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Percoco, Marco

Empfohlene Zitierung / Suggested Citation:
Percoco, M. (2021). Spatial health inequality and regional disparities: historical evidence from Italy. *Region: the journal of ERSA*, *8*(1), 53-73. https://doi.org/10.18335/region.v8i1.325

REGION
The Journal of ERSA
Powered by WU

Volume 8, Number 1, 2021, 53–73
DOI: 10.18335/region.v8i1.325
journal homepage: region.ersa.org

Spatial health inequality and regional disparities: Historical evidence from Italy

Marco Percoco[1]

[1] Bocconi University, Milan, Italy

Received: 17 May 2020/Accepted: 16 November 2020

Abstract. Geography and the quality of the environment may have long lasting effects on the living standards of individuals and this, in its turn, may substantially affect the distribution of income and regional disparities. In this paper I consider exposure to malaria as a measure of "bad geography" and illustrate evidence showing that it was a major determinant of individuals' health, (as measured by the height of military conscripts) as well as its disparities between individuals and regions in Italy. To estimate the relationship between malaria exposure and height, I rely on the "fetal origins hypothesis"; I hypothesize that exposure to malaria in utero or during childhood has persistent effects on health. The periods under scrutiny in this paper are the last two decades of the XIX century, a period without major public health interventions, and the years around the malaria eradication era in the 1950s. My results support the hypothesis that geographically targeted policies may reduce health inequality between and within regions.

Key words: Health inequality, place-based policies, spatial disparities, regional development, malaria, height

1 Introduction

The quality of the environment where individuals live has long-lasting effects on their health and consequently on a variety of socio-economic outcomes, including education and labor productivity. This well-established evidence further implies that there is an association between the quality of the environment, health and local development, not only in developing, but also in developed countries. Health is also considered as a desirable outcome by individuals assessing the quality of life in their regional environments. Life expectancy and child mortality are among the variables used to construct synthetic indicators, as in the case of the EU Regional Human Development Index (Haderman, Dijkstra 2014) and the Italian regions under study (Ferrara, Nisticò 2015).

This paper contributes to the literature by presenting historical evidence from Italy, with specific reference to the burden of malaria across regions. More broadly, this paper aims to present historical evidence on spatial and individual inequality in health and living standards in Italy, a country where such inequalities are still persistent (see e.g. Franzini, Giannoni 2010, Perucca et al. 2019).

In the 19th century, most physicians believed malaria was caused by "miasma" (poisoning of the air), while others made a link between swamps, water and malaria, but did not make the further leap towards insects (Snowden 2006). As a result of these theories, little was done to fight the disease before the end of the century. Italian scientists managed to predict the cycles of fever, but it was in Rome that the naturalist Giovanni Battista Grassi found that a particular type of mosquito was the carrier of malaria. After an extraordinary series of experiments on healthy volunteers in Italy (mosquitoes were released into rooms with volunteers), Grassi was able to make the direct link between the insects (all females of a certain kind) and the disease. The use of quinine to cure malarial fevers has been known for a long time. It has been systematically used since 1922 by the Italian Government to prevent malaria. The effects in Italy were so positive that its use as a preventive extended to other similarly situated countries; i.e., highly malarious farming countries. Although effective in reducing the burden of the disease, the use of quinine did not eradicate malaria, which was only eliminated in the 1945-1950 period, when the US government and the Rockefeller Foundation introduced DDT in the country.

Because of its impact on children's health, malaria has serious impacts on the individuals' physical growth and hence on their height. By relying on the 'fetal origins of adult outcomes' hypothesis and by taking a place-based perspective, this study estimates the impact of malaria eradication in Italy on the height distribution of military conscripts between and within regions. Taller individuals generally have higher income, so height is often used as a measure of historical living standards (Floud et al. 1990, Fogel 2004, Steckel 1995, 2004). This evidence also leads us to argue that the distribution of height across regions and across individuals can be considered as a measure of health and socio-economic inequality for periods in which data are not available.

In this paper, I present two pieces of evidence regarding the effect of malaria on adult height distribution in Italy. First, I illustrate that the quality of the environment, as proxied by malaria mortality rates, is crucial in predicting future height. In this case, I consider the average height of conscripts at regional level, born between 1889 and 1900, a period with no policy interventions to eradicate the disease. The second piece of evidence shows that the eradication of malaria that occurred between 1945 and 1950 has resulted in increased average height and distribution of height across individuals within regions, hence pointing to considerable redistributive effect of the policy.

The evidence reported in this paper indicates the clear effectiveness of place-based policies aiming at improving the individuals' quality of life, even in socio-economic terms.

2 Related literature

The aim of this paper is to examine the impact of malaria exposure in utero or during early childhood on height. My theoretical starting point is the so-called 'fetal origins' hypothesis (Barker 1990), i.e. the quality of the environment and the events to which a fetus or a child is exposed have major long-run impacts on health and cognitive abilities. The first evidence concerning the importance of the persistent effects of shocks during childhood was provided by Stein, Saenger (1975), who found adverse health outcomes for Dutch children born during the famine and the Nazi occupation. Barker (1990) has systematized the medical evidence available to date, arguing in favor of the 'fetal and infant origins' hypothesis of human development. A complete review of the evidence supporting the "fetal origins" hypothesis would fall outside the scope of this paper; hence, in what follows, I will focus mainly on the literature on malaria, with special emphasis on socio-economic outcomes.

Although the 'fetal origins' hypothesis has been proposed in the field of medical science, an increasing body of economic literature has shown that in utero and early life shocks may have relevant long-term effects on adults, especially in terms of educational attainments and income (see, among others Almond 2006, Barreca 2010, Bleakley 2010, Case, Paxson 2009, 2010, Chen, Zhou 2007, Cutler et al. 2010, Kim et al. 2010, Lucas 2010, Meng, Qian 2009, Neelsen, Stratmann 2011, Percoco 2013, 2016). Besides its theoretical appeal, one of the reasons for such a surge of economic studies relying on this hypothesis is that considering an environmental variable measured early in the lives of individuals significantly reduces the confoundedness due to adults' avoidance behavior. In other words, a given cognitive- and health-related outcome for an individual observed at a given point in time is probably not the result of exposure to certain environmental conditions in the same year; rather, it is the result of a very long-term and often unobserved process in which an individual may systematically choose to avoid exposure to adverse conditions. Given these caveats in assessing the effects of exposure to pernicious diseases on adult outcomes, an increasing body of literature is focusing on the 'fetal origins' hypothesis in order to have a reliable lower bound estimate of the impact.

Regarding malaria, Bleakley (2007) finds that on average one year of exposure to the disease reduced citizens' years of schooling by approximately 0.05 in the United States, whereas Barreca (2010) shows that 10 deaths from malaria per 100,000 inhabitants decreased the length of schooling by 0.23 years for cohorts born in the United States between 1900 and 1930. Lucas (2010) investigates the effect of malaria on lifetime female educational attainment in Sri Lanka and Paraguay, finding evidence of a negative effect of the disease on years of education and literacy. Similar results have been obtained by Bleakley (2010) for Brazil, Colombia and Mexico. Percoco (2013) studies the eradication of malaria in Italian regions during the early 1950s and finds evidence of a long-term positive effect on education through inter-generational transmission channels.

