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On the Relation Between Health and Income: A Cross-Country Analysis

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Abstract: An examination of the correlation between health and wealth cannot determine the direction of causality between the two. Countries' geographic characteristics have an important effect on health, and they are plausibly uncorrelated with other determinants of wealth. This paper uses two climate variables – population-weighted temperature and precipitation – to obtain instrumental variables estimates of the effect of health on wealth.

Keywords: Health, wealth, causality.

JEL Codes: I15

1 Introduction

Do we get richer because we are healthy or do we get healthy because we are rich? Health certainly has the potential to determine the quality of one's life and especially income. As Weil (2007) argues – workers living in a healthy environment do not miss many workdays, are more productive, can learn and adopt new technologies, do not drop labour market so easily, or eventually, it is much easier for them to find work. Acemoglu (2009), by contrast, thinks that the relation goes exactly the other way round. The rich usually have better access to modern health technologies, they can afford to go to specialists, undergo costly and lengthy treatments, buy medicaments and so on. Acemoglu argues that unhealthy nations are unhealthy precisely because they are poor, and they are unable to invest in health-improving technologies and health care as such.

In fact, the discussion on the relationship between health and wealth that has been going on among economists and other social scientists for many years, and has developed more vividly with the onset of the modern economic growth theory, which provided enhanced tools to tackle the issue. The question is not the correlation but the *causality*. In this paper, we try to show that the link between health and wealth is not correlational only, but it is also causal, and that the causality goes from health to wealth. We do not refute the idea that wealth can have an impact on health as well, but its main focus lies in demonstrating the causality from health to wealth.

Examining the correlation between health and wealth cannot identify directly the direction of the causation between the two. Nonetheless, temperatures or precipitation, have a well-recognized effect on health. Furthermore, these two countries' geographic features are plausibly uncorrelated with other determinants of wealth (as opposed to, e.g., distance, which plays an important role in determining trade). This paper uses the two purely geographical variables, the population-weighted temperatures and precipitation as instruments in estimating the effect of health on wealth. For the purpose of this paper, we proxy health by the incidence of tuberculosis (TBC henceforth) per 100,000. In order to curb the possibility of the selection bias, we include the whole sample of countries – both developed and developing ones.

We are not able to confirm that health boosts wealth in a causal way – while biased OLS coefficients are positive and statistically significant, the correct IV estimators are not. This suggests that the bias is indeed substantial. The innovativeness of this study primarily lies in two areas. First, unlike the vast majority of cross-country studies on health, we are focused on the impact of health on wealth rather than the economic growth. Second, the study aims to further strengthen the recent evidence on the positive impact of health on individual wealth coming from the randomized microeconomic trials in developing countries.

The remainder of the paper is structured as follows: section 1 presents the selected stylized facts on global health spending patterns as well as TBC incidence. Section 2 is devoted to the theoretical background, whereas section 3 presents the empirical findings. Section 4 describes the data as well as the empirical methodology including instrumentation. Section 5 presents the results and section 6 concludes.

2 Stylized facts and theoretical background

According to the World Health Organization (2007; WHO henceforth), the total global health per capita expenditure is 639 USD. The country with the highest total health spending is the United States (6,103 USD), whereas the country with the highest government per capita health spending is Norway (4,508 USD). On the contrary, the country with the lowest government spending for health is Burundi, with only 0.70 USD per capita. For further comparison, the annual spending by the municipal government of New York City with the population of about 8.2 million inhabitants is 429 million USD, whereas the government of Benin, the country having the same population as New York City, spends 86 million USD in total. Fig. 1 presents the uneven distribution of health spending across the world, whereas Fig. 2 demonstrates the positive correlation between health and wealth.

We realize that per capita health spending is not a perfect measure of public health in a given country. Its unreliability consists of not only the data quality but also the possibility of corruption. The quality of data has historically been very low since the health statistics have traditionally had a very poor record in developing countries, which is why per capita health spending is barely used in empirical studies. The second drawback lies in the possibility (and often reality) that health spending in many poor countries is subject to corruption, and health

