Impact of personal income on mortality by age: biological versus socio-economic effects

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Abstract
The influence of per capita income on life expectancy is well documented, mostly through studies of multinational samples. However, one expects fairly weak correlations at both ends of the life span, that is to say in early infancy and in age groups of elderly from 85 to 100 years. The reason is that at both ends mortality is largely controled by biological factors rather than by socio-economic conditions.

In order to test this conjecture, we explore the influence of income on age groups, separately in France, the United States and South Korea. More precisely in each country we compare income and mortality data in as many regional subunits as possible. One noteworthy constatation is that, contrary to a common view, personal income is only weakly correlated with infant mortality (i.e. mortality under the age of one year). More broadly, we propose as a conjecture that the common pattern revealed by the analysis of the three countries is also valid in other developed countries.

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1 Introduction

Let us start by indicating one of the main motivations of the present study.

1.1 The case of infant mortality

Infant mortality is often used as an indicator of poverty and difficult living conditions. The idea behind that is probably that newborns under one year are fragile and therefore more affected by hardships than older children. We wanted to see whether this belief is supported by solid evidence.

The curves of the correlation of infant death rate with income which will be given in the paper show that this argument is not correct. Under one year of age the correlation is rather low and not statistically significant. This is understandable because under one year the causes of death are mostly due to congenital anomalies which means that they are of biological rather than social origin.

1.2 Influence of age in the income-mortality relationship

The studies published in recent times on the relation between mortality and personal income (Marmot 2005, Cutler et al. 2006, Berkman et al. 2014, Chetty et al. 2016) are not much concerned with how this relation changes with age which is the topic of the present note.

The only studies of this question seem to go back to the 1960s; for instance, Frederiksen (1966a,b) studied this point as an aside of a broad study of population growth.

Apart from the specific issue of infant mortality just mentioned what led us to investigate this effect of age is our awareness of the special character of mortality at the two ends of the age spectrum. This point is developed in the next subsection.

1.3 Biological versus social factors

Mortality is influenced by many factors, whether biological (e.g. genetic background), medical (e.g. vaccines, antibiotics), social (e.g. marital status, see Richmond et al. 2016); economic and cultural aspects are of importance through what is globally called the standard of living.

Among all these conditions medical factors are of primary importance but a previous investigation (Richmond et al. 2016a) had led us to the observation that medical progress has little influence on mortality at the two ends of life span, i.e. on very young and very old age groups, more precisely during the first days or weeks after birth and similarly in ages over 90. For these age groups mortality is dominated by congenital malformations on the young end and by a multitude of wear-out effects which plague almost all organs in old age. In short, the mortality of these age groups appears largely determined by purely biological factors. Therefore one does not expect any substantial impact of other factors and this includes economic factors. Testing this conjecture was the main incentive for embarking on the present study.

If the conjecture is true, since one knows that personal income has a substantial influence on the life expectancy of adults (see for instance Preston 1975, Fig.1) a natural question was to explore the transitions between adulthood and the weak impact regimes prior and after adulthood.

1.4 Answer to a possible objection

In Preston (2007, p.484) one reads that the correlation between infant mortality and level of income is commonly found to be of the order of -0.8. This shows a close relationship; actually it is sufficiently
strong for infant mortality sometimes to be used as a proxy of income level. How is this compatible with the low correlation mentioned above?

The reason is very simple. Correlations as high as -0.8 are found in cross-sectional studies involving a broad set of countries ranging from developing to highly developed countries. For such samples the correlation reflects the fact that in developed countries the death toll of infectious diseases has almost vanished, whereas in developing countries it still represents a major cause of death in early infancy. This difference is demonstrated very clearly by the levels of the annual infant mortality: itself, namely around 3 per 1,000 in advanced countries whereas still 10 times more in many developing countries.

1.5 Multinational versus same nation samples

In the present paper, we consider more homogeneous data, namely cross-regional data within three developed countries, France, the United States and South Korea. This methodology leads to correlations which are lower than with multinational samples but they are also more significant for our purpose. For instance, it raises the question of the respective role of pregnancy and conditions prevailing after birth. Do strenuous living conditions prevailing in poor families (e.g. hard work, noise, pollution) during pregnancy lead to more congenital malformations and in turn, (at least for the most severe of them) to neonatal deaths? In fact, it will appear that in the first few weeks after birth there is only a weak connection with income. This suggests that, at least in developed countries, living conditions during pregnancy do not markedly affect the development of the embryo and fetus. In other words, in utero biological development seems fairly well protected from external factors.

How is this result compatible with the well-known harm due to smoking, drinking alcohol or taking drugs which affects embryogenesis? Well, the low correlation with income suggests that such hazardous behavior is only weakly income-dependent.

1.6 Outline of the paper

The paper proceeds as follows.