In another study on malaria eradication in colonial Taiwan during the early twentieth century, Chang et al. (2011) find that malaria exposure around birth worsens old-age health status; it particularly increases the likelihood of cardiovascular diseases as well as the hazard of mortality and leads to worse cognitive functions. Similarly, Hong (2011) shows that Union Army recruits, who spent their early childhoods in malaria-endemic counties of mid-nineteenth century USA, were on average 2.8 centimeters shorter than their counterparts born in malaria free areas. A somewhat similar result was found by Bozzoli et al. (2008), who estimated an inverse relationship between post-neonatal (one month to one year) mortality, used as a measure of disease and nutritional conditions during childhood, and average adult height.

There are good reasons to hypothesize that height is affected by malaria. In fact, adult height is affected by the balance between the demand and supply of nutrients, by exposure to diseases and by physical exertion (Silventoinen 2003). Crimmins, Finch (2006) also argue that the inflammatory responses developed as a defense against many childhood diseases divert energy from growth and thus reduce adult height. These conditions are generally encountered in the cases of exposure to malaria, especially Falciparum malaria. The study of height is also important because it has been shown to be a good predictor of health outcomes, including mortality (Song et al. 2003) especially from strokes (McCarron et al. 2002, Song et al. 2003), and of earnings (Case, Paxson 2008).

The height of conscripts in Italy in particular has recently attracted the interest of scholars across several disciplines. Arcaleni (2006) presents a comprehensive, descriptive analysis of the height trends of Italian conscripts between 1854 and 1980, whereas Peracchi (2008) reviews the evidence on the relationship between height and economic development.

The distribution of height across individuals also points to distribution of living standards, although under relatively strict assumptions. Let us assume height of individual i, h_i, depends on his/her living standards, y_i, so that it is possible to predict height across individuals with the formula:

$$h_i = \alpha y_i^{\beta} \epsilon_i \tag{1}$$

where α and β are two scale parameters, and ϵ_i is an i.i.d. term. By considering the logarithms, it is possible to reformulate the expression as (Deaton 2008):

$$\ln h_i = \alpha + \beta \ln y_i + \epsilon_i \tag{2}$$

To achieve the linear correlation of the dispersions of height and living standards around their means, under strong assumption of orthogonality between y_i and ϵ_i, the variance of h_i can be expressed as:

$$var(\ln h_i) = \beta^2 var(\ln y_i) + \sigma_{\epsilon}^2 \tag{3}$$

In other words, observing and analyzing the distribution of adult height across regions and individuals, it is possible to have a picture of the distribution of living standards between and within regions. These arguments are of extreme importance for this paper, since in the following sections I propose evidence supporting the negative association between malaria and height across regions and that a place-based policy aimed at eradicating the disease has had significant impact in terms of health inequality between and within regions.

3 An overview of the diffusion of malaria in Italian history

Italy was infested with malaria for hundreds of years until 1962, when its eradication was officially declared. Unlike other pernicious but sporadic diseases, malaria has been a persistent feature of many Italian regions, especially in the South. It shaped the socio-economic development of the entire country, so it was widely considered the "Italian national disease" (Snowden 2006).

Despite its importance, the attempts to document and report malaria incidence only started taking place in 1887, when health statistics began to be collected, and when it was made compulsory to register deaths classified by cause throughout the country. Even then, however, the impact of the disease was unclear and probably underestimated, owing, among other things, to uncertainty about the nature and causes of malaria itself[1].

The influential and fascinating work by Snowden (2006) provides a social history of the malaria eradication program which can be divided into four main phases.

The first phase ranges from the Italian Unification to 1904. The territorial pervasiveness of malaria in Italian regions was one of the main social issues faced by the Government in the aftermath of the 1861 Unification of the country (Amorosa et al. 2005). At that time, almost one third of Italian municipalities were under malaria threat. Life expectancy, which was only 22.5 years in areas affected by malaria and 35.7 in relatively safe areas, presents a sufficient illustration of the burden imposed by the disease. As a result, the economic costs in terms of health care expenditure and loss of productivity were particularly high, so the Italian Government decided to engage in a vast scale campaign to eradicate malaria.

The second phase of the eradication process ranges from 1904 to 1928. In fact, prior to the studies carried out by the physicians Giovanni Battista Grassi and Angelo Celli, malaria was considered to be caused by a miasma, particularly as a result of some gases produced by certain types of terrain. Grassi instead argued that the disease was transmitted by mosquitoes, and that it could have been controlled by using quinine. In 1904, Grassi conducted the first large scale experiment in the Agro Pontino, in the surroundings of Rome, and convincingly demonstrated the validity of his theories. Given the declining price of quinine induced by the increase of coffee production, the Government engaged in a program called "Chinino di Stato", resulting in the free distribution of quinine through a network of health care offices. The effect of this program was very large, decreasing the number of deaths from 15,593 in 1900 to 6,333 in 1914. However, during World War I, as physicians employed in the anti-malaria program were sent to the war front, the death toll of malaria rose once again, with the number of deaths increasing up to 11,487 in 1918.

The third phase begins with the so-called "Legge Mussolini" (i.e. the Mussolini Act) in 1928. By recognizing the failure of the quinine in definitively eradicating malaria in Italian regions, Mussolini aimed to reclaim the entire marshlands in the Agro Pontino, Latium (the so-called bonifica integrale) in order to settle new cities and eradicate malaria. With the employment of advanced technology for hygienic and hydraulic control, malaria was almost eradicated in the area. However, land reclamation interventions put in place during the fascist period were limited to certain areas and insufficient to guarantee the complete eradication of malaria in Italy.

The fourth phase is the phase of the ultimate eradication of malaria by means of DDT, as firstly introduced by American troops in 1944 and massively used by the Italian

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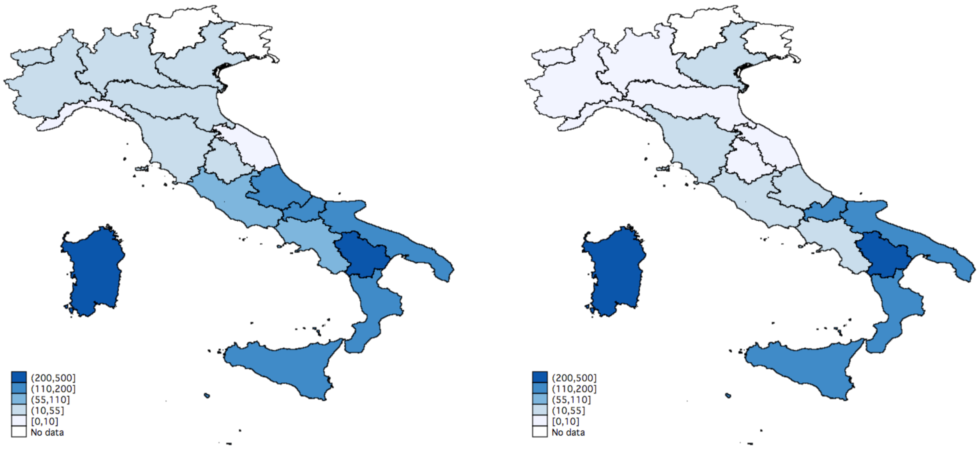
[1] Inter-regional mobility in the considered time period was almost nonexistent (Audenino, Tirabassi 2008). This is particularly relevant in my case because I use regional- and cohort-specific data matched with malaria mortality in the cohort's year of birth in the region, where height measurements took place. The substantial absence of inter-regional migration flows is important for the identification of the parameter of interest, so that the probability of birth in a given region and migration to another region where measurements took place is very low.