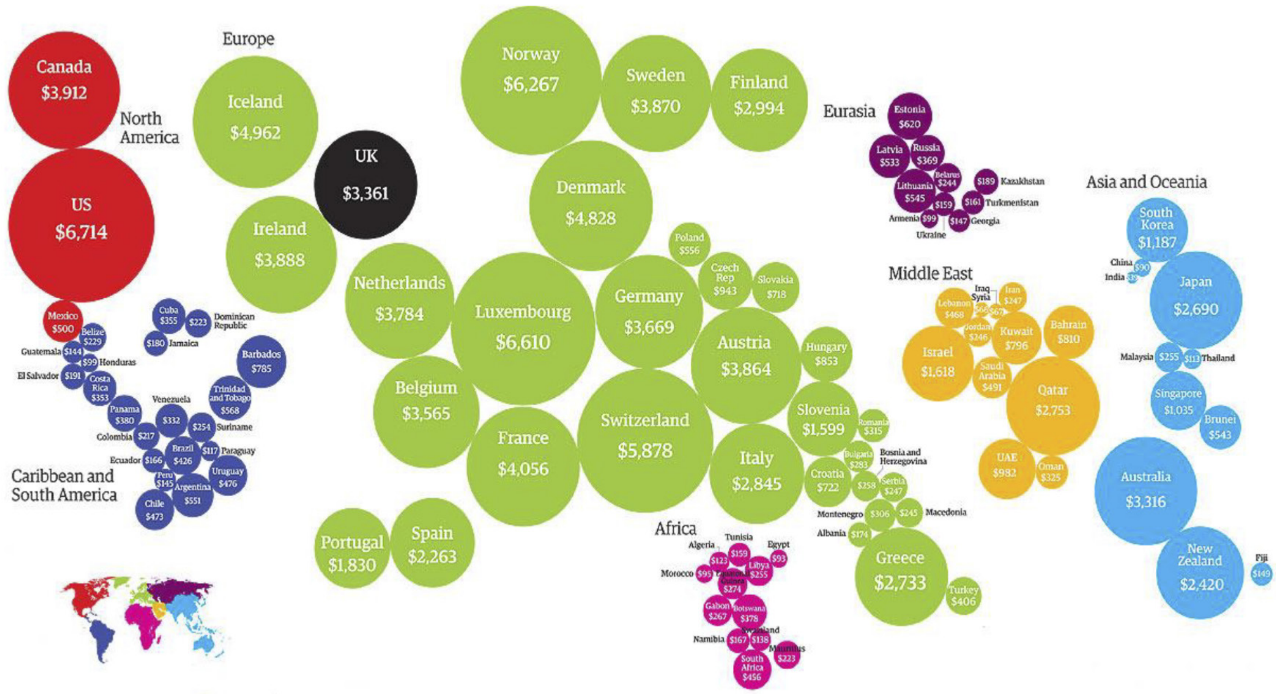

Fig. 1. Total health spending per capita in 2010

Source: World Health Organization 2010.

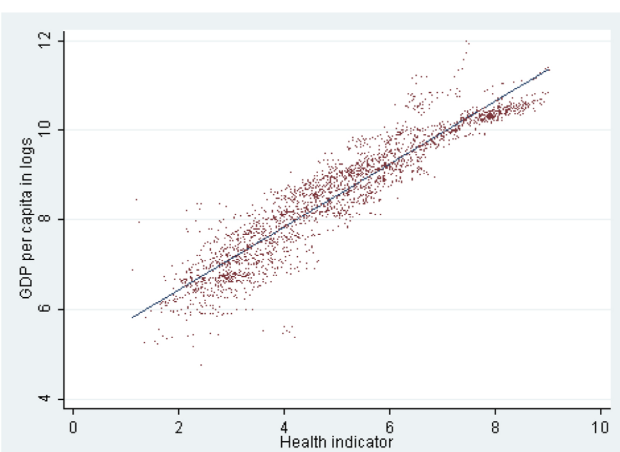

Fig. 2. The positive correlation between health and wealth (average for 1990–2011)

Source: Own preparation.

money simply does not reach the place it should. Therefore, our preferred measure in this paper is the incidence of tuberculosis per 100,000.

Tuberculosis (TBC) is an infectious and in many cases lethal disease that is caused by various types of mycobacteria.[3] TBC typically attacks the respiratory system, mostly lungs, and spreads through air by sneeze or cough. The classic symptoms of an active TBC infection include a chronic cough with blood sputum, fever, night sweats and rapid weight loss. The diagnosis relies on radiology as well as microscopic examination. Treatment of an active infection is very difficult[4] and requires

3 TB is the second greatest killer worldwide due to a single infectious agent after HIV/AIDS. In 2010, almost 9 million people fell ill with TB and almost 1.4 million died from it. TB distribution (as pictured in Fig. 3) is not regular across the world. Over 95 per cent of these deaths occur in low- and middle-income countries, and it is among the three top causes of death for women between 15 and 44 years in these countries. In 2009, there were about 10 million orphan children as a result of TBC death of their parents (WHO 2010). Fig. 4 shows the negative relation between wealth and the incidence of TBC.

4 Active, drug-sensitive TBC disease is treated with a six-month course of four antimicrobial drugs that are provided with information, supervision and support to the patient by a health worker or trained volunteer. Without such supervision and support, treatment adherence can be difficult and the disease can spread. Moreover, the developing world has been witnessing a growing antibiotics resilience resulting from their over-usage (!), which may make the treatment even more expensive and difficult. Whereas a standard six-month package of multidrug-resistant TBC costs 20 USD, the extended drug resilient can cost up to 5,000 USD (WHO 2010, on the over-usage of antibiotics consult Banerjee and Duflo (2011)).