• Firstly, we consider the case of France. For our purpose this country has some commendable aspects. (i) Metropolitan France is divided into 96 administrative units called “departements”. Given the relatively limited size of the country as compared with countries like the United States or China these units are fairly homogeneous areas. (ii) French demographic statistics give detailed infancy mortality data starting in the first days after birth and on the old age side there are data for all 5-year age-groups until the age of 100. Thanks to such broad data sets it is possible to give a fairly comprehensive view of the income effect. (iii) For each of the three countries that we selected at least one of the co-authors is a native speaker. It is true that nowadays translation softwares have largely removed the language barrier. Nevertheless, the ability to read the explanations and qualifications by ourselves made things easier.

• In the second part of the paper we examine the case of the United States. Our main goal is of course to see if the typical pattern observed for France will also be found in the US. As subunits the most appropriate choice consisted in the 50 states (plus the District of Columbia). Counties would be

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1The fact that France is studied first is not because one of the authors is French. The criterion which was used is the number of regional subunits: about 90 in France, 50 in the US and 15 in South Korea. In principle more subunits should give more accurate results but one must also make sure that there are enough individuals in each subunit so as to keep statistical fluctuations under control.
too small especially in the east and regions would be too inhomogenous. In addition to the methodology used in part one we propose what may be called a fast methodology in which one concentrates on “extreme” cases, that is to say on the states which have the lowest and highest incomes. This methodology is based on the realization that if it would be possible to conduct this observation as an experiment (in other words, as a prospective investigation) it would not make sense to include in the sample a large group of some 30 states which have almost all the same income. Such a group adds very little to the degree of significance of the correlation.

- South Korea is the third country that we examine. What was our motivation for including South Korea into this study. After observing that our theoretical argument was confirmed in the two cases of France and the US, we became convinced that similar confirmation would be observed in similar countries e.g. Germany or the UK. To consider an Asian country was a more interesting challenge. Not only are there clear cultural differences but also a much more rapid pattern of development. Will the same “law” hold despite these differences? That was the question and the answer was “yes”.

2 Age-specific income/mortality correlation in France

Infancy refers usually to the period of a child’s life before it can talk.

Here we give the word an extended meaning so that it covers the age-interval during which the age-specific death rate is decreasing. This decrease is due to the progressive elimination of new-borns affected by congenital anomalies.

Two comments are in order regarding Fig.1abcd.

(i) Not surprisingly in most cases the mortality rate is a decreasing function of income. Whenever the correlation is positive it is rather low and in fact not significant 9 in the sense that 0 belongs to the confidence interval of the correlation. Because we are chiefly interested in the magnitude (i.e. the absolute value) of the correlation, it is the opposite of the correlation which will be represented in subsequent graphs.

(ii) The relationship is not linear. When one draws the graphs of Fig.1abcd in linear rather than in log-log axes one sees (not shown here) one sees clearly a steep fall for low and mid-income which is followed by a part with a much flater slope. On the log-log plot of Fig.1abcd the the relationship becomes almost linear with the second part being limited to a few data points.

Correlations as a function of age are summarized in Fig.2.

For elderly the decrease of the correlation starts only after the age of 90 and even then it is a fairly small fall. In the United States we will see a more substantial fall. Before one tries to find a definite reason one should observe that the mortality rates in age groups above 90 are beset with large statistical fluctuations because of the small sizes of such age groups.

Fig.2. shows the gradual build up of the impact of economic factors. This part of the graph answers the question raised in the introduction about the transition between the biological and socio-economic regimes. It is a gradual, not an abrupt, transition.

2.1 Method

Before we consider two other countries, let us summarize the successive steps of the investigation.

1 The first, and possibly the most time-consuming step, is to obtain the data. This is highly country-dependent. The data may or may not be publicly available on Internet but one can be sure that they have been recorded. This is fairly evident for income because it is key-macroeconomic variable. The same also holds, though for a different reason, for age-specific mortality; the reason being that mortality is usually added to the record as soon as a new-born is born.
Fig.1a,b,c,d  Relationship between income and death rate in different age groups. $R$ gives the coefficient of linear correlation for ($x =$income, $y =$death rate) whereas $RL$ gives the correlation for the logarithms of the same variables. Fig.1a shows the data points for the first age interval whereas Fig.1d is for the last age interval. Fig.1b,c which are for mid-age intervals show higher correlations in conformity with life expectancy studies. Sources: INSEE (Institut National de la Statistique et des Etudes Economiques): DC1D, Décès selon le sexe, le groupe d’âges atteints dans l’année. Revenu mensuel déclaré par foyer fiscal.

Here is that there are international agreements for the publication of death data by causes of death. For the present investigation such data are needed, not only nationally, but for each of $n$ regional subunits, e.g. French départements or US states.

2 Then, for each of the age intervals, one plots the $n$ data points ($x =$income, $y =$death rate) as shown in Fig.1a,b,c,d. At the same time one computes the correlation between income and death rate.