(a) Mortality in 1889 (b) Mortality in 1900

Figure 1: Malaria mortality in 1889 and 1900

Note: The figure illustrates the distribution of the malaria death rate in Italy during the two years. There is no data for Trentino-Alto Adige and Friuli-Venezia Giulia, which were not part of the Kingdom of Italy. *Data source*: (Istituto Centrale di Statistica 1958).

government in the years 1945-1950.

In this paper I first focus on the pre-quinine period in order to eliminate possible bias due to policy interventions which might result in lower estimates of the effect of malaria. My data particularly cover the period 1889-1900, a time interval during which the geography of the malaria death toll was remarkably stable with marginal intra-regional variations allowing for an estimation of a panel model (Figure 1). The second piece of evidence I present concerns the impact of the final eradication of malaria on the distribution of height between and within regions, that is I provide evidence of change in the distribution of height among individuals born in regions with high malaria mortality rates.

4 Data

The data for the 1889-1900 period is on the height of conscripts from Costanzo (1948), cohorts of males born between 1889 and 1900. The number of total conscripts from each region in each year and the number of conscripts whose heights were measured are also reported[2]. The regions considered are: Piemonte-Valle d'Aosta, Lombardia, Liguria, Veneto, Emilia Romagna, Marche, Umbria, Toscana, Lazio, Abruzzo-Molise, Basilicata, Campania, Calabria, Puglia, Sicilia, and Sardegna.

As for the analysis of the distribution of height within regions, the sample we used to is from the ISTAT time series[3]. It refers to data collected during the compulsory medical examinations for military service. In Italy, the latter has been mandatory until 2005 and implied a first general visit to confirm the fitness for service. The dataset provides average height for people born between 1918 and 1990 in each region, although the data used in this study is from the 1930-1960 period. Additionally, there are also frequencies for different height intervals, i.e. percentage of people (for a given year in a given region) whose height falls in the intervals: less than 150 cm, 150-154, 155-159, 160-164, 165-169, 170-174, 175-179, more than 180 cm.

Data on deaths resulting from malaria are available in the Cause di Morte: 1887-1955, published by the Istituto Centrale di Statistica (Istituto Centrale di Statistica 1958).

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[2] A'Hearn et al. (2009) raise concerns about the non-normal distribution of height and propose a framework to adjust the empirical distribution. However, from their results, it seems that the adjusted time series does not significantly differ from the original one in the period considered in this paper; I therefore make use of the one observed originally.

[3] Data are available at the website: http://seriestoriche.istat.it/fileadmin/allegati/Sanita/tavole/Tavola_4.16.1.xls.

Table 1: Summary of statistics (Italy)

	Mean	Std.Dev.	Min	Max	Median
Mean height	160.003	0.765	156.77	161.93	160.115
Malaria death rate	65.12	78.12	0.669	312.63	21.89
Average Temperature	12.958	1.83	9.46	17.04	12.87
Average Precipitation	65.733	13.39	40.37	85.98	68.16

Notes: The malaria death rate is the number of deaths per 100,000 residents. Average temperature and precipitation are annual means. The total number of observations is 224.

Table 2: Summary of statistics (Center-North vs South)

	Center-North				Non-North			
	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
Mean height	160.461	0.44	158.96	161.57	159.646	0.77	156.77	161.93
Malaria death rate	8.81	4.12	0.669	17.38	108.917	80.34	2.05	312.63
Average Temp.	11.868	1.42	9.46	15.5	13.805	1.67	10.13	17.04
Average Prec.	74.079	8.92	57.68	85.98	59.242	12.7	40.37	77.76

Notes: North comprises all the regions the capitals of which are located above 43° latitude. Non-north comprises all the other regions, including Latium, where Rome is located. North: Piedmont/Aosta Valley, Lombardy, Veneto, Liguria, Emilia-Romagna, Tuscany, Umbria. Non-north: Marche, Latium, Abruzzi-Molise, Campania, Apulia, Basilicata, Calabria, Sicily, Sardinia. Malaria Deaths: there are 98 observations for the North and 126 observations for the South. The malaria death rate is the number of deaths per 100,000 residents. Average temperature and precipitation are annual means.

The book reports the number of malaria deaths between 1887 and 1955 for each region. Data for previous years are not available for all regions and are unreliable: indeed, the compulsory registration of deaths classified by causes was extended to the whole country only in 1887. I construct 'annual malaria death rates' as the number of deaths due to malaria divided by the resident population of each region; the latter is estimated using census data. I have taken data on general mortality, which will be used as a further control variable, from the same source.

Data on regional population have been compiled using the Annali di statistica: Sviluppo della Popolazione Italiana dal 1861 al 1961 (anno 94, Serie VII-Vol.17), published by ISTAT[4].

Descriptive statistics on conscripts' height, malaria incidence and climatic conditions are reported in Tables 1 and 2. Table 1 reports results for the whole of Italy, whereas Table 2 distinguishes between Center-North and South.

The average malaria mortality rate for the entire Peninsula during the 1889-1900 period (i.e. the death rate averaged across all years and regions) is 69.12 deaths per 100,000 inhabitants, and the standard deviation is quite large (approximately 78 per 100,000). Indeed, as discussed above, there was considerable variation in mortality caused by fevers across areas, due to different degrees of pervasiveness of the disease and its different forms. In the North, in fact, the average number of malaria deaths per 100,000 inhabitants over the 1889-1900 period did not reach 9 units, whereas the mean malaria death rate in the South was nearly 109 units per 100,000 residents. In the North, the median malaria death rate was 9.18, whereas in the South, it was 90.77. The most malarial region was Sardinia, which recorded the highest average malaria death rate over the period under scrutiny (i.e. 265.5 deaths per 100,000), as well as the maximum number of deaths per 100,000 in a given year (i.e. 312.63 in 1889). Conversely, the least malarial region was Liguria, which had the lowest mean malaria mortality rate (i.e. 2.06) and the

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[4] For each region, the book reports the resident and present population numbers recorded in census years (every ten years starting from 1861, with the exception of 1891, when no census was carried out) and the average annual growth rates of the population in the inter-census period. I estimate the resident and present population for all regions and years between 1889 and 1900 by applying the annual average inter-census growth rates to the population data from the 1881 census. Furthermore, data on GDP per capita, which will be used as a control variable, are from Daniele, Malanima (2007).

