorter as one moves from warmer to colder ecological zones. Importantly, for present purposes, both rules have found empirical support in the context of the human species.[7]

[6]The high degree of collinearity is well illustrated by the results reported in Table A1, panel C. When either indicator is regressed on past and current outcomes (i.e., absolute latitude or fraction of area in tropic and subtropics), they emerge highly significant. But when we simultaneously control for both, the parameter estimates loose precision; absolute latitude turns insignificant when we look at GDP per capita in 2000 (but not when we look at urbanization in 2000), whereas fraction of the country area in the tropics turns insignificant when we study the link to population density or urbanization in 1500. Multicollinearity seems like the most natural explanation for these results testifying to the difficulty in disentangling the two hypothesis.

[7]On Bergmann's rule see Roberts (1978), Ruff (1994), Katzmarzyk and Leonard (1998) and Gustavson & Lindenfors (2009). Empirical support for Allen's rule is found in Ruff (1994), Holliday (1997) and Katzmarzyk and Leonard (1998).

The most commonly cited interpretation of the two "latitude gradients" is that they have emerged due to selective pressure whereby individuals with body characteristics that ensure greater cold tolerance have been positively selected in colder locations, in the aftermath of the exodus from Africa (e.g., Ruff, 1994; Katzmarzyk and Leonard, 1998). Intuitively, shorter relative limb length reduces the surface area to volume (roughly equal to body mass) ratio, thereby limiting heat loss, which is an advantage in colder environments. Similarly, as a matter of geometric fact the surface area to volume ratio declines as body mass increases (see Ruff, 1994). Accordingly, a negative correlation between the surface area to volume ratio and absolute latitude is simultaneously consistent with both Allen's rule and Bergmann's rule (Schreider (1950, 1975) and could plausibly be the outcome of a process of positive selection towards elevated cold tolerance in human populations (amongst other mammals). This presumption is supported by empirical evidence of recent (i.e., over the last 50,000 years) genetic selection towards greater cold tolerance in human populations (Hancock et al., 2010).

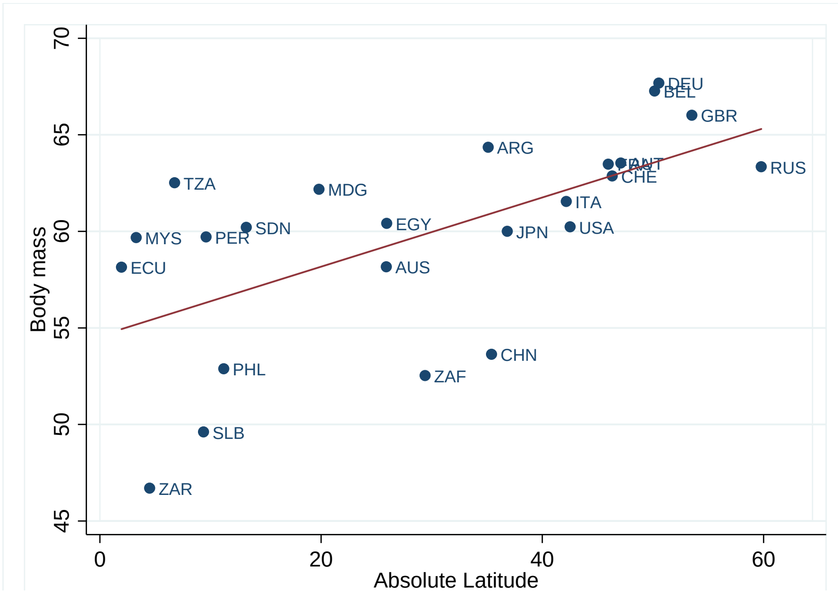
While a genetic interpretation of the two rules appears viable other possibilities exist, however. In particular, since the process of human growth is subject to some degree of plasticity, a shortening of relative limb length may also arise when growth occurs at relatively low temperatures. Hence, adjustment of body mass and proportions can be viewed as a form of acclimatization, which thus can arise without genetic change (see James, 2010).

For present purposes the exact cause of the latitude gradient is not a paramount issue. Whether the link between geography and physiology is caused by natural selection or plasticity and acclimatization the same stylized fact applies: average body mass is increasing with distance to the equator. However, to have bearing on the reversal documented above the latitude gradient should hold across *countries* and not just across indigenous societies, which has been the unit of analysis in the relevant empirical literature within physical anthropology (e.g., Ruff, 1994; Katzmarzyk and Leonard, 1998). This issue is thus worth exploring in some detail.

Figure 3 illustrates the correlation between absolute latitude and a measure of average body mass, which derives from the so-called "Goldman data set"(Auerbach and Ruff, 2004). More specifically, average body mass is calibrated using skeletal remains from the Holocene period up until about ca. 1500 C.E.[8] We view this small sample of observations as reasonable indicators

[8]See the appendix for details on this data and the calibration.

Figure 3: Bergmann's Rule



The figure shows the bivariate association between body mass and absolute latitude, across pre-industrial societies. The data on body mass derives from the Goldman data set (Auerbach and Ruff, 2004), which comprises morphological observations from skeletons dating from 1500 C.E. or earlier. The depicted line is estimated by OLS and is statistical significant at the 1% level of significance.

of (pre-industrial) initial conditions with respect to body mass characteristics.[9] As is visually obvious, Bergmann's rule holds up in this historical sample of countries.

More formally, Table 1 reports the results from regressing absolute latitude on body mass. In the first two columns we employ the Goldman data set. In the remaining columns we employ data on contemporary average body mass (circa 2000), which allows us to expand country coverage appreciably.[10] As seen from columns 1-4 we find that average body mass indeed seems to increase, in our cross-country samples, as one moves away from the equator. In column 2 the estimate does turn statistically insignificant, upon the inclusion of continental fixed effects, presumably because of too limited within-continent variation in our small sample of "pre-industrial" countries.

Table 1 about here

[9]Based on a similar presumption, previous research in human biology has employed the Goldman data set in order to examine the viability of the out-of-Africa hypothesis with regard to height. That is, whether the variability in height within population groups declines with migratory distance to east Africa, consistent with the serial founder effect; see Betti et al. (2009).

[10]The main data source for contemporary body mass is the Demographic Health Survey. See the appendix for further details.

Turning to economic significance, column 3 suggests that body mass increases by about 257 grams for each degree increase in latitude. This finding squares remarkably well with Ruff's estimates (1994, p. 77) of 255 grams, based on data for a world wide sample of indigenous societies. When we further allow for continental fixed effects (column 4), in contrast to the estimation strategy in Ruff (1994), the economic significance of the point estimate rises slightly. In the historical sample the point estimate is somewhat smaller (column 1), though still in the same ballpark.

Overall the results reported in column 1-4 complement the findings of e.g. Ruff (1994) and Gustavson and Lindenfors (2009) of a positive latitude gradient in body mass, in keeping with Bergmann's rule. But if the underlying cause of Bergmann's rule is natural selection it is not obvious that the regressions performed in columns 3 and 4 are the most relevant ones due to the extensive international migration during the Post-Columbian period (Putterman and Weil, 2010).

Hence, in Column 5 and 6 we instead examine the link between *ancestor-adjusted* absolute latitude and contemporary body mass.[11] Evidently, places that today are inhabited by individuals with ancestors who lived far from the equator are characterized by greater average body mass than places inhabited by individuals with ancestors from locations closer to the equator. This is true whether we condition on continental fixed effects or not. In terms of economic significance the results are very similar to those for "raw" absolute latitude.

Intriguingly, when we *simultaneously* control for absolute latitude and ancestor-adjusted latitude, the latter indicator holds the stronger predictive power (cf. column 7 and 8). These results would seem more favorable to a genetic interpretation of Bergmann's rule than a plasticity interpretation, which suggests that local geographic circumstances directly impact on body mass and shape.

In the Appendix (Table A2) we report additional results where the left hand side variable is the *surface area to volume ratio* (SAV), rather than body mass. Consistent with priors we find that as one moves away from the equator SAV systematically declines. Also, ancestor-adjusted absolute latitude appears to be a stronger determinant of contemporary cross-country variation

[11] The ancestor-adjusted latitude is constructed as follows. Suppose a country today comprises citizens' with ancestry from, say, N countries (the country under consideration included), located at absolute latitude, x_i for $i = 1, ...N$, and where their contemporaneous population share is λ_i. Then the ancestor-adjusted latitude is $\sum_i^N \lambda_i x_i$. The source of the international post 1500 migration matrix is Putterman and Weil (2010).

in SAV than the absolute latitude of the country. Once again the estimation results are well in accord with previous estimates by Ruff (1994) in independent samples.[12]

Finally, we also examine whether the results attained above, for contemporary body mass, carry over to sup-samples of countries: Europe and countries with largely "indigenous" populations, respectively. The results are qualitatively similar though at times less statistically significant likely because of the small samples (cf. Table A3).[13] Overall, it would appear that Bergmann's rule obtains across countries today and historically, across the world as well as within Europe: Average body mass is positively correlated with distance to the equator.