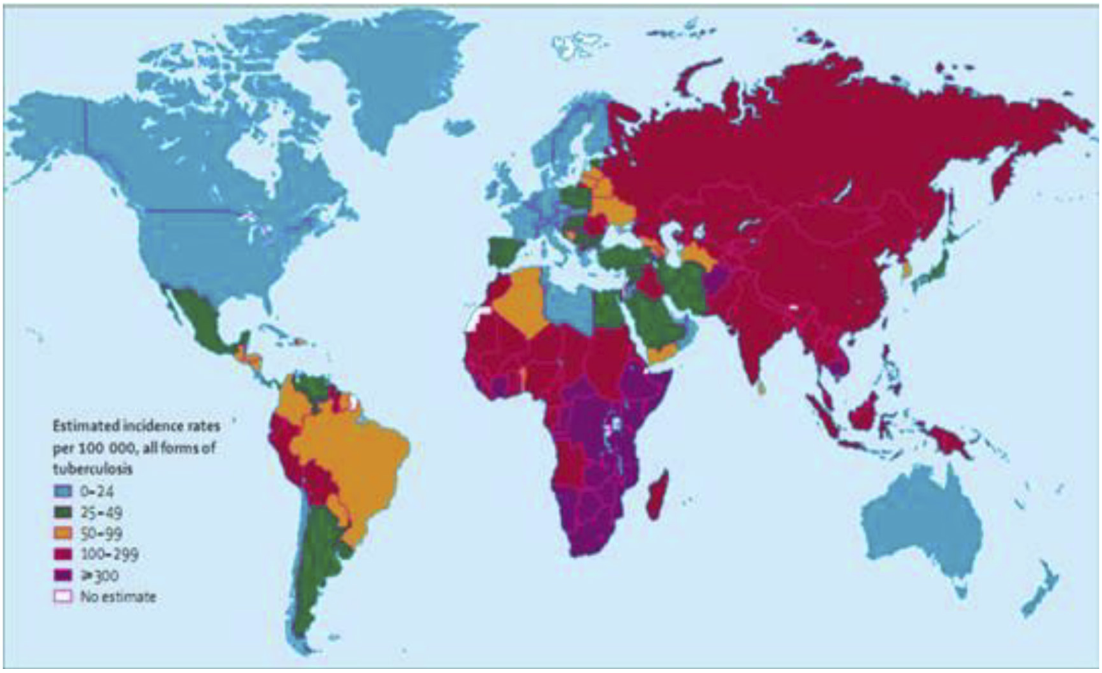

Fig. 3. Estimated Incidence Rates of All Forms of Tuberculosis per 100,000

Source: University of Wisconsin 2012.

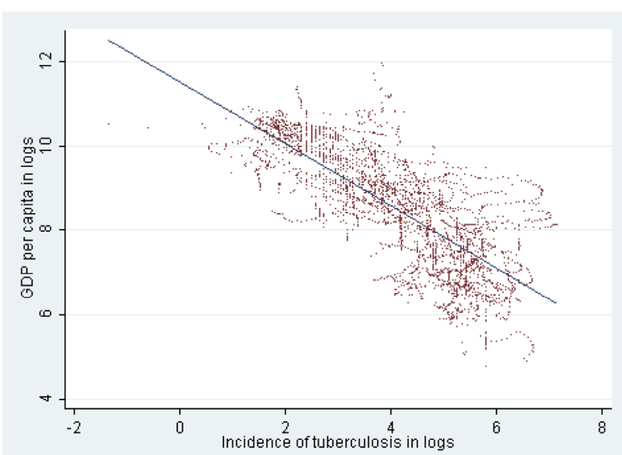

Fig. 4. The negative correlation between wealth and TBC incidence

Source: Own preparation.

handling with multiple antibiotics over a long period of time, which also makes it expensive. TBC is still prevalent in developing countries (though decreasing slowly as of 1990), mainly because of the generally compromised immunity in poor countries as well as the tight linkage of TBC to HIV/AIDS. HIV/AIDS has a devastating effect on the susceptibility to TBC, which makes TBC a leading killer of people living with HIV causing one quarter of all deaths[5] (Lawn and Zumla 2011).

Although the treatment of TBC is difficult and expensive, it can be *prevented* cheaply and easily through immunization.[6] Immunization against TBC is normally part of a rudimentary infant vaccination package in developed countries. The fact that many poor countries still face the disease is just a demonstration of their inability to provide their citizens with the vaccine.

Therefore, we introduce the incidence of TBC per 100,000 as an additional measure of public health in a particular country. Given the nature of the disease as well as its accessible and cheap prevention, the TBC prevalence tangibly demonstrates the concern of governments for the health of their people. Moreover, because

5 People who are co-infected with HIV and TBC are 21 to 34 times more likely to become sick with TB. Risk of active TB is also greater in persons suffering from other conditions that impair the immune system (WHO 2012).

6 The BCG vaccine was introduced in 1921 and remains the only licensed vaccine for the prevention of TB worldwide (Vaccine ORB 2012). In mid-1990s, vaccines to provide basic coverage for TBC, polio, diphtheria, tetanus, pertussis, and measles altogether costed about 1 USD per child. Inclusion of vaccines for hepatitis B and Hib raises the vaccine cost alone to 7–13 USD per child (not including the administration and injection equipment) in the developing world. When vaccine administration is included, the costs amount to between 20–40 USD per child (Kemri 2012).

of TBC's mechanism and its principal causes, it seems to be much better instrumented as compared to the other diseases prevalent in the developing countries. This will be explained in the section on instrumentation.

2.1 Theoretical background

Common sense as well as some stylized facts suggest that an individual's health status should be an important determinant of an individual's income, but clearly a framework is needed to link these concepts in a growth theory. Indeed, there are many channels through which health can positively influence the income of an individual. The very term of human capital is used to represent the stock of skills, education, various competencies and health (Becker 1964). School and health have become important in what we call *demographic transformation,* thanks to two[7] mechanisms (Scheffler 2004). First, an improvement in health leads to a decline in infant mortality rates. Thus, families choose to have less children because chances of their survival are higher. With fewer children, parents can spend more resources on each child, which results in a healthier and better educated population.

Growth theory also suggests that health should somehow matter for economic growth. In exogenous, Solow-type economic models, human capital decisions lead by returns to higher education. Mankiw, Romer and Weil (1992) augmented the standard Solow model by human capital in order to investigate how human capital makes the model better fit the data. The solution of the model suggests that a unique steady state exists and that higher human capital is linked to higher physical capital in the equilibrium. When cross-country differences are concerned, the countries with a greater propensity in both human and physical capital will be relatively richer given that this set of countries is experiencing the same rate of labour-augmenting technological process.[8] Then, the immediate implication is that attention should be paid to human and physical capital (assuming that countries have access to more or less the same world technology). Interestingly enough, David Weil's subsequent work on human capital led him to his recent finding that that the aggregate production function should be augmented by human capital in the form of health (Weil 2007). He argues that differences in health capital appear to be an important factor in explaining large cross-country income differences (Acemoglu 2009).