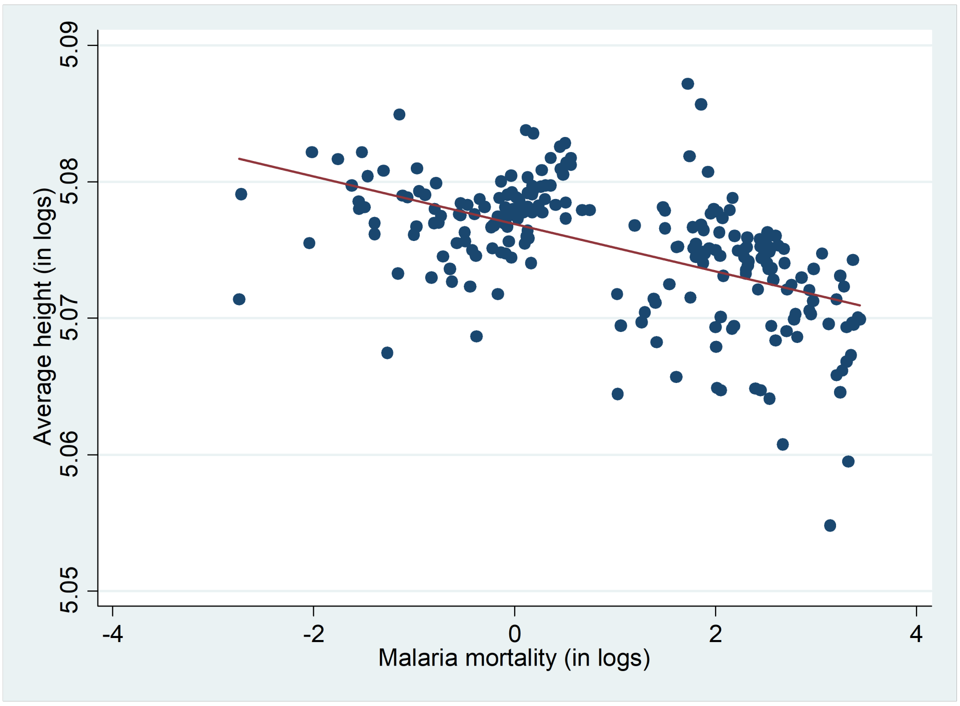

Figure 2: Malaria mortality and height

Table 3: Average height of conscripts

	Regions with high malaria mortality	Regions with low malaria mortality
Before the eradication	165.410	169.211
(1930-1944)	(1.976)	(2.167)
After the eradication	169.180	172.621
(1950-1960)	(1.998)	(1.910)

Notes: Regions with high malaria mortality: Abruzzo, Molise, Basilicata, Calabria, Lazio and Sardegna. Standard errors are in parentheses.

lowest number of deaths per 100,000 in a given year (i.e. 0.669 in 1900). Figure 2 reports the scatter plot for the pooled sample of the relationship between malaria in the year of birth and height. From the linear trend line, it seems that the correlation is negative, although far from being robust.

When it comes to climatic variables, average annual temperature was in general higher in southern regions, whereas rainfall was more abundant in the Center-North.

Table 3 reports descriptive statistics of the impact of malaria eradication on height of conscripts. In the table, regions are divided between the group with high mortality rates and the group with low mortality (i.e. above or below the national average), so the comparison is made between the averages of the 1930-1945 and 1946-1960 time periods. The difference between the two groups significantly decreased after the eradication. However, the observation of only one moment of the distribution of height may hide other, more significant changes occurring in the full distribution of the outcome of interest. To highlight those changes, Figures 3 and 4 plot kernel density for the high and the low mortality groups respectively. As evident, the most significant changes have occurred in the distribution of height of conscripts in regions with high malaria mortality with a sharp change in the tails, especially in the lower limit, implying an interesting change within regions more significantly affected by the treatment (i.e. the eradication).

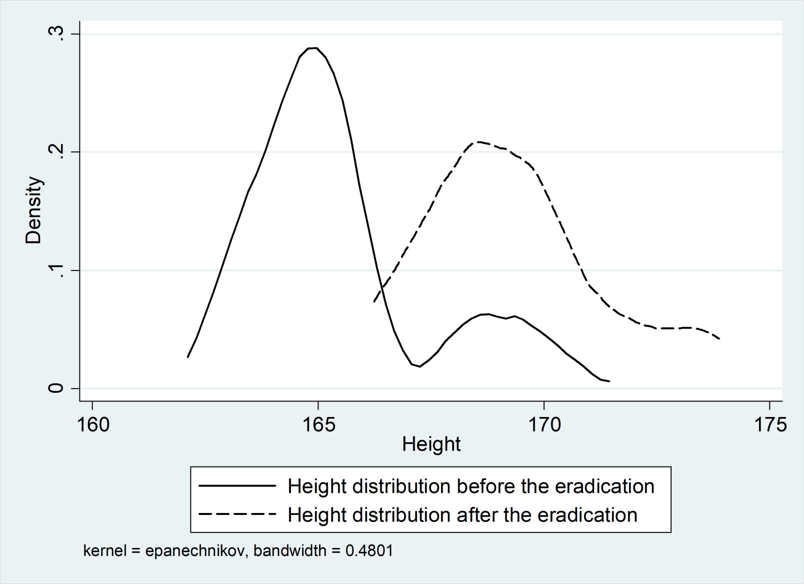

Figure 3: Change in height distribution in regions with high malaria mortality rates

5 The burden of malaria in the pre-eradication era

5.1 Methodology

I start my analysis by estimating OLS regressions where the dependent variable is the regional average height as a function of malaria mortality, controlling for region of birth fixed effects, year of birth fixed effects and region-specific time trends. The first specification is as follows:

$$MeanHeight_{it} = \beta Malaria_{it} + \delta_i \, Year_{cohort_t} + \gamma_t + \epsilon_{it} \tag{4}$$

where $MeanHeight_{it}$ is the average adult height of conscripts born in year t in region i; $Malaria_{it}$ is the incidence of malaria in region i in year t as measured by deaths per 100,000 inhabitants; δ_i is a set of region-of-birth fixed effects that captures features varying across regions but not across time (e.g. geographical characteristics, region-specific genetic backgrounds and even malaria endemicity); γ_t is a set of cohort (year of birth) fixed effects that accounts for birth conditions varying over time but remaining constant across regions (e.g. country-wide shocks). Finally, $\delta_i \, Year_{cohort_t}$ is a set of region-specific time trends used to account for the possibility that the evolution of mean height follows different linear paths in different regions, so that spurious time-series correlations may arise between height and malaria incidence. This latter set of variables is very important for the identification of β since it is meant to capture the evolution of living standards across regions, even in terms of access to healthcare facilities and local availability of food.

Equation (4) assumes that the effect of malaria on average height is only relevant in the conscripts' years of birth. In particular, this specification assumes that in utero and postnatal exposure may have an effect independent of the exposure in the following years. Equation (4) implicitly assumes that the height of individuals born in region i in year t reacts to malaria exposure only in time t, and that exposure in subsequent years is orthogonal to height by definition.

In order to relax this strong assumption, I propose an alternative specification, i.e.:

$$MeanHeight_{it} = \beta Malaria^{p}_{it} + \delta_i \, Year_{cohort_t} + \gamma_t + \epsilon_{it} \tag{5}$$

where $Malaria^{p}_{it}$ is a measure of malaria incidence over the time period t, which goes from the year of birth of the cohort (year 0) to some years after birth. For example, p may be a period of two years comprising the year of birth and the first year after birth, or a period of three years from the year of birth to the second year after birth, and so

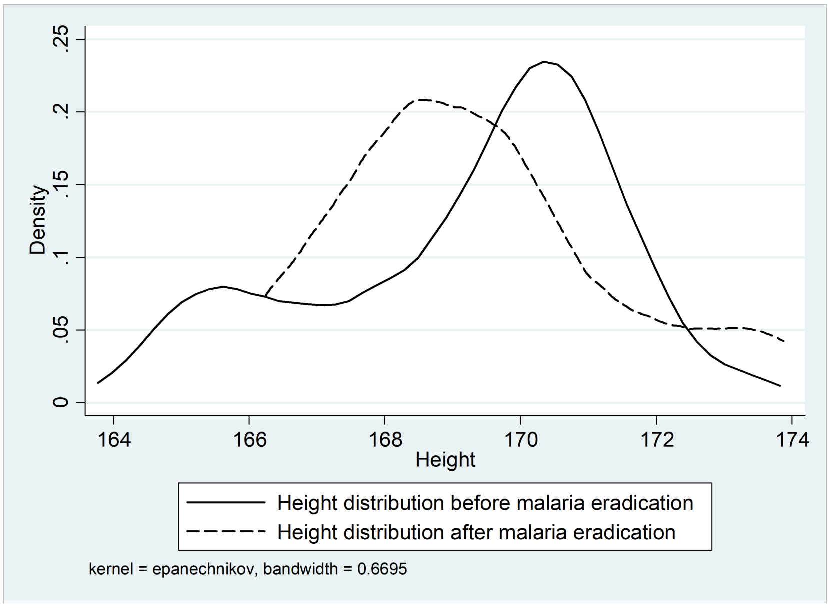

Figure 4: Change in height distribution in regions with low malaria mortality rates

on. In this way the effect of prolonged exposure to malaria during childhood is captured. As a measure of malaria over period p, I use the annual average malaria death rate (per 100,000 inhabitants) over the period under study[5].