2.2. **Physiology and Comparative Development.** The issue to which we now turn is how body mass appears to correlate with economic outcomes of interest. In the present context we are particularly interested in the potential link between body mass and, respectively, the timing of the fertility transition and current economic development.[14]

Table 2 reports on what the stylized facts are in this regard.[15] In columns 1, 4 and 7 we observe that pre-1500 average body mass is negatively correlated with the year of the fertility decline, and positively correlated with GDP per capita and urbanization as of 2000. Once we control for absolute latitude (columns 2, 5 and 8) the strength of the association between body mass and the outcome variables weakens. This is to be expected given the strong latitude gradient in body mass, and since absolute latitude probably influences the growth process (directly or indirectly) for other reasons than via body mass. Adding continental fixed effects seems to have little further impact on the point estimates, which naturally are imprecise due to the small sample size.

Table 2 about here

In order to explore the link between body mass and the outcomes in a larger sample of countries we invoke the data set on contemporary body mass. As can be seen from Table 3, the partial correlations now becomes much stronger. Of course, part of the reason why the partial

[12]When we ancestor-adjust latitude we find a point estimate for absolute latitude of $-.534$, which favorably compares with Ruff's estimate (1994, p. 77): $-.584$. Once again the results for the historical sample are slightly smaller in absolute value. A plausible interpretation is that the extent of measurement error on body mass is somewhat greater in the historical sample, which would bias the OLS estimates towards zero.

[13]By "indigenous" we mean nations where more than 90% of the current population has local ancestry.

[14]The key reason why the fertility transition is a particular object of interest is that many unified growth models assign a decisive role for the fertility transition in admitting the take-off to sustained growth. See e.g. Galor and Weil (2000) and Galor and Moav (2002). See Dalgaard and Strulik (2013) and Andersen et al. (2014) for evidence on the impact of the fertility transition on current levels of income per capita in a cross-country setting.

[15]See the appendix for data sources.

correlation increases (i.e., aside from the benign effects of a larger sample) is likely reverse causality: an earlier fertility transition, or a higher level of economic development, might simply be allowing for bigger people through e.g. nutritional improvements.

Table 3 about here

Hence, in an effort to deal with the reverse causality issue we provide IV estimates in column 3, 6 and 9. The instrument is ancestor-adjusted absolute latitude, and, as can be seen, the specifications simultaneously control for geographic absolute latitude (and thus factors correlated with local climatic conditions). As a result, identification is attained by comparing countries with citizens of greater average body mass due to their "geographical ancestry", once local geography conditions have been filtered out.

The instrument is clearly relevant as seen from Table 1; that is, Table 1 in effect reports the first stage results for the regressions reported in columns 3, 6 and 9 of Table 3. However, as can be seen from Table 3 the instrument is statistically weak, judged from the Kleibergen-Paap F-Statistic. Nevertheless, the Anderson-Rubin test, which is robust to weak instruments, testifies to a casual impact from body mass on the three outcomes, conditional on the exclusion restriction. Overall these results suggests that body mass is a predictor of both the timing of the fertility transition as well as contemporary economic development.[16]

The preceding analysis can be summarized in five stylized facts:

(1) In pre-industrial times, the extent of economic development varied inversely with distance to the equator, cf Figure 2, and Table A1.

(2) Currently, the extent of economic development and distance to the equator is positively correlated, cf. Figure 1, and Table A1.

(3) Average body mass is, today and historically, positively correlated with the distance from the equator (Bergmann's rule).

(4) Societies inhabited by physiologically bigger people, today and historically, underwent the fertility transition earlier.

(5) Societies inhabited by physiologically bigger people, today and historically, are more prosperous today.

[16]In the appendix, Table A4, we examine the robustness of the partial correlation between body size and the timing of the fertility decline to the use of an alternative data source; the results are very similar to those reported in Table 3. We also examine the simple partial correlations in the context of a purely European sample, again with results close to those reported in Table 3 (cf. Table A5).

In the remainder of the paper we develop a unified growth model, which is consistent with this set of facts and thus provides an explanation for the striking historical reversal in the latitude-development correlation.

3. The Model

3.1. **Preferences.** Consider an economy populated by a measure L_t of adult individuals, called households or parents. We abstract from gender differences such that any per capita variable can be thought of as being measured in per parent terms. Households derive utility from children, spending on child quality, and from consuming non-food (luxury) goods.

As Strulik and Weisdorf (2008) and Dalgaard and Strulik (2014) we assume that utility is quasi-linear. Non-food goods enter linearly, which makes them less essential and easier postponable. This creates a simple device according to which consumption is restricted to subsistence needs when income is sufficiently low. The qualitative results would not change under a more general utility function as long the intertemporal elasticity of substitution for child nutrition is smaller than for non-food (luxury) consumption.

Spending on child quality comes in two dimensions: nutrition and schooling. Following the anthropological literature (Kaplan, 1996) we assume that from the preference side there is not a big difference between both quality components. Thus both enter parental utility with the same weight. The most natural way to model this idea is to assume that both components are imperfect substitutes such that child quality (Becker, 1960) is given by the compound $c_t h_{t+1}$, in which c_t is child nutrition expenditure (approximating physiological quality) and h_{t+1} is human capital of the grown up child (approximating educational quality).

Summarizing, the simplest functional representation of utility is

$$u = \log n_t + \gamma \left[\log c_t h_{t+1}\right] + \beta x_t, \tag{1}$$

in which n_t is the number of offspring, x_t is non-food consumption, and β and γ are the relative weight of non-food consumption and child quality in utility.

Parental child expenditure is driven by (impure) altruism, the "warm glow", i.e. it is not instrumental; parents do not calculate how expenditure improves child productivity and future wages. Moreover, notice that parents take into account how education improves human capital of their children but not how nutrition affects body size. Given that humans invested in nutrition of their offspring long before they understood human physiology, this seems to be a plausible assumption. Moreover, at the steady state, the stock variable (body mass) is proportional to nutritional investments. Accordingly, in the long-run the two formulations will lead to similar steady-state results.[17]

3.2. **Technology.** Following Galor and Weil (2000) and Galor and Moav (2002) we assume that production takes place according to a constant returns to scale technology using the factors land X and human capital $\tilde{H}_t$, such that aggregate output is

$$Y_t = A_t \tilde{H}_t^{\alpha} X^{1-\alpha}, \tag{2}$$

in which A_t is the endogenously determined level of technological knowledge at time t. Aggregate human capital is determined by the number of workers L_t times their human capital h_t times their physical capacity (muscle force) which scales with body mass m_t, such that $\tilde{H}_t \equiv m_t^{\tilde{\phi}} h_t L_t$. We denote human capital in the narrow sense, i.e. the aggregate productive knowledge incorporated in people, by H_t, $H_t = h_t L_t$. Following again conventional unified growth theory, we assume no property rights on land such that workers earn their average product and income per capita is given by $y_t \equiv Y_t / L_t$. Normalizing land to unity we obtain

$$y_t = A_t m_t^{\phi} h_t^{\alpha} L_t^{\alpha-1}, \tag{3}$$

in which $\phi \equiv \alpha\tilde{\phi}$. For simplicity we focus on a one-sector economy such that output can be converted without cost into food and non-food.

The main motivation for adding body mass to the production function is that body mass matters to the amount of force the individual can muster; "brawn", in other words. Because muscle force is proportional to muscle cross-section area, measured in meters^2, it rises with weight as $m^{2/3}$ (e.g., Astrand and Rodahl, 1970; Markovic and Jaric, 2004). Of course not all tasks of the production processes rely on 'brute force' to the same extent. Theoretical reasoning and empirical estimates in sport physiology suggest that individual performance in different tasks scales with body size as m^{ϕ}, in which $\phi = 2/3$ for exerting force (as for example plowing and digging), $\phi = 0$ for moving and $\phi = -1/3$ for supporting body weight (Markovic and Jaric,

[17] In Dalgaard and Strulik (2012) we demonstrate that a "utility from body mass" and a "utility from nutrition" yield very similar results at the steady state. Yet the utility from body mass formulation is analytically considerably more cumbersome.

2004). In practise, one would then probably expect a positive exponent, which is bounded from above at 2/3.