Neoclassical economic models emphasize how human capital investments (schooling, on-job training, investment in health, etc.) respond to future rewards and how they evolve over time; for example, Ben-Porath (1967) in which human capital investments decisions are being made constantly during the lifetime of an individual. An alternative perspective on human capital was provided by Nelson and Phelps (1966), who argue that the main role of human capital is to cope with change and new technologies rather than increasing productivity in existing tasks.

Their model provided a solid explanatory base for the role of human capital in endogenous models. By emphasizing the ability of coping with change, disruption and technological change, the Nelson-Phelps model (1966) tackles the reality of endogenous models, in which TFP is embedded. In these models, the rate at which the gap between TFP and the current level of productivity is closed depends on the level of human capital (absorption capacity). Hence, in reality, markets must allocate workers between R&D and production, so that there are at least two ways of incorporating human capital in the models – as a factor increasing productivity or as a factor increasing technology adaption. In either way, human capital emerges as an outcome of expensive investment, and thus, it is endogenously conditioned in the models.

Among the latest contributions, Aghion, Howitt and Murtin (2011) revisit the Nelson-Phelps model developing a simple theoretical model, where both the accumulation and the level of health matter for growth.

2.2 Poverty traps

Given the numerous appealing channels through which health can influence income levels and growth rates,

7 Scheffler (2004) also introduces a third argument. He holds that the adult education of women reduces the cost of making the population healthy. In his opinion, education of females translates into an increased health of their families, because women are the primary 'producer' of family health. Hence, educated females are crucial to the process of economic growth because healthier people are more productive. Another way how females improve health of their families is by providing quality-nutrition.

8 Mankiw, Romer and Weil (1992) in addition tested the Solow model empirically as well. They found that a significant part of the income differences across countries can be explained by the differences in human and physical capital investment behavior.

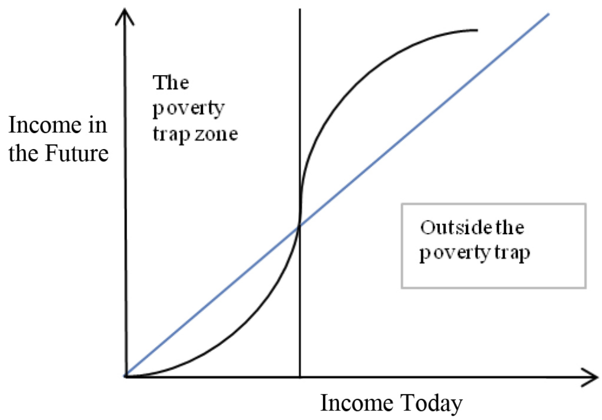

Fig. 5. The S-Shaped Curve and the Poverty Trap
Source: Banerjee and Duflo 2011.

economists also ask about the consequences of deactivation of some or all of those channels. Health, or more precisely the lack of it, is seen as the source of a number of different traps. For instance, sick workers miss many workdays just because they live in a noxious environment, sick children cannot go to school, and sick mothers who give birth are more likely to have sickly children if they survive the birth at all. Each of these channels is a potential mechanism to throw people to poverty.

The idea is conceptualized in a so-called poverty trap and dates back to 1958 when Dipak Mazumdar, a doctorate student of Economics at the London School of Economics, defined something he called a nutrition-based poverty trap. His idea was very simple – a human body needs a certain number of calories in order to survive, whereas poverty constrains the calories supply. When people get richer, they can afford to buy more food, which raises the level of bodily needs' satisfaction. Thus, extra food enables raised labour productivity and increased output. This simple bodily mechanism creates an S-shaped curve between the income today and income tomorrow as depicted in Fig. 5. The extreme poor earn less than they need in order to do meaningful work, but those who have enough to eat can perform demanding agricultural work. This makes a trap – the poor get poorer because they cannot achieve sufficient productivity in agriculture.

This nutrition-based trap is virtually but a specific case of later thought of health-based poverty trap promoted by Sachs (2005). Banerjee and Duflo (2011) put this 'theory' of Sachs's (2005) of malaria-infested countries more formally using the S-curved shape in Fig. 1. Malaria-infested countries (or any other epidemic disease-infested countries) – for example, most of sub-Saharan African countries – are stuck in the left part of the curve, where their malaria-depleted workers are unproductive, thus poor, and hence incapable of treating malaria, which is trapping them in the vicious circle. Nonetheless, if someone helped these countries eliminate malaria (e.g., by the means of foreign aid), that someone would set the trap loose, and the malaria-struck workers would end up in the right upper corner of the diagram.[9]

3 Empirical background

The complexity of the health-income relationship is obvious from a brief survey of the literature. First, a fair shade of the literature deals with the link between health and economic growth rather than health versus the level of wealth, but notable exceptions exist. Sachs (2005) demonstrates that malaria-infested countries are on average much poorer. For example, countries like Côte d'Ivore or Zambia, where a half of the population is jeopardized by malaria, have per capita incomes that of a third of those countries where no one today is exposed to malaria (Gallup and Sachs 2001). Being so poor *because of* malaria makes it hard for them *to prevent* malaria, and thus, keeping them poor. Sceptics, however, refute this idea and point out that it is not clear whether malaria-struck countries are poor because of malaria, or perhaps their incapability to control malaria is an indicator of the poor governance of these countries. If the latter is the case, then malaria eradication could achieve very little in making people richer.