There are good reasons to consider estimates of β via OLS to be biased. Firstly, malaria may be correlated with unobservable variables that also influence long-term health, thus creating a problem of endogeneity which would bias the estimation of the parameter β. Secondly, the way I measure malaria, i.e. by the number of deaths per 100,000 inhabitants, is only a proxy for the true incidence of the disease. Malaria deaths were often misreported and probably under-reported. Furthermore, since some forms of malaria are less deadly than others, mortality data do not capture the true pervasiveness of the disease, because the incidence of these mild forms is underrepresented by the number of deaths that they cause, so that β may be biased downward due to a measurement error. An instrumental variable estimation (IV) therefore seems more appropriate[6]. Craig et al. (1999) discuss the relationship between monthly temperature and rainfall surfaces and malaria prevalence. They argue that transmission below $18°C$ is unlikely, because few mosquitoes survive the 56 days necessary for sporogony to complete, whereas temperatures above $22°C$ are sufficient for stable transmission. The rate at which sporogony takes place increases with temperatures in the range of $15°C$-$40°C$ (Martens et al. 1995). Sporogony takes approximately 7-8 days in $30°C$, 8-10 days in $28°C$, 15-16 days in 20-$21°C$, and 200 days when the temperature is around $16°C$. Development stops below $16°C$ for Plasmodium falciparum and below $15°C$ for Plasmodium vivax, but temperatures above $32°C$ cause high vector population turnovers, weak mosquitoes and high mortality. Kirby, Lindsay (2009) find that rates of survival to adulthood are highest for mosquitoes' larvae reared at $25°C$ and decrease with increasing temperature. Furthermore, the time necessary for the development from larvae to the adult stage is also temperature dependent, taking a minimum of 7 days.

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[5] A similar approach was also adopted in Percoco (2016) during the evaluation of the Spanish flu.

[6] This approach has already been taken by, among others, Barreca (2010), who uses climatic variables for instrumenting malaria, and Chang et al. (2011), who instead use the number of public health physicians and other medical personnel per 10,000 inhabitants as an instrument for measuring the malaria death rate in colonial Taiwan. Similarly, Hong (2011) predicts malaria risk using monthly average temperature. Barreca (2010) considers the malaria death rate to be a function of the fraction of the year in which the average daily temperature is between $22°C$ and $28°C$, i.e. the range in which malaria transmission is believed to be less constrained by temperature. The influence of climatic conditions on malaria transmission operates through three channels: mosquito larvae development, mosquito survival, and sporogonic duration – all of them depending on weather conditions.

Table 4: Malaria and height (OLS estimates)

	Malaria mortality					
	in $p = 0$ (1)	in $p = 0$ (2)	in $p = 3$	in $p = 3$	in $p = 5$	in $p = 5$
Malaria	0.000233	4.87e-05	–	–	–	–
			-0.00385***	-0.00465***	-0.00581***	-0.00647***
	(0.239)	(0.0512)	(-3.155)	(-2.636)	(-3.147)	(-3.280)
General mortality		0.0169**		-0.0266		-0.0204
		(2.565)		(-1.018)		(-0.524)
GDP per capita		-0.0221		0.0297***		0.0435***
		(-1.103)		(3.815)		(3.773)
R^2	0.825	0.834	0.829	0.840	0.830	0.840
# of Obs.	224	224	224	224	224	224
F test	12.84	12.30	13.62	13.80	13.46	13.41

Notes: All variables are in logarithms. Robust t-statistics are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Time dummies, region dummies and region-specific time trends are included.

According to Craig et al. (1999), it is important to use precipitation to indicate the probable presence of malaria vectors, their survival and the potential for malaria transmission. Another important aspect of malaria transmission is the fact that suitable conditions must persist for a period long enough for vector populations to increase and for the transmission period to be completed. Three months should be a long enough for transmission (Craig et al. 1999).

In the analysis presented in this paper, I follow Craig et al. (1999) and use climatic variables as instruments to explain the pervasiveness of malaria exogenously. I particularly use average temperature and average rainfall in the year and region of birth as instruments to identify β.

Data on both temperature and rainfalls are from various years of the *Annali del Regio Ufficio Centrale di Meteorologia e Geodinamica*, the data for which are available from several monitoring stations for each region. I consider the simple average across stations for both rainfall and temperature within each region.

5.2 Results

Table 4 presents estimates of OLS regressions, where the logarithm of average height is used as a dependent variable. It's important to note that I always include region and time fixed effects as well as regional time trends, although the associated coefficients are not reported. In model 1, the death rate in the year of birth is used as the only explanatory variable. The associated coefficient is not significant at conventional levels: a result that holds also when controlling for GDP per capita and general mortality (both in logarithms). In models 3 and 4, the average death rate for malaria during the first three years of life is used as an explanatory variable. Interestingly, the coefficient turns out to be highly significant and with a negative sign, a result that is confirmed also in models using average malaria mortality during the first five years of life, although with lower significance.

The results of the ordinary least square estimation prompt some considerations regarding the possible impact of childhood malaria on adult height, and hence on long-term health. In fact, it seems that only in utero or postnatal (i.e. where $p = 0$ and $p = 1$) exposure to the disease is not enough to explain differences in adult heights among different cohorts across regions. Consequently, it is necessary to consider the level of pervasiveness of malaria over a longer period of time. The average malaria death rate computed over the year of birth and the first three years after birth (or the total number of deaths per 100,000 inhabitants in the period) proved to have a statistically significant effect on mean height. The above analysis also suggests that malaria has a stronger long-term impact in the first few years of life of a cohort than in later childhood years.

Table 5: Malaria mortality and climatic variables (2SLS estimates; first stage regressions)

	Malaria mortality					
	in $p = 0$ (1)	in $p = 0$ (2)	in $p = 3$	in $p = 3$	in $p = 5$	in $p = 5$
Temperature	0.327***	0.320***	0.402***	0.293***	0.272***	0.631***
	(4.498)	(4.310)	(2.849)	(3.082)	(3.562)	(3.666)
Rainfalls	0.290**	0.201**	0.136**	0.294***	0.250**	0.307***
	(2.266)	(2.253)	(2.353)	(5.028)	(2.374)	(4.834)
General		0.885		0.846		0.882
mortality		(0.631)		(0.602)		(0.721)
GDP per		0.125		0.119		0.182
capita		(0.323)		(0.313)		(0.431)
F test	16.07	16.24	18.72	37.19	19.22	41.15

Notes: All variables are in logarithms. Robust t-statistics are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Time dummies, region dummies and region-specific time trends are included.