3.3. **Human Capital.** Human capital production is a positive function of parental education expenditure per child e_t and the level of knowledge that could potentially be learned at school A_t. Specifically we assume that

$$h_{t+1} = \nu A_t e_t + \bar{h}, \qquad 0 < \nu \leq 1. \tag{4}$$

The parameter $\nu > 0$ controls for the productivity of the education sector (or the share of productive knowledge that can be conveyed at school): The constant $\bar{h}$ denotes human capital picked up for free, for example, by observing parents and peers at work. The production function for human capital could be made more general at the cost of analytical inconvenience. The only crucial part is, as in Galor and Moav (2002), that the return on education is not infinite for the first unit of educational expenditure. This feature, generated by the assumption of some costless acquisition of human capital, produces a corner solution, i.e. the possibility that not investing in human capital is optimal in some environments. It allows us to capture the long epoch of stagnation where investment in formal education arguably did not take place (to a first approximation).

3.4. **Physiological Constraints.** Parents are assumed to experience utility from consumption above subsistence needs x_t but not from subsistence food consumption. Yet they have to eat to fuel their metabolism. The metabolic rate is endogenous and depends – as in Dalgaard and Strulik (2012, 2014) – on body size and fertility. As elaborated by Kleiber (1932) and many studies since, energy requirements of non-pregnant humans scales with body size according to $B_0 \cdot m^b$, with $b = 3/4$; this parameter value has withstood empirical falsification for decades, and is consistent with theoretical priors, see Dalgaard and Strulik (2012) for more details. Moreover, rearing up a child from conception to weaning increases the mother's metabolic needs by a factor ρ (Prentice and Whitehead, 1987; Sadurkis et al., 1988). This means that metabolic needs of an adult with n_t children is given by $(1 + \rho \cdot n_t)B_0 m_t^b$. In order to convert energy into goods we employ the energy exchange rate ϵ, which is measured in kcal. per unit of a unique consumption good.[18] Summarizing, the parental budget constraint reads

$$y_t = x_t + (c_t + e_t)n_t + (1 + \rho n_t)\frac{B_0}{\epsilon} m_t^b. \tag{5}$$

In order to construct the intergenerational law of motion for body size we begin with the following energy conservation equation:[19]

$$E_t^c = b_c N_t + e_c(N'_{t+1} - N_t) \tag{6}$$

in which E_t^c is energy consumption during childhood after weaning (prior consumption is covered by adult metabolic needs), N_t denotes the number of human cells after weaning, N'_{t+1} is the number of cells of the child as a grown up, b_c is the metabolic energy a cell requires during childhood for maintenance and replacement, and e_c is the energy required to create a new cell. Hence the left hand side is energy "input" and the right hand side captures energy use.

Observe that the conservation equation does not allow for heat loss. The extent of heat loss is thus implicit in the parameters; a human who manages greater heat loss can thus be seen as one featuring greater energy costs of cell maintenance and repair, i.e. a greater parameter value for b_c. As discussed in Section 2 there is good reason to believe that humans operating under different climatic circumstances are different in terms of cold tolerance, i.e., are different in terms of how effective the body is at releasing heat. Accordingly, a simple representation of acclimatization or genetic selection toward cold resistance would be that of a *smaller* value for b_c implying less "wasted" energy expenditure due to heat loss. Hence, in our simulations below we will allow b_c to differ across countries and study how this affects the relative timing of the take-off and thereby comparative development, economically and physiologically.

The next step involves solving (6) for N'_{t+1} so as to obtain the number of cells of an adult as a function of the number of cells of a child after weaning and energy intake during childhood, i.e. isolating N'_{t+1} in the equation above. We can further exploit the fact that the mass of a body is simply the mass of a cell $\bar{m}$ times the number of cells. This implies for the size of an adult that $m_{t+1} = \bar{m}N'_{t+1}$. Moreover, using the fact that after weaning the size of a child equals μ times

[18] See Dalgaard and Strulik (2012) for a more detailed elaboration of these physiological foundations.

[19] Implicitly, we draw on West, Brown, and Enquist's (2001) model of ontogenetic growth; see also Dalgaard and Strulik (2012).

the size of the mother (Charnov, 1991, 1993) we have $\bar{m}N_t = \mu m_t$.[20] This leaves us with:

$$m_{t+1} = \frac{\bar{m}}{e_c} E_t^c + \left(1 - \frac{b_c}{e_c}\right) \mu m_t. \tag{7}$$

The intergenerational law of motion for body size has a simple interpretation: The size of the adult, m_{t+1} is determined by energy consumption during childhood, E_t^c, plus initial size, μm_t, adjusted for energy needs during childhood, $-(b_c/e_c)\mu m_t$.

Given that c_t denotes consumption of a child in terms of goods, total energy intake during childhood is $c_t \cdot \epsilon = E_t^c$, where ϵ converts units of goods into calories. Inserting this into (7) we obtain a law of motion for body size across generations:

$$m_{t+1} = a \cdot \epsilon \cdot c_t + (1 - d) \cdot \mu \cdot m_t, \tag{8}$$

in which a and d are "deep" physiological parameters that are given at the population level and which may differ across populations, as observed above. In particular, we will allow d (implicitly, b_c) to differ: b_c will be assumed to be larger in locations closer to the equator, and smaller in places further away from to the equator where greater cold tolerance is assumed to prevail.

3.5. **Individual Optimization.** Parents maximize (1) subject to (4) and (5) and non-negativity constraints on all variables. In order to avoid uninteresting case differentiation we assume that $\gamma < 1/2$ such that fertility is always strictly positive (see below). Let λ denote the shadow price of income and – to save notational space let $B_t \equiv B_0 m_t^b/\epsilon$ denote the metabolic needs of a non-fertile adult in terms of goods. The first order conditions for a utility maximum are:

$$0 = (\beta - \lambda) \cdot x_t \tag{9a}$$

$$0 = 1/n_t - \lambda(c_t + e_t - \rho B_t) \tag{9b}$$

$$0 = \gamma/c_t - \lambda n_t \tag{9c}$$

$$0 = \left[\frac{\gamma \nu A_t}{\nu A_t e_t + \bar{h}} - \lambda n_t\right] \cdot e_t. \tag{9d}$$

Depending on the environment the solution is assumed at the interior or at the corner where non-negativity constraints on education or on non-food consumption are binding with equality.

[20] A physiological justification for this assumption is that child development until weaning depends on energy consumption in utero and during the breastfeeding phase. Since larger mothers consume absolutely more energy the offspring should be larger at this point as it receives a fraction thereof. With this interpretation the linearity should be seen as a simplification. It has no substantive implications for our main results if the linearity is relaxed except for reduced tractability.

These solutions identify a "modern equilibrium", a "pre-modern equilibrium", and a "subsistence equilibrium", respectively.

3.6. **Interior Solution: The Modern Equilibrium.** The interior solution of (9) is obtained as:

$$n_t = \frac{(1-2\gamma)\nu A_t}{\beta(\nu A_t \rho B_t - \bar{h})} \tag{10a}$$

$$c_t = \frac{\gamma\left(\nu A_t \rho B_t - \bar{h}\right)}{\nu A_t(1-2\gamma)} \tag{10b}$$

$$e_t = \frac{\gamma\rho\nu A_t B_t - (1-\gamma)\bar{h}}{(1-2\gamma)\nu A_t} \tag{10c}$$

$$x_t = y - B_t - 1/\beta. \tag{10d}$$

PROPOSITION 1. *At the modern equilibrium, child nutrition, education, and fertility are independent from income. Education and nutrition are increasing functions of knowledge and fertility is a declining function of knowledge. With rising knowledge, education, nutrition, and fertility converge to the constants*

$$e^* = c^* = \frac{\gamma\rho B_0 (m^*)^b}{\epsilon(1-2\gamma)}, \quad n^* = \frac{\epsilon(1-2\gamma)}{\beta\rho B_0 (m^*)^b}$$

and body size converges towards the constant

$$m^* = \left(\frac{a\gamma\rho B_0}{(1-2\gamma)[1-(1-d)\mu]}\right)^{1/(1-b)}.$$

The proof begins with assuming that m_t converges towards a constant m^* and concludes that consumption converges to c^* for $A_t \to \infty$. Inserting c^* into (8) and solving for the steady state at which $m_{t+1} = m_t$ provides the solution for m^* and verifies the initial assumption that body size is constant. Inspection of (10) provides the results of comparative statics.

A key result here is that education and nutrition are positively correlated. The result is intuitive. When the return on education increases because of increasing knowledge (increasing A_t), parents prefer to spend more on education and substitute child quantity for quality. The lower number of children reduces the total cost of child nutrition, to which parents respond by spending more on nutrition for each child.

Another important result is the trade-off between fertility and body size; since bigger mothers face greater metabolic costs of child rearing, compared to smaller mothers, the result is intuitive.