Indeed, given the policy relevance of malaria prevention, campaigns of malaria eradication were studied in various countries with the use of experimental or *quasi*-experimental techniques. For instance, it has been demonstrated that life outcomes (education or earnings) of children born after the successful anti-malaria campaign in the high-prevalence regions caught up with the outcomes of the children born in low-prevalence

9 Naturally, the mechanism of poverty traps has been censured, for instance, by Collier (2008) who argues that poverty itself cannot be a trap. In his opinion, if poverty were intrinsically a trap, we would all still be poor – many societies were poor once and most of them managed to lift out of it. Although the notion of a poverty trap is certainly popular among the laic public, it has never acquired much of appeal within the academic community. In fact, probably the most common, widespread and erudite way of considering health as an important precursor of economic growth/wealth is through human capital.

regions (Banerjee and Duflo 2011). In addition, evidence from the US and a number of countries in Latin America shows that a child who grew up malaria-free earns 50 per cent more per year, for his entire adult life, as opposed to a child who got the disease (Centers for Disease Control and Prevention 2012). Similar results were later found in India (Cutler et al. 2010), Paraguay and Sri Lanka (Lucas 2010), although the scope of the gain differs from country to country.

Second, the poor realize that better health can help them live their lives in a greater dignity and affluence. Banerjee and Duflo (2011) use the eighteen-country dataset to provide evidence for that. The poor were asked whether they had felt 'worry, tension or anxiety' in the recent past, and while 25% report they did, majority declared that the most frequent source of the stress was their concern about their own health or the health of their close relatives. In many of the eighteen countries, the poor spend a sensible amount of their money on health ranging from 3% in Pakistan to 6% in India, which is fairly comparable to the obligatory contribution rates in the advanced economies. In most countries, roughly one fourth of the respondents had visited a general practitioner in the previous month. The poor also spent a lot on single health events. Eight per cent of the Indian respondents jointly spent about 228 USD PPP in the month prior to the research, which is ten times the monthly budget of a single average family. When the poor face a serious health threat, they cut their spending, sell assets or even borrow at high rates.

There is some indicative evidence, though that the poor do not consider better nutrition part of their 'struggle' for better health. Jensen and Miller (2011) found a particular extraordinary example of what they called 'flight to quality' in food consumption. In two regions of China, they randomly selected households that were given substantial subsidies on the price of basic staple – wheat noodle in one region, and rice in another one. Economists usually expect that when the price of something goes down, consumers want more of that something. However, just the opposite happened. The households that were allotted subsidies for a particular staple ate less of it, and ate more shrimps and meat, even though the price of shrimps and meat did not change on the contrary to the staples. Overall, the total caloric intake of the subsidized households did not increase, and neither did the nutritional contents although the purchasing power of these households was in fact bigger. A likely explanation for this odd occurrence is that eating staples is associated with being poor, and while feeling 'richer', the subsidized households wanted to eat better tasting food.

Third, although various benefits of health on wealth and well-being have been shown; the general pattern of the health-wealth relationship is neither straightforward nor easy to explain. A number of randomized evaluations on health and wealth similar to those afore-mentioned have evidenced the bi-directionality and complexity of the health-wealth link. For example, in another of their studies, Banerjee, Deaton and Duflo (2004) performed a survey in the poor areas of India to learn that it is not clear whether wealth leads to better health, or better health towards health and that the causality between health and wealth goes most likely both ways. Moreover, they find that the individuals belonging to the lower-third of income distribution reported poor health and vice-versa, although the pattern is not always congruous across the groups. This finding leads to another assumption that the poor tend to have poor health.

Case and Deaton (2006) performed a similar study in both rural and urban parts of India and South Africa. They found that the health-wealth relation is very complicated as well as their respondents jointly agree that they have to miss meals because of a shortage of money, which contradicts the findings of Banerjee and Duflo (2011) about the unwillingness of the poor to spend more on nutrition or more quality nutrition. Interestingly, despite the lack of food, the urban South African women report the same prevalence of obesity and hypertension as Afro-American women do in the United States. This phenomenon could be explained by the lower quality of nutrition, which would in turn again validate the idea that poor people are of poor health.

The randomized trials that we are referring to are one of the experimental methods for Development Economics promoted and run by the Massachusetts Institute of Technology (MIT) -based Poverty Action Lab. They have evidenced that improving the health of individuals in developing countries can significantly translate into their ability to accumulate wealth. But why does it come clear from the field studies that health means wealth, or at least more of it, for individuals in developing countries – something that could not have been agreed on for so long? For an individual living on a dollar a day, health and disease can easily become the matter of life and death. Losing a job because of an illness and the subsequent inability to work for the time of treating this illness is very likely to bring about extreme poverty. As a result, such an individual is not capable of feeding his/her own family, which often prevents children from going to school. Because the disposable income of such a family plummets suddenly, the nutrition standards, the amount of food, or health expenses are also likely to deteriorate. On the contrary, a healthy individual who is able to work can feed and sustain his/her own family providing its members with rudimentary needs. In such a context, health is clearly a precursor of one's health rather than its outcome.

Randomized experiments that provided us with this reasoning have, however, become the subject to a number of criticisms, most of which can be found in the seminal work by James Heckman (1992). The increase in popularity and usage of randomized trials, thus, necessitates further 'formal' analysis of the suggestions coming from these field experiments. This need for an additional support of the outcomes of the randomized trials has served as the major motivation for writing this thesis. Therefore, our paper attempts to line up with the assumption that individual health can matter for individual health by analysing the relation on the macro using the standard estimation techniques. To our best knowledge, a cross-country research of the health-wealth relation is an innovative contribution to the literature in the field that is divided between macro-studies of the health-growth relation and micro randomized experiments.