Table 6: Malaria and height (2SLS estimates; second stage)

	Malaria mortality					
	in $p = 0$ (1)	in $p = 0$ (2)	in $p = 3$	in $p = 3$	in $p = 5$	in $p = 5$
Malaria	0.000333	5.17e-05	–	–	–	–
			-0.00415***	-0.00517***	-0.00581***	-0.00718***
	(0.839)	(0.516)	(-4.055)	(-3.316)	(-3.147)	(-4.181)
General		0.0191**		-0.0218		-0.0204
mortality		(3.164)		(-1.182)		(-0.604)
GDP per		-0.0221		0.0207***		0.0421***
capita		(-1.200)		(3.815)		(3.443)
R^2	0.715	0.742	0.745	0.840	0.830	0.840
# of Obs.	224	224	224	224	224	224

Notes: All variables are in logarithms. Robust t-statistics are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Time dummies, region dummies and region-specific time trends are included.

As discussed in previous sections, the parameter of interest, β may be affected by endogeneity and can be instrumented by using temperature and rainfalls. To this end, Tables 5 and 6 report estimates of the first and second stages respectively. It should be noted that, in the case of 3-5 years average malaria mortality, instruments are averaged as well. This is confirmed by the results presented in Table 4, although it is important to note that the magnitude of the coefficient of interest is higher across all the six specifications with respect to the estimates in Table 4 – a result in line with the hypothesis of omitted variable bias in the OLS regressions.

The overall results presented in this section confirm the negative impact of exposure to malaria on height, although only prolonged exposure is statistically significant. The magnitude of the estimated coefficients, however, is very small. To get an idea about the magnitude, let us consider a reduction in malaria mortality from 108.917 in the South to 8.81 in the Center-North, corresponding to a reduction of approximately 91% in the mortality rate. If we consider the estimates in Table 5 as the most reliable and assume an average β coefficient of -0.05, then the increase in the height of the Southern population would be about +0.45% (0.7 centimeters), i.e. sufficient to fill the gap in height between North and South.

These calculations imply that the differences in the incidence of malaria across regions significantly affects spatial health inequality as approximated by conscripts' height.

6 Malaria eradication and health inequality

In the previous section, after accounting for several factors, I have illustrated that spatial disparities in terms of malaria incidence were a major driver of spatial health disparities. In this section, I estimate the effect of malaria eradication on spatial health inequality within and between regions.

Starting with the seminal paper by DiNardo et al. (1996), literature was focused on the impact of policy interventions on the distribution of outcome variables and on its decomposition to assess the most important factors. Recent contributions have particularly refined the use of quantile regressions and prediction decomposition or the evaluation of counterfactual distributions (Chernozhukov et al. 2008, DiNardo et al. 1996, DiNardo, Tobias 2001, Elder et al. 2011, Machado, Mata 2005, Melly 2006). This approach, however, assumes that the treatment affects only some categories, i.e. only some units belonging to some intervals in the distribution. In principle, in the case of malaria, the eradication of the disease in given regions has affected all height intervals, so a quantile regression approach is not feasible, as there is no distinction between treated and control quantiles. To circumvent this problem, and given the characteristics of the dataset, I propose the use of an equation system defined as:

$$height_{hit} = a_{ht} + \alpha_h high_{hi} + \beta_h post_{ht} + \delta_h high_{hi} \times post_{ht} + \epsilon_{hit} \tag{6}$$

where the dependent variable is the share of conscripts with height falling in interval h defined as above, in region i and in year t; α denotes a common trend; $high_{hi}$ is an indicator variable for regions with high mortality; whereas $post_{ht}$ is an indicator for the post-eradication period, i.e. after 1950. Our parameters of interest in system (6) are δ_I as they measure the shift in the distribution after treatment in the regions (i.e. those with high mortality).

According to (6), the counterfactual is defined by the share of conscripts in each interval before and after the treatment in regions with high versus low malaria mortality rates. The system of equations (6) is hence suitable to estimate the changes in the distribution of height through estimates of the movement of the share of conscripts falling in given intervals.

In order to obtain more efficient results, system (6) is estimated though SUR methodology.

We start our analysis with an estimation of the baseline system of equations in (6), the results of which are reported in Table 7. As stated in the previous section, our parameters of interest are those associated with the interaction $high_{hi} \times post_{ht}$, measuring the effect of eradication across height intervals. As documented in the table, the coefficients are significant at 99% across categories, with the sole exception of the interval 174-179 cm. Interestingly, lower categories have negative coefficients, indicating a decreasing share of conscripts falling in those height intervals. The interval 150-154 cm presents a reduction of about 2.8%, whereas the largest drop is in the 155-159 cm interval, with a contraction of 6.3%. Intervals 165-169 cm and 170-174 cm increase by 7.2% and 8.6% respectively. Interestingly enough, the coefficient associated with the highest category, i.e. those taller than 180 cm, has a negative and significant coefficient, indicating a considerable contraction in the domain of the distribution function. The Appendix reports several robustness checks confirming the results.

Overall, our results point to a robust change in the distribution of height of Italian conscripts due to the eradication of endemic malaria with the tails of that distribution becoming thinner; this is especially true of the left one, exhibiting a shift of population towards higher height intervals.

7 Conclusion

An increasing body of social science studies rely on the ‘fetal origins hypothesis’, according to which in utero, infant, and childhood conditions and shocks can considerably influence adult outcomes. Adult outcomes, in their turn, determine the accumulation and the quality of the human capital of regions and countries, thus influencing economic development.

Table 7: Height distribution change (SUR estimates)

	Intervals							
	<150cm	150-154	155-159	160-164	165-169	170-174	175-179	>180cm
High_{ir}	0.820***	3.192***	8.664***	9.086***	-0.879**	-9.579***	-7.719***	-3.590***
	(0.0356)	(0.127)	(0.340)	(0.496)	(0.372)	(0.404)	(0.464)	(0.415)
Post_{it}	-0.252***	-1.132***	-4.919***	-11.00***	-9.615***	3.733***	11.13***	12.04***
	(0.0302)	(0.108)	(0.289)	(0.422)	(0.316)	(0.343)	(0.394)	(0.353)
$\text{High}_{ir} \times \text{Post}_{it}$	-0.736***	-2.798***	-6.320***	-3.023***	7.181***	8.639***	1.282*	-4.214***
	(0.0536)	(0.191)	(0.512)	(0.748)	(0.561)	(0.609)	(0.699)	(0.626)
Constant	0.313***	1.373***	6.469***	18.30***	29.09***	25.51***	13.58***	5.363***
	(0.0195)	(0.0694)	(0.186)	(0.272)	(0.204)	(0.221)	(0.254)	(0.227)
R^2	0.477	0.536	0.604	0.619	0.507	0.521	0.626	0.630
# of Obs.	976	976	976	976	976	976	976	976

Notes: The share of conscripts falling in the interval is the dependent variable for each regression. Significance: ***: $p<0.01$; **: $p<0.05$ *: $p<0.1$.

With the present paper I add to this body of literature by analyzing the experience of Italy.

I particularly focused on the last twelve years of the nineteenth century, examining whether the conscripts born in regions and years with high malaria incidence were on average significantly shorter as adults than those born in years when the incidence was relatively lower.

I used aggregate data at regional level, and found, through both OLS and IV regression estimates, that exposure to malaria during the year of birth (in utero or postnatal exposure according to the quarter of birth) does not significantly influence mean adult height. However, the average level of exposure experienced by conscripts during the first three to five years of life does have a causal and negative effect on height. My estimates suggest that if the South had had the same malaria mortality as the North of Italy, then the difference in conscripts' height would have been almost nonexistent.