As seen below, this trade-off is obtained in all regimes, though the level of fertility and body size may vary. Empirically, there is strong support to be found in favor of a "size-number trade-off". Within biology the association is documented in e.g. Charnov and Ernest (2006) and Walker et al. (2008), and in the context of human societies the inverse link between size and number of offspring is documented in e.g. Hagen et al. (2006) and Silventoinen (2003); see Dalgaard and Strulik (2012) for a fuller discussion.

3.7. **Corner Solution for Education: The Pre-Modern Equilibrium.** The pre-modern era is defined by the feature that there is no education but income is high enough for parents to finance consumption above subsistence level.

Proposition 2. *Parents do not invest in education when the level of knowledge A_t is sufficiently low and thus the return on education is relatively low such that*

$$A_t \leq \bar{A} \equiv \frac{(1-\gamma)\bar{h}}{\nu\gamma\rho B_t}.$$

The threshold $\bar{A}$ is declining in the weight of child quality in utility (γ), the metabolic needs of adults ($B_t = B_0 m_t^b/\epsilon$), and the productivity of education ν.

The proof solves (10c) for $e_t = 0$. Notice that the threshold is more easily crossed when parents put more weight on child quality or when parents are heavier. The latter result occurs because children of bigger parents are more energy intensive, which causes parents to have fewer children and makes them more inclined to invest in their education.

The solution at the pre-modern equilibrium (i.e. for $x_t > 0$ and $e_t = 0$) are

$$n_t = \frac{1-\gamma}{\beta\rho B_t} \equiv n^x \tag{11a}$$

$$c_t = \frac{\gamma\rho B_t}{1-\gamma} \equiv c^x \tag{11b}$$

$$x_t = y - B_t - 1/\beta. \tag{11c}$$

Notice that the child quality-quantity decision is, in contrast to the modern equilibrium, independent from knowledge.

3.8. **Corner Solution for Education and Parental Consumption: Subsistence Equilibrium.** It seems reasonable that mankind spent most of their history at or close to subsistence.

PROPOSITION 3. *Parents do not spend on non-food (luxury) consumption when*

$$y \leq \bar{y} = B_t - 1/\beta.$$

The threshold $\bar{y}$ is increasing in the metabolic needs of adults.

The proof solves (11c) for $y_t \leq 0$. The result becomes immediately intuitive after noting from (11a) and (11b) that total child expenditure $c_t n_t$ is simply $1/\beta$ at the pre-modern equilibrium.

The solution at the subsistence equilibrium ($e_t = x_t = 0$) is obtained as

$$n_t = \frac{(1-\gamma)(y_t - B_t)}{\rho B_t} \equiv n^s, \tag{12}$$

and nutrition per child c_t is the same as in (11b).

PROPOSITION 4. *Fertility at the subsistence equilibrium is increasing in income and declining in body size.*

The proof follows from inspection of (12). This result was already obtained and extensively discussed by Dalgaard and Strulik (2012). We next compare fertility and body size at the three equilibria.

PROPOSITION 5. *Fertility is highest at the pre-modern equilibrium and lowest at the modern equilibrium, $n^s \leq n^x \geq n^*$. Body size is the same at the subsistence and pre-modern equilibrium and highest at the modern equilibrium.*

For the proof notice that $n^* < n^x$ because $2\gamma > \gamma$ and that $n^s \leq n^x$ when $1/\beta < y_t - B_t$, i.e. whenever the subsistence constraint binds. For body size notice that $c^* > c^x$ since $(1-2\gamma) < 1-\gamma$ and that steady-state body size is a unique function of childhood nutrition.

In theory there is also the possibility that people take up education before they leave subsistence. In practice we rule this implausible case out by an appropriate choice of parameter values. This implies that there is a unique sequence of macroeconomic development, which we discuss next.

4. Macroeconomic Dynamics and Stages of Development

We next place the households into a macro economy. The size of the adult population evolves according to

$$L_{t+1} = n_t L_t. \tag{13}$$

Following conventional unified growth theory (Galor and Weil, 2000, and many other studies), we assume that knowledge creation is a positive function of education and population size. Denoting growth of knowledge by $g_{t+1} = (A_{t+1} - A_t)/A_t$, we thus assume

$$g_{t+1} = g(e_t, L_t) \tag{14}$$

with $\partial g/\partial e_t > 0$, $\partial g/\partial L \geq 0$, $g(0, L_t) > 0$ and $\lim_{L\to\infty} g(e_t, L_t)$ bounded from above. The assumption that there is technological progress without education, $g(0, L_t) > 0$, makes an escape from the Malthusian trap and the take-off to growth feasible. The assumption that the effect of population size on g is bounded means that there cannot be permanent long-run growth driven by population growth alone. It excludes the empirical unobserved case that technological progress generated by population growth overpowers the depressing effect of limited land such that the pre-modern economy explodes with forever rising population and rising rates of technological progress without the initiation of education.

Suppose that human history begins at a sufficiently low level of A such that both the education constraint and the subsistence constraint are binding initially. Human economic and physiological development then runs through three distinct phases: A Subsistence Regime, a Pre-Modern Era and a Modern Era.

4.1. **The Subsistence Regime.** When both the subsistence constraint and the education constraint are binding, there is a positive association of income and population growth, see (12). There is also a positive association with the population level and knowledge creation. Malthusian forces in production, however, keep income near the level of subsistence. The economy is at or converges towards a quasi-steady state. To see this formally, begin with inserting nutrition (11b) into (8) and compute the steady state for $m_{t+1} = m_t$:

$$m^s = \left(\frac{a\gamma\rho B_0}{(1-\gamma)[1-(1-d)\mu]} \right)^{1/(1-b)}. \tag{15}$$

Comparing (15) with m^* from Proposition 1 leads to the conclusion:

Proposition 6. *During the Malthusian era, humans are smaller than at the modern steady state.*

The proof utilizes that $1-\gamma > 1-2\gamma$. Notice that the result remains true for the pre-modern era, since nutrition does not change when the economy transits from the Malthusian to the pre-modern era.

It is worth observing from (15) that a larger value for d implies greater body mass at the steady state. Hence, if, via selection or plasticity and acclimatization, the body shape of people changes to allow for less heat loss, and thereby greater cold tolerance, then the model predicts that such societies will also feature heavier people. In this sense the model suggests that "Allen's rule" leads to "Bergmann's rule"; given changes in body shape, changes in body weight follow (in the long run).

Since nutrition per child is constant during the Malthusian era and no income is spent on non-food (luxury) consumption and on education, all income gains are spent to expand fertility. Observing from (3) that income growth is fueled by knowledge growth and observing from (14) that knowledge growth is solely fueled by the expanding population verifies the following statement:

Proposition 7. *During the Malthusian era fertility (population growth) increases with population size,* $n_t = f(L_t)$, $f' > 0$.

This phenomenon has been extensively discussed in Kremer (1993).

4.2. **The Pre-Modern Era.** With output per capita gradually growing the economy eventually surpasses the threshold $\bar{y}$ and people start enjoying utility from non-food (luxury) consumption. Food provision per child remains constant but fertility rises to a higher plateau, see (11). The economy has escaped subsistence, but economic growth is still low since fertility is high and limited land depresses output per capita.

4.3. **The Modern Era.** With further growing knowledge the economy eventually surpasses the threshold $\bar{A}$ and parents start investing in the education of their children. This has a double effect on economy growth. Education raises the productivity of the current worker generation as well as, through knowledge improvements, the productivity of the next worker generation, which then in turn invests even more in education such that the economy eventually converges to the steady state e^*. Along the transition to the steady state, fertility declines, which reduces the Malthusian pressure and leads to further increasing income. As a result, the economy takes off enjoying accelerating growth rates. Eventually, economic growth stabilizes at a high plateau at the end of the fertility transition when education expenditure has reached its steady state.

With respect to education and fertility the transition to the modern era is similar to the transition established in conventional unified growth theory (e.g. Galor and Weil, 2000). The present model additionally explains the physiological transformation of humans: with the take-off to growth, humans start getting bigger. As explained above, the uptake of education and the entailed reduced fertility make nutrition of children more desirable and, subsequently, the next generation of adults is bigger. The grandchildren are even bigger because there is a double effect: grandchildren are born bigger because they are conceived by larger mothers, and their parents spend more on nutrition because increasing knowledge makes them prefer child quality in both the education and nutrition dimension. Eventually, however, nutrition and thus body size converges to constants (see Proposition 1).

5. Physiological Constraints and Comparative Economic Development

5.1. **Analytical Results.** Consider a setting where all countries share the same knowledge base. That is, technology is locally determined by population size (and when relevant: education) but the produced ideas spread instantaneously.