3 Finally, the $n$ correlations are plotted in a summary-graph whose $x$ axis is age. This gives a graph similar to Fig.2 on which one can read how the connection between income and death changes with age.
Fig. 2  Income/mortality correlations as a function of age in France, 2018 For convenience of the representation, the graph shows the opposite of the correlations. The parts of the curve which are below the zero line correspond basically to non significant correlations. The red solid line is a centered moving average over 3 successive data points, i.e.: \( m(i) = \frac{y(i-1)+2y(i)+y(i+1)}{4} \). Sources: INSEE (Institut National de la Statistique et des Études Économiques): DC1D, Décès selon le sexe, le groupe d’âges atteints dans l’année. Revenu mensuel déclaré par foyer fiscal.

3  The age-specific income/mortality relationship in the US

In this section we examine the same variables in the United States.

Fig. 3a,b  Income/mortality correlation as a function of age, United States, 2010. Left-hand side: graph in which the focus was on the 5 states with lowest and highest incomes respectively; right-hand side: graph for all states. Sources: Personal income by state on the website of the “Bureau of Economic Analysis” (BEA); CDC (Centers of Disease Control) WONDER website for detailed mortality by underlying causes of death.
In the US the income data can be found on the website of the “Bureau of Economic Analysis” whereas the mortality data are available on the “CDC-WONDER” website for detailed underlying mortality.

The analysis which leads to Fig.3a relies on the repetition of the same observation in each state. Let us for a moment assume that one can choose at will the income level in each state. Then, the most accurate procedure would be to take as many incomes as possible in extreme (i.e. very low and very high) income levels and to cover the mid-income interval with a number of cases providing uniform covering density. This makes sense because the confidence interval of a correlation is determined by two factors: (i) the level of the correlation and (ii) the number of data points. As one expects the correlations on both ends to be lower than in the middle, a high density of data points will be necessary to define accurately the left- and right-ends of the curve.

How can one use this argument in the real situation where income levels cannot be attributed at will? While it is of course impossible to generate more data points than those provided, one can limit the number of data points falling in the mid-income range. The main advantage of this procedure is that one can get good correlation estimates just by visual inspection of the position of the lowest and highest income cases. This procedure gives a clearer insight into why correlations are low or high. The comparison of Fig.3a and 3b shows that with only 10 states one gets a picture very similar to the one based on 51 states.

4 The age-specific income/mortality relationship in South Korea

In case of South Korea, the data of regional income and mortality rate by province can be obtained from the Korea National Statistical Office (KNSO). However, there is no publicly open source for detailed infant mortality data by province in Korea. Hence, we acquired the raw data of “The Complementary Survey for Causes of Death” from “Microdata Integrated Service” (MDIS) and processed the data to calculate the infant mortality of different age periods by province.

Fig. 4 displays the similar pattern with the previous cases. As expected, the mortality rate in Korea shows little correlation with income at both ends of the life span, where biological factors are more dominant than socio-economic ones. Specifically, the effect of income factors gradually accumulates with age until it reaches the peak at the age of 60-64 (r=-0.89), and a sharp fall occurs between the groups of the age 70-74 (r = -0.61) and the age 75-79 (r = -0.03). This observation confirms that our theoretical argument holds not only in the cases of the Western countries but also in an Asian country despite their cultural difference.

5 Conclusion

The methodology used in the present paper differs from the more standard approach mainly in two ways.

- Instead of using a sample comprising different countries we analyzed regional units within the same country. In terms of health and mortality the main difference between developing and developed countries is the fact that infectious diseases are still important causes of death in the first whereas they have been almost completely eliminated in the second. For that reason one is not surprised to find a high correlation between income and life expectancy in samples containing a mixture of developing and developed countries. The correlations analyzed here cover effects which are more subtle.
- Most publications mentioned in the introduction took life expectancy as their target variable but this does not allow to study separately the effect of income level on diverse age groups.

2Whereas it is possible to explore the old-age interval by computing the life expectancy for people having reached 60,
Fig. 4  Income/mortality correlation as a function of age, South Korea, 2017. The data consist of 16 provincial level divisions of Korea. Sources: Regional income and mortality data obtained from the Korea National Statistical Office (KNSO). Infant mortality data are produced based on the survey data acquired from Microdata Integrated Service (MDIS).

What should be the next step?
In sociology and in economics it is not so common to be able to predict what will be observed. In a physics-like perspective the next step would be to check to what extent a similar pattern holds in other developed countries, for instance Australia, Canada, China, Germany, Italy, Japan or Spain. As in physics cases which do not follow the law will be of greater interest than those which are in agreement with it for then one must find out for what reason the law is violated. This should bring about a better understanding.

Ethical statement
1 The authors did not receive any funding.
2 The authors do not have any conflict of interest.
3 The study does not involve any experiment with animals that would require ethical approval.
4 The study does not involve any participants that would have to give their informed consent.

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