Furthermore, by considering cohorts of conscripts born before and after the eradication of malaria in Italian regions, I documented a shift in the distribution of height with an increase in its average and a convergence towards the interval of 164-174 centimeters. This result is suggestive of the redistributive impact of malaria eradication, although some further work on the topic is still needed. The results in the specific case of malaria in Italy point to intra- and interregional redistributive effects of policies addressing issues related to geography of regions. Furthermore, the evidence presented in this study suggests that place-based policies might successfully address spatial health inequality.

References

A'Hearn B, Vecchi G, Pracchi F (2009) Height and the normal distribution: Evidence from Italian military data. *Demography* 46: 1–25. CrossRef.

Almond D (2006) Is the 1918 inuenza pandemic over? Long-term effects of in utero inuenza exposure in the post-1940 U.S. population. *Journal of Political Economy* 114: 672–712. CrossRef.

Amorosa L, Corbellini G, Coluzzi M (2005) Lessons learned from malaria: Italy's past and sub-Sahara's future. *Health & Place* 11: 67–73. CrossRef.

Arcaleni E (2006) Secular trend and regional differences in the stature of italians, 1854-1980. *Economics and Human Biology* 4: 24–38. CrossRef.

Audenino P, Tirabassi M (2008) *Migrazioni italiane. Storia e storie dall'Ancien régime a oggi.* Bruno Mondadori, Milano

Barker DJ (1990) The fetal and infant origins of adult disease. *British Medical Journal* 301: 1111. CrossRef.

Barreca A (2010) The long-term economic impact of in utero and postnatal exposure to malaria. *Journal of Human Resources* 45: 865–892. CrossRef.

Bleakley H (2007) Disease and development: evidence from hookworm eradication in the american south. *Quarterly Journal of Economics* 30: 73–117. CrossRef.

Bleakley H (2010) Malaria eradication in the americas: a retrospective analysis of childhood exposure. *American Economic Journal: Applied* 2: 1–45. CrossRef.

Bozzoli C, Angus D, Quintana-Domeque C (2008) Adult height and childhood disease. Working Papers 1119, Princeton University, Woodrow Wilson School of Public and International Affairs, Research Program in Development Studies

Case A, Paxson C (2008) Height, health, and cognitive function at older ages. *American Economic Review* 98: 463–467. CrossRef.

Case A, Paxson C (2009) Early life health and cognitive function in old age. *American Economic Review* 99: 104–109. CrossRef.

Case A, Paxson C (2010) Causes and consequences of early-life health. *Demography* 47: S65–S85. CrossRef.

Chang S, Fleisher B, Kim M, Liu S (2011) Long-term effects of early childhood malaria exposure on education and health: Evidence from colonial Taiwan. IZA Discussion Papers 5526, Institute for the Study of Labor (IZA)

Chen Y, Zhou L (2007) The long-term health and economic consequences of the 1959-1961 famine in China. *Journal of Health Economics* 26: 659–681. CrossRef.

Chernozhukov V, Fernandez-Val I, Melly B (2008) Inference on counterfactual distributions. mimeo. CrossRef.

Costanzo A (1948) La statura degli italiani ventenni nati dal 1854 al 1920. *Annali di Statistica* 8: 59–123

Craig M, Snow R, le Sueur D (1999) A climate-based distribution model of malaria transmission in sub-Saharan Africa. *Parasitology Today* 15: 105–111. CrossRef.

Crimmins EM, Finch CE (2006) Infection, inflammation, height, and longevity. *Proceedings of the National Academy of Science* 103: 498–503. CrossRef.

Cutler D, Fung W, Kremer M, Singhal M, Vogl T (2010) Early-life malaria exposure and adult outcomes: Evidence from malaria eradication in India. *American Economic Journal: Applied Economics* 2: 72–94. CrossRef.

Daniele V, Malanima P (2007) Il prodotto delle regioni e il divario Nord-Sud in Italia (1861-2004). *Rivista di Politica Economica* Marzo-Aprile: 267–315

Deaton A (2008) Height, health and inequality: The distribution of adult heights in India. *American Economic Review* 98: 468–474. CrossRef.

DiNardo J, Fortin NM, Lemieux T (1996) Labor market institutions and the distribution of wages, 1973-1992: A semiparametric approach. *Econometrica* 64: 1001–1044. CrossRef.

DiNardo J, Tobias JL (2001) Nonparametric density and regression estimation. *Journal of Economic Perspectives* 15: 11–28. CrossRef.

Elder TE, Goddeeris JH, Haider SJ (2011) Isolating the roles of individual covariates in reweighting estimation. Michigan State University, mimeo

Ferrara AR, Nisticò R (2015) Regional well-being indicators and dispersion from a multidimensional perspective: Evidence from Italy. *Annals of Regional Science* 55: 373–420. CrossRef.

Floud R, Wachter K, Gregory A (1990) *Height, health and history: Nutritional status in the United Kingdom 1750-1980.* Cambridge University Press, Cambridge. CrossRef.

Fogel R (2004) Health, nutrition, and economic growth. *Economic Development and Cultural Change* 52: 643–658. CrossRef.

Franzini L, Giannoni M (2010) Determinants of health disparities between Italian regions. *BMC Public Health* 10: 296. CrossRef.

Haderman S, Dijkstra L (2014) The EU regional human development index. JRC Science and Policy Reports, EU Joint Research Center

Hong SC (2011) Malaria and economic productivity: A longitudinal analysis of the American case. *The Journal of Economic History* 71: 654–671. CrossRef.

Istituto Centrale di Statistica (1958) Cause di morte 1887-1955. Istituto centrale di statistica, rome

Kim S, Deng Q, Belton F, Li S (2010) The lasting impact of mother's fetal malnutrition on their offspring: Evidence from the China great leap forward famine. mimeo

Kirby MJ, Lindsay SW (2009) Effect of temperature and inter-specific competition on the development and survival of Anopheles gambiae sensu stricto and An. arabiensis larvae. *Acta Tropica* 109: 118–123. CrossRef.

Lucas A (2010) Malaria eradication and educational attainment: Evidence from Paraguay and Sri Lanca. *American Economic Journal: Applied Economics* 2: 46–71. CrossRef.

Machado JAF, Mata J (2005) Counterfactual decomposition of changes in wage distributions using quantile regression. *Journal of Applied Econometrics* 20: 445–465. CrossRef.

Martens WJ, Niessen LW, Rotmans J, Jetten TH, McMichael AJ (1995) Potential impact of global climate change on malaria risk. *Environmental Health Perspectives* 103: 458–464. CrossRef.

McCarron P, Mona O, McEwen J, Smith. G (2002) McCarron et al. respond to height cardiovascular disease relation: Are all risk factors equal? *American Journal of Epidemiology* 155: 690–691. CrossRef.

Melly B (2006) Estimation of counterfactual distributions using quantile regression. University of St Gallen, mimeo

Meng X, Qian N (2009) The long term consequences of famine on survivors: Evidence from a unique natural experiment using China's great famine. NBER working paper 14917. CrossRef.

Neelsen S, Stratmann T (2011) Long-run effects of fetal influenza exposure: Evidence from Switzerland. *Social Science and Medicine* 74: 58–66. CrossRef.

Peracchi F (2008) Height and economic development in Italy, 1730-1980. *American Economic Review Papers and Proceedings* 98: 475–481. CrossRef.

Percoco M (2013) The fight against disease: Malaria eradication and regional development in Italy. *Economic Geography* 89: 105–125. CrossRef.

Percoco M (2016) Health shocks and human capital accumulation: The case of Spanish flu in Italian regions. *Regional Studies* 50: 1496–1508. CrossRef.