Suppose, moreover, that two countries differ in terms of the parameter d, due to natural selection or plasticity and acclimatization. In the subsistence environment this variation will generate differences in body mass and income, as established in Dalgaard and Strulik (2012): In colder environments, average body mass is greater and population density will be lower. To see the latter result more clearly, assume that in pre-historic times the evolution of knowledge was so slow that constant knowledge is a reasonable approximation, $A_t = A$. The pseudo steady state becomes a real steady state at which, from (13), $n_t = 1$. Inserting (15) into (12) and solving $n_t = 1$ for $L_t = L^s$ provides population density

$$L^s = \left(\frac{\epsilon(1-\gamma)A\bar{h}}{B_0\left[\rho/(2-\gamma)\right]} \right)^{1-\alpha} \left(\frac{(1-\gamma)(1-d)\mu}{a\gamma\rho} \right)^{\frac{b-\phi}{1-\alpha}}, \tag{16}$$

Observe that lower d increases m^s in (15) and reduces L^s in (16), as long as $b > \phi$. The latter parameter restriction implies that when body mass goes up, subsistence requirements rise faster than food procurement. On empirical grounds $b = 3/4 > \phi < 2/3$, as discussed above.

Moreover, as discussed in Dalgaard and Strulik (2012) this parameter restriction ($b > \phi$) is in fact a necessary condition for a subsistence equilibrium to be viable during pre-industrial times.

Now, for our theoretical experiment we consider countries (or areas) that share the same initial fertility and the same technology and all parameter values aside from the one for heat loss, d. We assume that d is lower in country A than in country B. Consequently, humans are bigger in country A, and initial population size (i.e., density) is lower in country A. Inspecting (16) and applying Propositions 2 and 3 then verifies the following result.

PROPOSITION 8. *Consider two countries which are identical aside of the metabolic needs of adults determined by d (heat loss). Then the country with the smaller d*

- *is inhabited by larger individuals*
- *is less densely populated*
- *creates less knowledge in the Malthusian era*
- *and enters the modern era earlier.*

These results reproduce the stylized facts listed in Section 2, when it is further recalled that an earlier take-off will yield an income gap between the two countries if observed at an appropriate point in time after the country inhabited by bigger people has taken off. Moreover, these results are quite intuitive.

Relatively higher metabolic costs of fertility will, in the Malthusian era, work to lower fertility in places inhabited by physiologically bigger people. Furthermore, low population density works to stifle technological change in keeping with the Kremer (1993)–mechanism; more people, more ideas. However, the high metabolic costs of fertility and subsequent nutrition of larger children makes the "heavier country" more inclined to invest in education, and thus to substitute child quantity with quality. As a result, a lower critical level of technology is required for the fertility transition to take place. Consequently, an income gap emerges in favor of the country inhabited by physiologically bigger people.

These results can be illustrated numerically. For that purpose we use the parameterizations suggested in Dalgaard and Strulik (2012). Specifically, we set $b = 3/4$, $B_0 = 70$, $\mu = 0.15; \rho = 0.2$, $\epsilon = 0.28$ and, for the benchmark run, $d = 0.5$. We set β and γ such that population growth peaks at 1.5 percent annually and fertility converges to replacement level at the modern steady state. This provides the estimates $\gamma = 0.1$ and $\beta = 0.0053$. We set a such that the body weight at Malthusian times is 60 kg. This provides the estimate $a = 1.65$. Country B (the country closer to the equator) is populated by individuals who share the same parameters except d, which is 0.8. In country B body weight is therefore 49.6 in the subsistence regime. At the economic side of the model we set $\alpha = 0.8$ and $\phi = 0.25$.

In keeping with the theoretical analysis above, we assume all ideas are shared between the two countries, A and B. Concretely, let $\tilde{A}_t^j$ denote the knowledge that has been *created* in country j, $j = A, B$. Knowledge *available* in country j, denoted by A_t^j, is given by

$$A_t^j = \tilde{A}_t^A + \tilde{A}_t^B. \tag{17}$$

Hence, at any given point in time the two countries share ideas; or, equivalently, new ideas diffuse "instantaneously". In order to facilitate numerical experiments we need to choose a functional form for the creation of knowledge, equation (14). Following Lagerlöf's (2006) parametrization of the Galor and Weil (2000) model we assume knowledge created in country j grows at rate

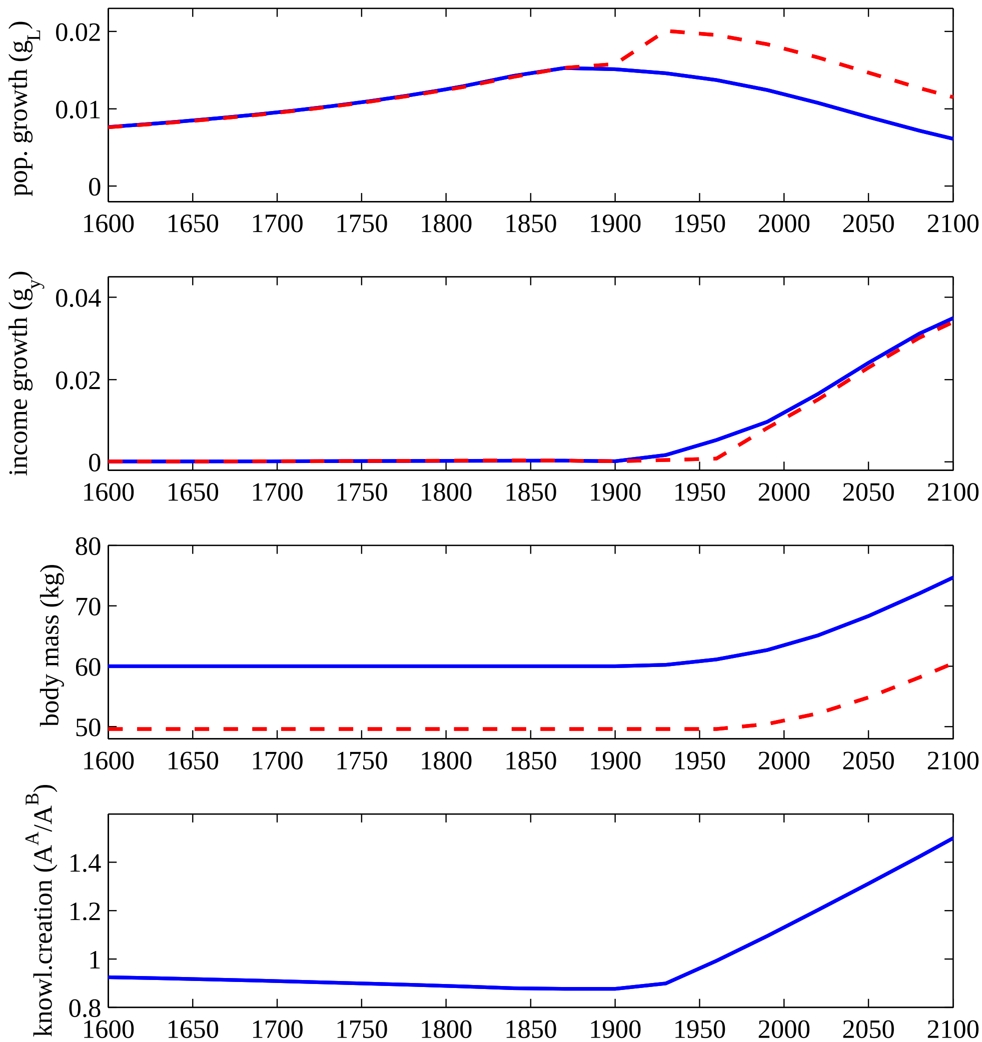
$$g_{t+1}^j = \delta(e_t^j + \lambda) \cdot \min\left\{(L_t^j)^\eta, \ \ \Lambda\right\}. \tag{18}$$

We set the productivity parameters such that the model generates plausible growth rates during the subsistence era, pre-modern era, and modern era. This leads to the estimates $\delta = 0.05$, $\lambda = 0.8$ and $\eta = 0.3$. We set $\Lambda = 2.5$.

Finally, we normalize $\nu = 1$ and $\bar{h} = 1700$ such that country A experiences a century of almost constant high fertility rates before fertility begins to decline. After running the experiment we convert all variables in units per year using a period length of 30 years. We start the economies in the year 1000 and determine the initial population size and technology level such that country A leaves the Malthusian phase in the year 1830. The implied initial fertility rate is 1.106 and the implied population growth rate is 0.34 percent. Country B shares the same initial technology and the same initial fertility rate, which means that it is more densely populated since people are smaller. The implied initial population ratio is $L^B(0)/L^A(0) = 1.42$.