Fourth, because the health-wealth relation is so complex and patently bi-directional, the economic profession recognized that the study of the mutual link between health and wealth using the aggregated macro data is too complex for estimation by ordinary least squares. Therefore, the most recent papers use more advanced estimation techniques, conventionally instrumental variables. For instance, Aghion, Howitt and Murtin (2011) instrument for the initial level and growth of life expectancy using Lorentzen, McMillan and Wacziarg (2008) instruments; that is, the Malaria Ecology Index developed by Sachs et al. (2004) as well as the sixteen geographic and climatic variables. They find that better life expectancy is growth-enhancing. Gallup and Sachs (2001) join the discourse on the effects of disease environment on economic growth. They argue that the coincidence of severe malaria and low income is due to many factors, and it is not clear whether malaria is a cause or a consequence of poverty. They debate that certain malaria vectors are geographically specific, so in these areas malaria kills the rich and the poor alike. They, too, construct an instrument using the distribution of malaria vectors (the above-mentioned Malaria Ecology Index). Their findings, however, are rather straightforward. They conclude that the impact of malaria on an economy is substantial, but the channels are not clear.

Acemoglu and Johnson (2006) challenge the discussion on health and growth by studying the effect of life expectancy at birth on the economic growth between 1940 and 1980. Their point of departure is the epidemiological transition that thanks to the global health technology interventions, there has been a reduction in mortality from various diseases. They instrument for changes in life expectancy at birth based on pre-intervention distribution of mortality from these diseases. In order to check the robustness of this instrument, they constructed three alternative instruments, one of them being TBC distribution.[10] All the instruments were proven to be robust. Their conclusions, however, do not follow the newly-emerging consensus that disease environment and health conditions explain income differences across countries as well as that improving health will spur economic growth. By contrast, they find that the increase in life expectancy lead to a rapid increase in population growth, and the birth rates did not decline enough in order to compensate for better life expectancy. Indeed, they find a small initial positive impact of life expectancy on income per capita, but this effect lasted for about forty years only. Overall, the increase in life expectancy along with the population growth seems to have reduced individual income at first, with the negative effect slowly fading away over the next forty years. All in all, they find no proof that the increase in life expectancy led to accelerated economic growth, and thus, leave the whole discussion puzzled.

Based on the empirical findings, we can derive a number of facts for the purpose of this paper. We see that the incidence of TBC can serve as a good measure for public health given the nature of the disease and the disease environment as such in the TBC-infested countries. Moreover, microeconomic evidence from randomized trials in developing countries supports the conjecture of this paper that health can matter for health. Therefore, studying it on a macro level seems to be relevant.

10 In 1940–1980, TB belonged to the three main killer diseases along with malaria and pneumonia.

4 Data and Method

We exploited three databases: Penn World Tables for the data on GDP per capita and the investment rate, the World Bank Development Indicators (2012) for the remaining variables, and Dell, Jones, and Olken (2008) database on the aggregated data of precipitation and temperatures to the country-year level.

The compiled panel covers the yearly observations from 1990 to 2011 for 215 countries and dependent territories. The dataset contains the whole World Bank country set in order to curb a selection bias. Fig. 6 below summarizes the data from all three databases. The dataset includes two measures of health status – TBC incidence of tuberculosis per 100,000 people and the combined private and public health spending per capita.

Additionally, three control variables based on Sala-i-Martin (1997) were comprised – primary school completion rate, for example, the percentage of students completing the last year of primary school, investment share of PPP converted GDP per capita at 2005 constant prices, and the sum of exports and imports of goods and services measured as share of GDP. These three variables have been found significant and robust in the vast majority of the regressions Sala-i-Martin (1997) ran.

Tab. 1. Summary Statistics

Variable	Observations	Mean	Standard Deviation
GDP per capita	3300	10585.46	13345.09
Investment Rate	2368	0.21	0.13
Trade as GDP Share	3692	0.87	0.50
Primary School Completion Rate	2235	0.83	0.24
Weighted Temperature	756	22.58	5.00
Weighted Precipitation	756	13.35	7.66
TB Incidence	4191	131.22	167.41

Source: Own preparation.

4.1 Empirical Methodology

In line with the basic methodology of running cross-sectional regressions used in the empirical literature on economic growth, we will estimate the following equations:

$$\text{Health indicator}_{i,t} = a + \beta \text{ weighted temperatures}_{i,t} + \gamma \text{ weighted precipitation}_{i,t} + \varepsilon_{i,t}$$

$$\log y_{i,t} = a + \beta \text{ control variables}_{i,t} + \delta \text{ health indicator}_{i,t} + \zeta_{i,t}$$

where $\log y_{i,t}$ is gross domestic product divided by mid-year population in country i over given time period t. We use two health indicators: incidence of TBC per 100,000 people and the sum of private and public health spending per capita. The control variables include the primary completion rate, for example, percentage of students completing the last year of primary school divided by 100, the investment share of PPP converted GDP per capita at 2005 constant prices, and the sum of exports and imports of goods and services measured as a share of GDP. We will provide both OLS and IV estimations for the cross-country regressions, which span the period 1990–2011.

The control variables are chosen in accordance with the Sala-i-Martin's (1997) results on the robustness of around 60 variables, which had been found significant in at least one regression prior to his work. Based on his findings, we include the afore-mentioned control variables since they were significant in more than 90 per cent of Sala-i-Martin's famous four million regressions that he ran.

To address the endogeneity problem, we instrument for TBC incidence using the weighted temperatures and precipitation for every country. Geographical features have become a popular instrument since Frankel and Romer (1999). Neither geography nor climate is directly associated with per capita income; yet, it might not be a coincidence that the poorest countries in the world are usually situated in extreme conditions as far as weather is concerned. For instance, the hottest country in the world, Mauritania, having an average population-weighted temperature of 28.4°C belongs to the least developed countries (LDCs henceforth) according to the United Nations (UN henceforth). Mongolia, the world's coldest country, with the population-weighted temperature of -1.77°C ranks between the 120^{th} to 130^{th} position on the list of the world's poorest countries with the rank varying from the source (International Monetary Fund, World Bank, or CIA Factbook).