Perucca G, Piacenza M, Turati G (2019) Spatial inequality in access to healthcare: Evidence from an Italian alpine region. *Regional Studies* 53: 478–489. CrossRef.

Silventoinen K (2003) Determinants of variation in adult body height. *Journal of Biosocial Science* 35: 263–285. CrossRef.

Snowden F (2006) *The conquest of malaria: Italy, 1900-1962*. Yale University Press, New Haven, Conn. CrossRef.

Song YM, Smith GD, Sung J (2003) Adult height and cause-specific mortality: A large prospective study of South Korean men. *American Journal of Epidemiology* 158: 479–85. CrossRef.

Steckel RH (1995) Stature and the standard of living. *Journal of Economic Literature* 33: 1903–1940

Steckel RH (2004) The best of times, the worst of times: Health and nutrition in pre-Columbian America. NBER working papers 10299. CrossRef.

Stein S, Saenger M (1975) *Famine and human developmnt: The Dutch hunger winter 1944-1945*. Oxford University Press, Oxford

A Appendix: Robustness checks

To test the robustness of the baseline specification results (3), I have run several checks. Firstly, the term $high_{ir} \times post_{it}$ can be confounded with an eventual process of height convergence across cohorts and regions because of a general improvement in living standards. In Table A.1, I present estimates of a version of (3) in which regional GDP per capita is used as a further regressor (the time series are taken from Daniele, Malanima 2007 and are in constant 2002 prices). Notably, all estimates maintain their signs and significance, although the coefficients associated with higher intervals have slightly lower point values with respect to the ones reported in Table 2.

Table A.1: Height distribution change – Robustness checks (SUR estimates)

	Intervals							
	<150cm	150-154	155-159	160-164	165-169	170-174	175-179	>180cm
High_{ir}	0.769***	2.915***	7.440***	6.750***	-2.314***	-8.405***	-5.489***	-1.674***
	(0.0388)	(0.137)	(0.340)	(0.427)	(0.291)	(0.420)	(0.373)	(0.255)
Post_{it}	-0.160***	-0.705***	-2.885***	-6.157***	-4.587***	3.207***	5.987***	5.289***
	(0.044)	(0.155)	(0.386)	(0.484)	(0.330)	(0.477)	(0.423)	(0.289)
$\text{High}_{ir} \times \text{Post}_{it}$	-0.736***	-2.771***	-6.290***	-3.427***	6.004***	7.935***	1.910***	-2.613***
	(0.058)	(0.204)	(0.508)	(0.638)	(0.434)	(0.627)	(0.557)	(0.381)
GDP per capita	-0.001***	-0.001***	-0.002***	-0.00511***	-0.004***	0.001***	0.005***	0.006***
	(2.44e-05)	(8.59e-05)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.420***	1.926***	8.949***	23.34***	32.87***	23.59***	8.602***	0.313
	(0.029)	(0.102)	(0.254)	(0.319)	(0.217)	(0.314)	(0.279)	(0.191)
R^2	0.487	0.554	0.662	0.749	0.707	0.561	0.780	0.863
# of Obs.	976	976	976	976	976	976	976	976

Notes: The share of conscripts falling in the interval is the dependent variable for each regression Significance: ***: $p<0.01$; **: $p<0.05$ *: $p<0.1$.

Table A.2: Height distribution change – Excluding treatment cohorts (SUR estimates)

	Intervals							
	<150cm	150-154	155-159	160-164	165-169	170-174	175-179	>180cm
High_{ir}	0.769***	2.915***	7.440***	6.750***	-2.314***	-8.405***	-5.489***	-1.674***
	(0.0388)	(0.137)	(0.340)	(0.427)	(0.291)	(0.420)	(0.373)	(0.255)
Post_{it}	-0.160***	-0.705***	-2.885***	-6.157***	-4.587***	3.207***	5.987***	5.289***
	(0.0440)	(0.155)	(0.386)	(0.484)	(0.330)	(0.477)	(0.423)	(0.289)
$\text{High}_{ir} \times \text{Post}_{it}$	-0.736***	-2.771***	-6.290***	-3.427***	6.004***	7.935***	1.910***	-2.613***
	(0.058)	(0.204)	(0.508)	(0.638)	(0.434)	(0.627)	(0.557)	(0.381)
GDP per capita	-0.001***	-0.001***	-0.002***	-0.005***	-0.004***	0.001***	0.005***	0.006***
	(2.44e-05)	(8.59e-05)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.420***	1.926***	8.949***	23.34***	32.87***	23.59***	8.602***	0.313
	(0.029)	(0.102)	(0.254)	(0.319)	(0.217)	(0.314)	(0.279)	(0.191)
R^2	0.487	0.554	0.662	0.749	0.707	0.561	0.780	0.863
# of Obs.	854	854	854	854	854	854	854	854

Notes: The share of conscripts falling in the interval is the dependent variable for each regression. Cohorts of conscripts born between 1945 and 1950 are excluded. Significance: ***: p<0.01; **: p<0.05 *: p<0.1.

Table A.3: Height distribution change – Excluding treatment cohorts and testing for pre-existing trends (SUR estimates)

	Intervals							
	<150cm	150-154	155-159	160-164	165-169	170-174	175-179	>180cm
High$_{ir}$	0.610***	2.316***	5.773***	4.593***	-2.800***	-6.468***	-3.565***	-0.465*
	(0.0388)	(0.135)	(0.329)	(0.411)	(0.309)	(0.412)	(0.357)	(0.249)
Post$_{it}$	-0.241***	-1.008***	-3.729***	-7.250***	-4.834***	4.188***	6.961***	5.901***
	(0.0417)	(0.145)	(0.353)	(0.440)	(0.331)	(0.442)	(0.383)	(0.267)
High$_{ir}$ × Post$_{it}$	-0.724***	-2.726***	-6.165***	-3.264***	6.041***	7.789***	1.765***	-2.704***
	(0.0540)	(0.188)	(0.458)	(0.571)	(0.429)	(0.574)	(0.497)	(0.346)
GDP per capita	-3.15e-05	-0.001***	-0.001***	-0.0041***	-0.004***	0.001**	0.004***	0.005***
	(2.37e-05)	(8.25e-05)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
Trend * High$_{ir}$	0.001***	0.001***	0.002***	0.002***	0.001***	-0.002***	-0.002***	-0.001***
	(1.65e-05)	(5.73e-05)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
Constant	0.300***	1.474***	7.689***	21.71***	32.50***	25.05***	10.06***	1.227***
	(0.029)	(0.101)	(0.247)	(0.308)	(0.231)	(0.309)	(0.267)	(0.186)
R^2	0.554	0.620	0.725	0.798	0.713	0.633	0.825	0.887
# of Obs.	854	854	854	854	854	854	854	854

Notes: The share of conscripts falling in the interval is the dependent variable for each regression. Cohorts of conscripts born between 1945 and 1950 are excluded. Significance: ***: p<0.01; **: p<0.05 *: p<0.1.

Regression estimates in Tables A.2 and A.3 report estimates of functions in which the cohorts of individuals born between 1945 and 1950, i.e. during the treatment period, are included. Table A.2 reports estimates in which those cohorts are excluded, and it is quite surprising to see that there is no change in the magnitude of estimated parameters. Finally, the specification, the results of which are in Table A.3, considers a time trend specific to regions with high mortality (i.e. an interaction term between a time trend and height). It is important to note that, in this case, results also do not significantly change from my baseline specification.