Figure 4 shows the implied trajectories for population growth, income growth, and body mass. Solid lines reflect trajectories of country A and dashed lines show country B. The bottom panel shows the relative stock of technologies invented in country A. The figure starts in the year 1600 because the years before 1600 look very much like 1600 (aside from population growth which is gradually increasing). Both countries share virtually the same population growth rate

Figure 4: Long-Run Comparative Dynamics



Solid lines: country A ($d = 0.5$); dashed lines: country B ($d = 0.8$).

during the subsistence phase, implying that country B remains more populous and poorer than country A. Because of its larger size, country B produces more innovations; the innovation ratio $A^A/A^B = (L^A/L^B)^\eta$ is around 0.9 during the Malthusian phase and mildly falling.

In the year 1870, country A starts investing in education and initiates the fertility transition. Consequently income growth takes off one period later, when the educated children enter the workforce and contribute to knowledge creation. In country B the take-off takes place two generations later. The technological leadership switches after the take-off of country A and the innovation ratio improves very quickly. In the 1950 we observe for the first time since the year 1000 that both countries contributed the same to the worldwide stock of knowledge. From then on country A's relative contribution is increasing rapidly due to its better educated workforce. After the take-off, body weight is gradually increasing and reaches 65 kg in the year 2000.

Country B benefits from the take-off of country A since the newly created knowledge diffuses freely. In country B however, the resulting increasing productivity is initially used predominantly to further expand fertility because the country is still in its subsistence phase and then briefly enters the pre-modern phase. Consequently, population growth rises further and approaches a high plateau in the first half of the 20th century while income growth is improving only very little. Then, in 1930, with two generations delay, country B invests in education and in 1960 income takes off, population growth starts to decline, body size increases, and income growth converges to that of country A.

5.2. **Robustness: Gradual Diffusion and Imperfect Knowledge Sharing.** The assumption of instantaneous diffusion of ideas is admittedly extreme and "biases" the results in the direction of an early take-off in societies that are inhabited by larger but fewer people. In order to allow for only partial (and in any event: gradual) diffusion of ideas, we replace (17) with

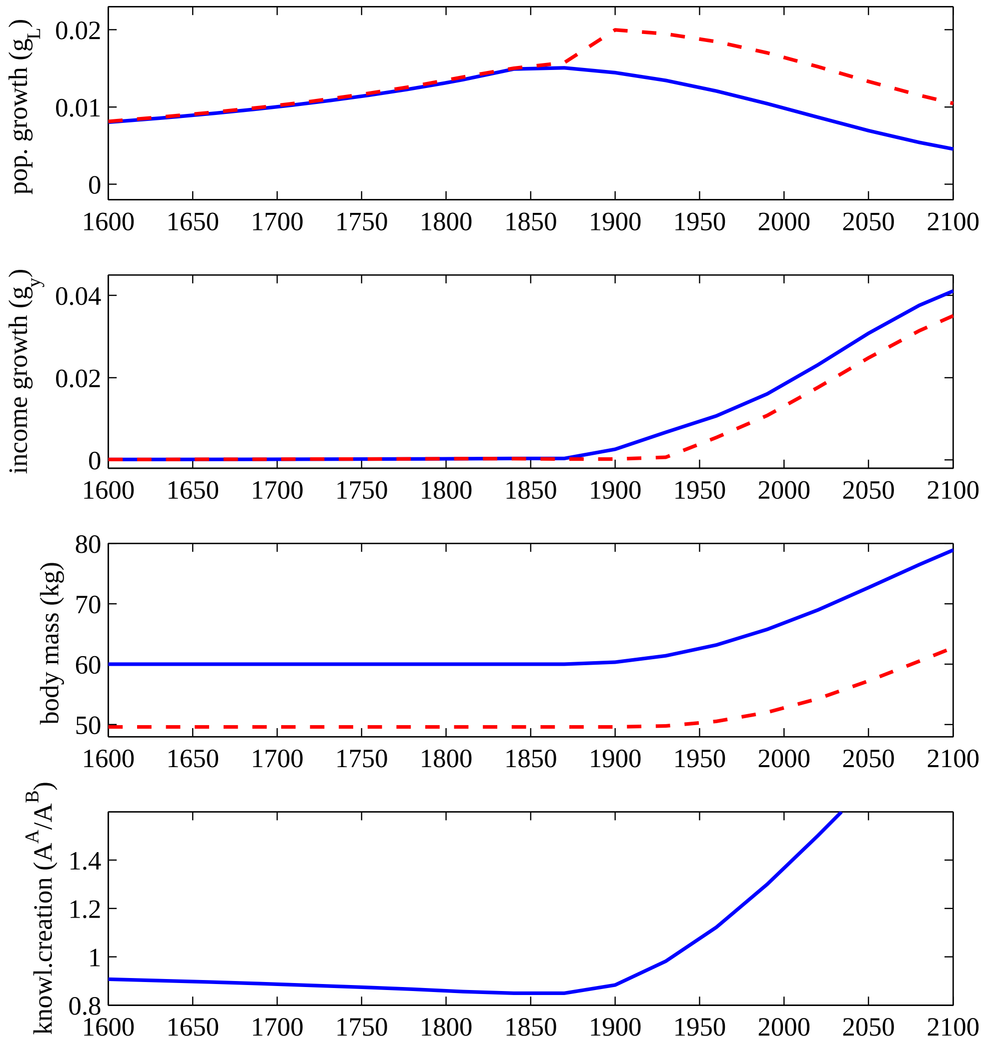
$$A_t^A = \tilde{A}_t^A + \xi \tilde{A}_{t-k}^B, \qquad A_t^B = \tilde{A}_t^B + \xi \tilde{A}_{t-k}^A, \tag{19}$$

In the equation above, ξ captures the fraction of ideas that (asymptotically) can be diffused. Hence, $\xi < 1$ means that some ideas are never diffused. Furthermore, the equation above captures that new ideas arrive in the non-innovating countries with a delay of k generations. Aside from these novel elements, we keep the structure of the model unchanged, along with the parameter values discussed above.

The initial value of technologies available in each country is adjusted such that both countries initially share the same fertility rate (as in the benchmark run). This implies that the initial technologies created in each country are given by $\tilde{A}_0^A = (A_0^A - \xi A_0^B)/(1-\xi^2)$ and $\tilde{A}_0^B = (A_0^B - \xi A_0^A)/(1-\xi^2)$. We adjust the initial value of population size such that country A experiences the take-off in 1870 and the outcome is comparable with Figure 4.

Figure 5 shows results for $\xi = 1$ and $k = 2$, i.e. for 60 years delay in international knowledge diffusion. Interestingly and, perhaps, surprisingly, the delayed knowledge flow does not delay the take-off of country B. The reason is, that imperfect knowledge flows operate also during Malthusian times, during which country B is the technological leader. It thus reduces the speed at which country A reaches the threshold $\bar{A}$. The difference to the development in Figure 4 is mainly that delayed knowledge flows reduce the catch up speed of country B after its take off.

Figure 5: Long-Run Comparative Dynamics: Gradual diffusion of ideas



Parameters as for Figure 4 but knowledge diffuses with a lag: knowledge created in one country at time t reaches the other country at time $t-2$.

More generally, we can use the model and ask the question: For which delay in international knowledge diffusion does the result of the earlier take-off of country A break down? The results are summarized in Table 4.

If all knowledge is usable in all countries ($\xi = 1$), then country A takes off first up to a diffusion lag of 12 generations (720 years). The maximum diffusion lag, naturally, decreases as we reduce the degree of international knowledge sharing. If only 60 percent of knowledge are transferable internationally, country A takes off for up to a diffusion lag of 5 generations (300 years). If 20 percent or less of the knowledge are shared internationally, country A fails to take off earlier.

Table 4. Robustness Checks: Knowledge Diffusion

ξ	1	0.8	0.6	0.4	0.2
k	12	9	5	2	–

The table shows for alternative degrees of international knowledge sharing ξ up to which diffusion lag (in terms of generations) the result that the initially backward country A takes off first continues to hold.

We experimented with different numerical specifications of the model and found generally that country A takes off 1 to 2 generations earlier and that this result is robust against substantial impediments to knowledge diffusion; usually we can allow for 10 or more generations delay when all knowledge is shared internationally and up to just 50 percent international knowledge sharing when the diffusion delay is 3 generations or less. The theoretical result of the geo-reversal, which we could prove only for perfect knowledge sharing, appears to be robust against substantial imperfections in international knowledge sharing.

6. Conclusion

In the present paper we have provided a theory designed to shed light on the remarkable shift in the "latitude gradient" with respect to economic development, which appears to have occurred over the last roughly 500 years.