Geography and climate can influence the aggregate output of an economy through a variety of channels, one of them being a disease environment. Countries located in the extreme climate conditions such as tropic or subtropic zones are prone to a myriad of diseases not present in advanced countries situated in moderate climate zones. Malaria, as explained by Gallup and Sachs (2001) is geographically specific with the most active mosquito

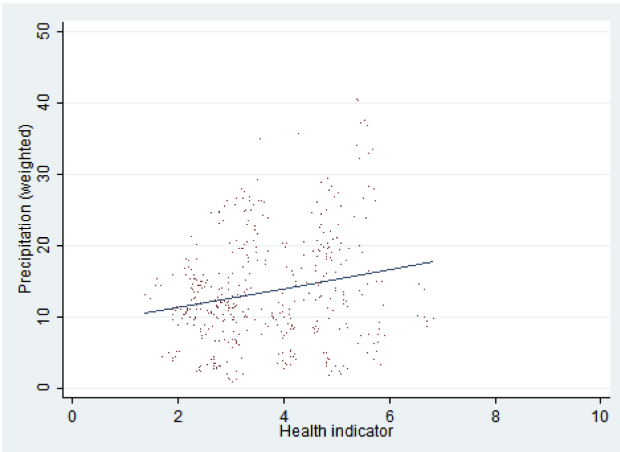

Fig. 6. The relation between the incidence of TBC and weighted precipitation

Data: The data on TBC from WDI, The World Bank. Data on population-weighted precipitation from Dell, Jones, and Olken (2008).

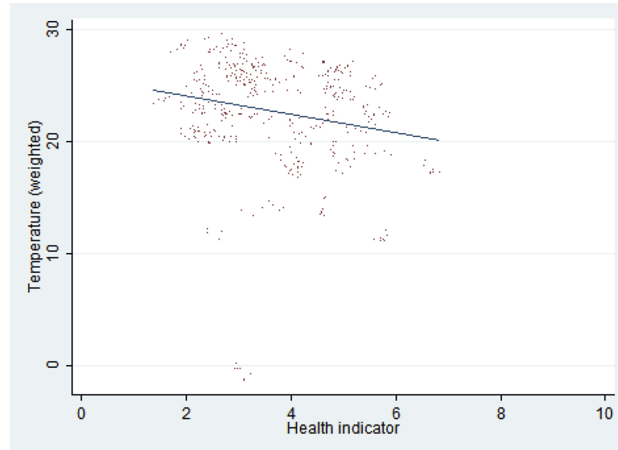

Fig. 7. The relation between the incidence of TBC and weighted temperature

Data: The data on TBC from WDI, The World Bank. Data on population-weighted temperature from Dell, Jones, and Olken (2008).

vectors situated in sub-Saharan Africa. Schistosomiasis (bilharzia or snail fever), a parasitic disease caused by freshwater snails, is most commonly found in Africa, Asia and South Africa because of the dispersion of the snails. Yellow fever is a viral haemorrhagic disease caused by a yellow fever mosquito spread in Central Africa and most of Latin America. Apart from these geographically specific parasite-based diseases, the developing world is struck by the acquired immune deficiency syndrome (AIDS), which has become the main disease killer along with malaria.

In the previous studies, malaria could have been used as a proxy for many tropical diseases, which are not adequately controlled for by life expectancy. However, AIDS has started having an increased economic impact, which makes proxying and instrumenting more complex. In order to account for both diseases that are currently the biggest issue in the developing world (AIDS and malaria), we chose to use the incidence of TB as the variable to be instrumented for. As mentioned earlier, TBC is a disease, whose distribution is not uniform across the globe, with roughly eighty per cent of the cases occurring in developing countries (Kumar, Abbas, Fausto, Mitchell 2007). This skewed distribution virtually reflects two phenomena occurring in developing countries: a) a lack of immunization coverage in developing countries and b) compromised immunity of the individuals in poor countries mostly caused by the challenging disease environment they are exposed to. Hence, TBC is better instrumented for than malaria itself would be.

As far as the instruments themselves are concerned, Fig. 6 illustrates the relationship between the weighted precipitation and the incidence of TBC. The link between the two seems to be rather strong and negative. By contrast, the link between weighted temperature and TBC is zero-sloped with a number of outliers, as shown in Fig. 7. Thus, the weighted precipitation seems to be potentially a better instrument than the weighted temperature.

5 Results

The following section discusses the outcomes of the regressions we ran – regression and IV panel regression. Tab. 2 presents the results of these estimations. Hausman test identifies the fixed effects to be the preferable functional form.

As explained above, we instrument for the health expenditure or the incidence of tuberculosis per 100,000 in 215 countries and dependent territories using the aggregated weighted temperature and precipitation. The model follows the results of Sala-i-Martin (1997), in which all the control variables have a positive and significant impact on the income per capita. Most notably, by increasing primary school completion rate by one percentage point, we increase income per capita by roughly 0.2–0.5 points, whereas increasing investment rate by one percentage point would result in an increase in GDP per capita by 0.1–0.5 points. Trade, too, appears to have a significant but small impact on