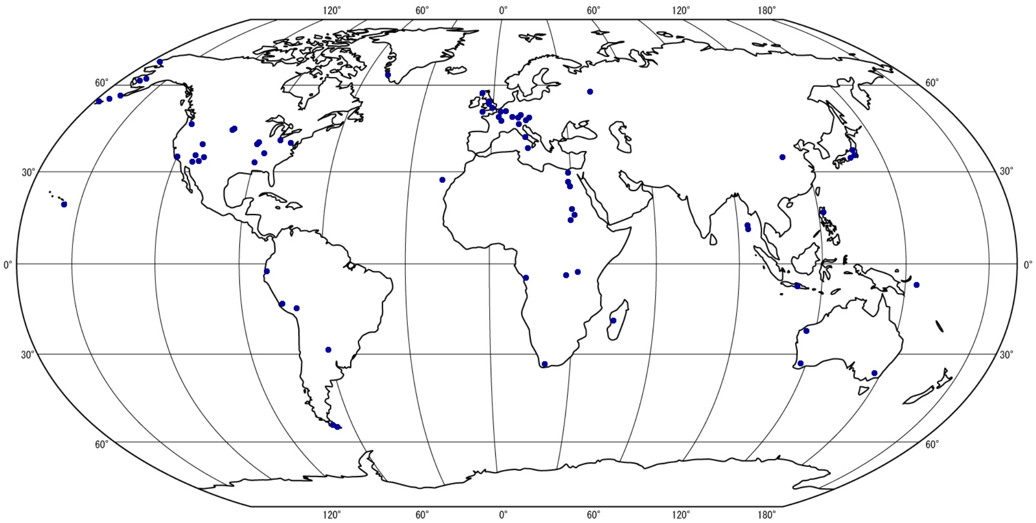
The main hypothesis is that differences in the physiological constraints faced by individuals in different geographical locations are responsible for the observed reversal. In places where humans inherently were bigger historically, the physiological costs of children were greater, leading to low economic development early on. However, the relatively high cost of children simultaneously provided a comparative advantage in child quality investments for physiologically bigger parents, which worked to bring forth an earlier take-off in places inhabited by (on average) bigger people. Since average body mass exhibits a clear latitude gradient (Bergmann's rule) our theory suggests that this physiological mechanism could have been responsible, at least in part, for the changing latitude gradient in economic development.

In order to substantiate this hypothesis, we have developed a unified growth model. Importantly, the model allows us to examine the robustness of the highlighted explanation to an important countervailing mechanism. In historical times it appears plausible that more people led to more ideas; this could work to circumvent the physiological mechanism, thereby allowing the more innovative society inhabited by more but physiologically smaller people to take off earlier. We find, however, that even if knowledge diffusion is gradual, and possibly incomplete, the physiological mechanism is likely to prevail.

The physiologically-led explanation for the reversal of fortune is attractive in that it should apply to developments within any continent in the world, which is consistent with the data (cf. Figure 1 and 2). Moreover, previous contributions, which explained a reversal of fortune in terms of the timing of the Neolithic (Olsson and Paik, 2014) or land productivity (e.g., Litina, 2013), do not account for the "latitude reversal", as documented in Table A1. Naturally, this does not rule out that other forces, beyond the highlighted physiological one, may have contributed to the remarkable shift in economic activity, away from the equator, which has occurred over the last half millennium. Lack of diffusion of agricultural techniques, as argued in the context of the "temperate drift hypothesis', could also have played some role (though see Acemoglu et al, 2002, for a critical discussion of this mechanism). We leave the exploration of alternative pathways, and relevant empirical testing of competing and complementary mechanisms, to further research.

In terms of possible extensions of the present study, it is worth observing that the model fully ignores the issue of obesity. While this is surely less of a problem for most of human history, it is clearly an issue for the 21st century. Hence, an interesting extension of the model above would be to allow for obesity, and thereby potentially gain insights into the consequences of the developed theory for comparative differences in incidence of obesity across the world.

Figure A1: The Goldman data



The figure shows the approximate location of the samples included in the Goldman data set. Source: `http://web.utk.edu/ auerbach/Goldman.htm`

Data Appendix

Pre-industrial body size and shape. The underlying data is taken from the so-called Goldman data set, which is available online at `http://web.utk.edu/ auerbach/GOLD.htm`. As noted above, the data derives from skeletons from different points in time during the Holocene, ranging from as early as 3500 B.C.E to as late as the early Medieval period (ca 1500 C.E.).

The samples are distributed reasonably evenly around the world; cf figure A1. In the data set individual measurements are assigned to a country, and each country observation in our regression data represents the average across available information for each country. The data we employ refers to males, as the number of observations on females in the Goldman data set is more limited.

In order to calibrate body mass (m) we employ the data on femoral head anterior-posterior breath (FH) and the formula developed by Ruff et al. (1991) (which pertains to males):

$$m = (2.741 \cdot FH - 54.9) \cdot 0.90. \tag{20}$$

In order to obtain data on body surface area (BSA) to volume (V) we employ the (male specific) formula developed by Tikuisis et al. (2001):

$$BSA = 128.1 \cdot m^{0.44} \cdot h^{0.6}, \tag{21}$$

where h denotes height. Height can also be calibrated in the historical sample by employing the Goldman data on femoral maximum length (FM) and the formula (for males) developed by Genoves (1967):

$$h = 2.26 \cdot FM + 66.379 - 2.5. \tag{22}$$

Finally, dividing BSA by m gives the BSA to volume ratio. Technically, $V = m/BD$, where BD is body density, which is a constant (Wang and Hihara, 2004).

Contemporary body mass and proportions. For most of the countries in the sample data on body mass is from Demographic Health Surveys (DHS); extracted by StatCompiler (`http://www.statcompiler.com/`) on 24.1.2012. Survey's close to the year 2000 were selected. Since mothers are singled out in the DHS, implying women are in the age interval 15-49; the sampled individuals were therefore born in 1985 or earlier.

We supplemented these data with information on height for 9 European countries. The data also concerns women, born in 1980. The source is Garcia and Quinta-Domeque (2007), supplemented by Herpin (2003, p. 73) for France. In the latter case the data concerns 20-29 year-olds, observed in 2001 (implying they were born around 1980). The French figure is adjusted down by 0.8 cm to correct for self reporting (see Hatton and Bray, 2010). Finally, in order to generate data on weight we employed data on female BMI (in 2000) from the study by Finucane et al. (2011, Supplementary material p. 60 ff). Using these BMI numbers along with the height data (for the 9 country European sample), weight data is constructed using the formula $BMI = w/h^2$ (height in m).

With body mass and height in hand we can construct BSA using Tikuisis et al. (2001) formula for females

$$BSA = 147.4 \cdot m^{0.47} \cdot h^{0.55}. \tag{23}$$

.

Other data.

- Data on population density in 1500 and current (2000) GDP per capita is taken from Ashraf and Galor (2011).
- The data on the timing of the fertility decline derives from two sources: Reher (2004) and Caldwell and Caldwell (2001).

- Land productivity is taken from Ashraf and Galor (2011) and reflects the first principal component of arable land and soil suitability for agricultural crops.
- Years since the Neolithic revolution. From Ashraf and Galor (2011).
- The data on (year 2000) urbanization rates are from World Development Indicators (`http://data.worldbank.org/data-catalog/world-development-indicators`)
- Data on absolute latitude from Andersen et al. (2014). Ancestor-adjusted latitude is constructed as described in the text.

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Table 1. Bergman's Rule Across Countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Body mass (Pre ind)				Body mass (contemporary)			
Absolute latitude	0.179***	0.087	0.257***	0.285***			0.055	0.129
	(0.051)	(0.082)	(0.028)	(0.057)			(0.078)	(0.094)
Absolute latitude (Ancestor adj)					0.272***	0.278***	0.218***	0.165**
					(0.029)	(0.053)	(0.079)	(0.081)
Continent Fes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	24	24	71	71	71	71	71	71
R-squared	0.377	0.519	0.402	0.617	0.424	0.620	0.425	0.624

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.
(ii) Cls 1 and 2 employs data on body mass deriving from skeletal remains as recorded in the Goldman dataset; cls 3-8 employs data from the year 2000, as described in the text.

Table 2. Pre-industrial body size, the fertility decline and current development outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Year of fertility decline			log GDP per capita			log urbanization rate		
Weight (pre-ind)	-4.555***	-2.215**	-1.294**	0.154***	0.058	0.071	0.050***	0.027	0.020
	(0.623)	(0.811)	(0.580)	(0.035)	(0.055)	(0.055)	(0.014)	(0.022)	(0.023)
Absolute latitude		-1.168***	-0.725***		0.046**	0.040*		0.011	0.011
		(0.221)	(0.215)		(0.019)	(0.020)		(0.007)	(0.007)
Continent FE	No	No	Yes	No	No	Yes	No	No	Yes
Observations	21	21	21	24	24	24	24	24	24
R-squared	0.517	0.786	0.913	0.335	0.549	0.743	0.321	0.430	0.645

(i) All regressions contain a constant term, and estimation is in all cls by OLS. (ii) *** p<0.01, ** p<0.05, * p<0.1

Table 3. Body size, the fertility decline and contemporary development outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES		Year of fertility decline			log GDP per capita			log Urbanization rate	
Weight	-1.186***	-0.664**	-3.601*	0.093***	0.087***	0.230*	0.048***	0.050***	0.175**
	(0.339)	(0.321)	(1.997)	(0.015)	(0.018)	(0.119)	(0.009)	(0.010)	(0.074)
Absolute latitude		-0.627***	0.192		0.007	-0.034		-0.003	-0.039
		(0.224)	(0.642)		(0.010)	(0.035)		(0.007)	(0.024)
Estimator	OLS	OLS	IV	OLS	OLS	IV	OLS	OLS	IV
Anderson-Rubin (p-value)			0.029			0.008			0.000
Kleibergen-Paap (F-static)			4.045			4.081			4.081
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	66	66	66	71	71	71	71	71	71
R-squared	0.820	0.844		0.757	0.759		0.577	0.578	

(i) Cols 1-3 focues on the timing of the fertility decline; cols 4-6 on GDP per capita in 2000; 7-9 the urbanization rate in 2000. (ii) All regressions contain a constant term. (iii) cols 3,6 and 9 are 2SLS regresssions where the excluded instrument is ancestor adjusted absolute latitude. (iv) the Anderson-Rubin test concern the significance of the endogenous variable, and is relevant in a setting where the instrument is statistically weak, as is the case in all columns; cf the Kleibergen-Paap F static. (v) weight is observed around the year 2000. (vi) *,**,*** denotes significance at the 10,5 and 1% level, respectively.

Table A1: Robustness of the Latitude Reversal to Alternatives

Panel A: Land productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	log population density 1500			log urbanization rate 1500			log GDP per capita 2000			log urbanization rate 2000		
Absolute Latitude	-0.050***		-0.042***	-0.020**		-0.019**	0.024***		0.020**	0.013***		0.012***
	(0.010)		(0.009)	(0.008)		(0.008)	(0.008)		(0.008)	(0.003)		(0.003)
Land productivity		0.540***	0.491***		0.101	0.056		-0.283***	-0.261***		-0.129***	-0.117***
		(0.066)	(0.061)		(0.071)	(0.070)		(0.056)	(0.059)		(0.026)	(0.027)
Continent FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	146	146	146	80	80	80	148	148	148	148	148	148
R-squared	0.460	0.540	0.625	0.339	0.283	0.342	0.476	0.516	0.547	0.376	0.398	0.452

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.

Panel B: Timing of the Neolithic Revolution

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	log population density 1500			log urbanization rate 1500			log GDP per capita 2000			log urbanization rate 2000		
Absolute Latitude	-0.049***		-0.048***	-0.020**		-0.020**	0.025***		0.025***	0.013***		0.013***
	(0.010)		(0.009)	(0.008)		(0.007)	(0.008)		(0.008)	(0.003)		(0.003)
Yrs since Neolithic Transition		0.185**	0.169**		0.046	0.044		-0.011	-0.009		0.036	0.037
		(0.074)	(0.069)		(0.032)	(0.036)		(0.055)	(0.055)		(0.025)	(0.023)
Continent FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	146	146	146	82	82	82	148	148	148	148	148	148
R-squared	0.485	0.402	0.510	0.342	0.284	0.349	0.494	0.448	0.494	0.385	0.320	0.397

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.

Panel C: Fraction of Area in the Tropics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	log population density 1500			log urbanization rate 1500			log GDP per capita 2000			log urbanization rate 2000		
Absolute latitude	-0.051***		-0.040***	-0.020**		-0.024**	0.023***		0.011	0.013***		0.007*
	(0.010)		(0.012)	(0.008)		(0.009)	(0.008)		(0.010)	(0.003)		(0.004)
Fraction area in tropics		1.239***	0.476		0.370	-0.237		-0.757***	-0.549*		-0.406***	-0.274**
		(0.261)	(0.313)		(0.304)	(0.346)		(0.217)	(0.282)		(0.108)	(0.137)
Continent FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	150	150	150	82	82	82	152	152	152	152	152	152
R-squared	0.476	0.442	0.484	0.342	0.295	0.346	0.485	0.495	0.500	0.379	0.389	0.399

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.

Table A2. Body proportions and latitude across countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	SAV (pre ind)				SAV (contemporary)			
Absolute latitude	-0.402***	-0.194	-0.471***	-0.645***			0.287	-0.194
	(0.129)	(0.196)	(0.057)	(0.142)			(0.210)	(0.243)
Absolute latitude (Ancestor adjusted)					-0.534***	-0.645***	-0.817***	-0.475**
					(0.055)	(0.129)	(0.217)	(0.216)
Continent FEs	No	Yes	No	Yes	No	Yes	No	Yes
Observations	24	24	71	71	71	71	71	71
R-squared	0.336	0.537	0.291	0.522	0.351	0.534	0.360	0.536

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contain a constant term.
(ii) "SAV" is short for "Surface area to volumne ratio", see Appendix for data construction. (iii) Cls 1 and 2 employs data on SAV deriving from skeletal remains as recorded in the Goldman dataset; cls 3-8 employs data from the year 2000, as described in the text.

Content: The table examines whether the surface area to volume ratio is declining in distance to the equator, as predicted by Bergmann's rule, as well as Allen's rule. The resuts show that the expected correlation emerges both in a data set pertaining to pre-industrial societies (cls 1-2) as well as contemporary (ca 2000) countries (cls 3-8).

Table A3. Bergman's rule: Subsamples

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Body mass (contemporary			SAV (contemporary)		
Absolute latitude	0.101*	0.337***	0.313***	-0.094	-0.655***	-0.709***
	(0.056)	(0.034)	(0.070)	(0.093)	(0.072)	(0.176)
Sample	Europe	Indigenous	Indigenous	Europe	Indigenous	Indigenous
Continent Fes	No	No	Yes	No	No	Yes
Observations	13	40	40	13	40	40
R-squared	0.115	0.511	0.752	0.045	0.443	0.657

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.
(ii) The sample "Europe" focuses exclusively on European countries, and the sample marked "indigenous" focuses attention on countries in which at least 90% of the current population decends from the current country.

Table A4. Body size and the fertility decline: Alternative indicator

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Year of Fertility decline (Caldwell and Caldwell)						
Absolute latitude (Ancestor adj)	-1.510***	-0.542	-0.862***	-0.809*	-1.815***	-0.401**	
	(0.274)	(0.334)	(0.263)	(0.451)	(0.299)	(0.183)	
Absolute latitude				-0.059		0.004	0.116
				(0.514)		(0.252)	(0.271)
Body Mass							-1.511**
							(0.761)
Estimator	OLS	OLS	OLS	OLS	OLS	OLS	IV
Anderson-Rubin (p-value)							0.0175
Kleibergen-Paap F statitistic							7.163
Sample	Full	Full	No ISL	No ISL	Full	Full	Full
Continent Fes	No	Yes	Yes	Yes	No	Yes	Yes
Observations	93	93	92	92	40	40	40
R-squared	0.356	0.634	0.654	0.654	0.480	0.710	0.690

(i) All regressions by OLS except col 7; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.
(i) All cls marked "full sample" employs all data available; cls marked "No ISL" omits Iceland, see text for details.
(iii) in Col 7 the omitted instrument is ancestor adjusted absolute latitude. (iv) cols 5-7 considers a sub-sample where both data on body mass and the timing of the fertility transition are available.

Table A5. Body size, Geography and outcomes: Europe

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Year of fertility decline			log GDP per capita 2000			log Urbanisation rate 2000		
Absolute latitude	-1.376*		-1.176	0.025*		-0.000	0.014***		0.009***
	(0.672)		(0.910)	(0.014)		(0.011)	(0.003)		(0.002)
Body mass		-6.704*	-4.897		0.301***	0.301***		0.076***	0.066***
		(3.434)	(3.350)		(0.058)	(0.068)		(0.016)	(0.016)
Observations	18	10	10	37	13	13	37	13	13
R-squared	0.286	0.342	0.502	0.062	0.778	0.778	0.279	0.585	0.673

(i) All regressions by OLS; *,**,*** denote significance at 1,5 and 10%, respectively; all regressions contains a constant term.

Content: This table examines the association between body mass, and absolute latitude on the one hand, and development outcomes on the other, in a sample that is limited to European countries. Overall we find that body mass is associated with outcomes in the expected fashion, and that it tends to diminsh the influence from absolute latitude on outcomes, as expected.