Tab. 2. Regression Results

Log GDP per capita	**Log health expenditure**	**TBC incidence**	**Log health expenditure**	**TBC incidence**
		Second stage regression		
Health indicator	0.304	-0.123	0.043	-0.035
	(0.000)	(0.000)	(0.774)	(0.904)
Primary school completion rate	0.263	0.546	0.228	0.279
	(0.000)	(0.000)	(0.035)	(0.003)
Investment as % of GDP	0.096	0.467	0.130	0.140
	0.211	(0.000)	(0.569)	(0.588)
Trade volume as % of GDP	0.186	0.210	0.113	0.108
	(0.000)	(0.000)	(0.068)	(0.046)
		First stage regression		
Temperature (weighted)			-0.075	-0.041
			(0.022)	(0.085)
Precipitation (weighted)			-0.005	-0.005
			(0.087)	(0.083)
Primary school completion rate			0.231	-0.154
			(0.424)	(0.260)
Investment as % of GDP			1.172	-0.576
			(0.009)	(0.068)
Trade volume as % of GDP			-0.237	-0.056
			0.123	(0.504)
Constant	6.636	8.257	7.391	7.595
	(0.000)	(0.000)	(0.000)	(0.000)
N of observations	997	1259	178	310
R squared between	90.5%	68.4%	81.1%	71.8%
R squared within	65.7%	18.0%	17.4%	8.5%

Note: Data from WDI, The World Bank, Dell, Jones, and Olken (2008) and Penn World Tables (ed. 5.6). Sargan-Hansen test for overidentifying restrictions does not reject the null of validity.

income with the coefficient being 0.2. The differences between the panel estimates stem from the availability of data (changing sample size). As far as the measures of health are concerned, health spending has a positive coefficient, whereas TBC incidence a negative one. The cross-sectional variation seems to be an important driver of the outcome, because when focusing on time variation, most of the coefficients are insignificant.

Given the endogeneity of both health indicators, we run the instrumental regression. We instrument using weighted precipitation and weighted temperature indicators. Unfortunately, data availability limits the sample further. When instrumenting, the sign of the coefficients is preserved, but the precision of estimates drops substantially, turning them insignificant. However, preserved sign of the coefficients suggest that if there were an endogeneity bias, it is not – so to say – large. Precision drops mostly due to smaller sample size, which is visible also with the other coefficients of the IV estimates. Significance of the human capital indicator hint the importance of the traditional human capital *(H)* along with health human capital *(Q)*, following Weil's

(2007) production function that includes both *H* and *Q*. Clearly, an individual's health is not enough when one lacks basic literacy skills, exactly as these skills by themselves are not enough when this very individual cannot work because of a disease.

Finally, one could consider the cases of countries with (relatively) high income per capita, but also relatively high incidence of diseases like tuberculosis due to inequality and poor health service quality for the poor majority. We inspected such cases in our study. A careful examination reveals that high income and high TBC incidence countries are relatively few (over the whole sample, 13 such countries) and also usually small (such as Aruba, Farao Islands, Serbia or Timor-Leste). For the sake of estimations, we excluded these countries from the estimations and obtained results qualitatively, the same as presented in Tab. 2.

Earlier research in this field relied on biased OLS estimators or utilized GMM, to address the endogeneity problem. Estimations employing GMM typically confirm the positive, causal relationship between health and wealth (Hansen, 2012; Husain et al. 2014). The novelty of our approach is to utilize a conceptually exogenous instrument rather than lagged differences of the endogenous variables. Also, our dependent variable is different (health expenditure and incidence of TBC versus life expectancy in the earlier studies).

Some earlier studies also exploited possible nonlinearities in the relationship between health and wealth. Such analysis would not be particularly informative in our case. Conceptually, one would expect a relationship *within* country to be non-linear, with the premise that eventually, with high life expectancy, health is not the driving factor behind wealth accumulation. However, data constraints limit the time dimension to be exploited in our study. When introduced to the IV regressions, the non-linear term picks up mostly cross-country differences and the null result is maintained.

6 Conclusions

In the paper, we have attempted to shed some more light on the issue of the cross-country health-wealth relation using the conventional IV estimation technique and two geographic instrumental variables: population-weighted temperatures and precipitation. Because examining the correlation between health and wealth cannot identify the direction of the causation, the main research question was to show that the health-wealth relation is causal, and that the causality goes from the health to wealth.

This paper was motivated mainly by the recent micro-evidence on the importance of health for wealth coming from randomized trials in developing countries. We have tried to find further support for the idea that health matters for wealth. The results of our paper similarly show that health does matter for wealth of individuals, and that the direction of the causality between the two goes from health to wealth, though it is not very strong. This study has also generally contributed to cross-country macroeconomic research by emphasizing *wealth* rather than *economic growth* in the analysis.

Such an emphasis on individual wealth rather than the aggregate outcome of the economy is becoming increasingly important from the perspective of welfare economics and poverty alleviation both in developing and developed countries. Whereas the recognition of the health-to-wealth relation in poor economies can attract more attention to development assistance for health, and rich economies might reconsider various health-related policy options in the fight against income inequalities. Therefore, further wealth-focused research is surely recommended.

As far as our paper is concerned, we recognize a number of shortcomings that might be helpful for future research. Virtually, there are two issues of concern when it comes to this and any ensuing research – the issue of 'measuring' health, and the issue of data quality. Because the statistics on per capita health spending in developing countries is not always reliable, there is an urging need for other ways of 'gauging' health. In the paper, we have proposed a number of different ways (TBC incidence, the percentage of births attended by trained health staff, the number of doctors per 1,000, etc.). Unfortunately, most of the proposed proxies are not available for the whole panel of countries, and therefore, alternative variables should be thought of.

To conclude, our paper generally follows the mainstream findings of the existing research by learning that the health-wealth relation is not only correlational, but also causal. Clearly, richer countries can afford better healthcare, thus also having lower incidence of tuberculosis. However, with instruments such as temperature and precipitation, we were not able to find convincing evidence that there is a direct effect of health on wealth of countries. The consistent signs of the coefficients suggests, though, that there is room for further analyses.

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