The reversal of the relation between economic growth and health progress: Sweden in the 19th and 20th centuries[1]

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Health progress, as measured by the decline in mortality rates and the increase in life expectancy, is usually conceived as related with economic growth, especially in the long run. In this investigation, models using GDP growth as index of the dynamic status of the economy, and the decline in several mortality-based indicators as indices of health progress, show that, both in the short- and in the long-run, economic growth is significantly associated with health progress in Sweden throughout the 19th century. However, the relation becomes weaker as time passes and is completely reversed in the second half of the 20th century, in which economic growth affects negatively health progress. The reversal in the relation between economic growth and health progress is shown by different statistical models. Some models using inflation and unemployment as economic indicators reveal similar results.

1. Introduction

One of the unarguable proofs of social progress in recent centuries is the reduction of mortality rates and the associated increase in life expectancy. Thirty years ago, only 36 out of 178 countries had a life expectancy at birth of over 70 years, while there are now 87 nations exceeding this figure [1]. In a large number of countries most humans are today able to reach an advanced age, a privilege that was enjoyed worldwide by a very small minority only one century ago [2].

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The historical decline of mortality has been attributed to various factors associated with economic and social advancement, including the rising availability of material goods, urbanization and improvement of physical infrastructures and housing, increasing levels of education, improvement in personal and social hygienic behaviors, medical advances, the disappearance of slavery, and other significant reductions in discrimination for gender, religious, or ethnic reasons [2-6]. It is generally agreed that the dramatic reduction of mortality due to infectious disease during the past two centuries has been the major determinant of the transition from high to low levels of death rates in every country. Consequently, among the potential causes explaining the drop in mortality, a prominent one is the improvement in nutrition, leading to a strengthening of the immune resistance to infection [3, 4, 7-10]. Public policies improving the hygienic quality of drinking water, milk, and various other foods; sanitizing the urban environment; and cleaning up housing have been also claimed as major factors for the dramatic reductions in mortality rates [11, 12]. Though there are extant controversies and lacuna in knowledge [13], since the microbiological knowledge and the pharmacological or biological tools to fight infections (antibiotics, chemotherapeutic drugs, and vaccines) became available only many years after the accelerated drop in infectious disease mortality had started, it is usually accepted that progress in medical technology may have had a quite limited role in the historical decline of mortality [13-15]. Views on the impact of medical technologies and medical care on mortality rates in recent decades cover a wide spectrum [16-18] At any rate, if the improvement in nutrition were the basic link in the chain leading to the secular decline in death rates; or if it were the public policies such as supply of clean drinking water, building of sewage networks, removal of garbage, and widespread vaccinations; or if several of these factors played important roles, what is undeniable is that the historical decline in mortality must be somewhat related to the process of economic development.

Assuming that particular aspects of the process of economic development were associated with the secular decline in mortality rates, it would be expected that the faster the process of economic development, providing health-improving goods, services, and infrastructures, the faster the progress in health as measured by declines in mortality rates. Indeed, research on preindustrial societies has shown links between harvest yields, grain prices, real wages, and changes in mortality. However, mortality responses to agricultural failures, grain price inflation, or changes in real wages become more muted as the level of development increases [19-22]. Moreover, in the United States and Britain, some historical periods of rapid economic growth during the early industrialization have been shown to coincide with increasing mortality [23-26]. In modern India and China, during recent decades of strong economic growth the declines in mortality have been small, compared with strong drops in death rates during the slow-growth decades before economic liberalization [6].

A whole body of research, mostly published in medical journals, claiming short-term and long-term effects of periods of economic slowdown in rising mortality rates in 20th century industrial economies [27-32] has been discredited by later and more solid studies showing short-term oscillations of mortality fluctuating up in expansions and down in recessions, with the death rate sometimes even reversing its declining long-term trend during periods of accelerated economic growth [33-44]. Recent research seems therefore to suggest an inverse relation between the rate of improvement in health conditions and the rate of economic growth, at least in the short run and in advanced economies in recent decades. Moreover, in modern industrialized nations, it is not hunger but harmful caloric overconsumption and its pathologic effects—overweight, diabetes, hypertension, cardiovascular disease, and cancer—that are the scourge of the poor [45]. A little known historical natural experiment was the one occurring in the Nordic countries during World War II, when major drops in mortality due to cardiovascular disease and diabetes took place, apparently as a consequence of food shortages and cuts in the consumption of dairy products [46].

Though it is increasingly accepted that in the short-run economic growth may have harmful effects on health, in the long-term a beneficial impact of economic growth on health improvement is usually accepted. For instance, in a recent commentary [47], Christopher Ruhm—probably the author who has more forcefully shown in recent years the association between economic expansions and mortality increases—has stated that

> Higher mortality during temporary expansions need not imply negative effects of permanent growth. The key distinction is that transitory increases in output usually require more intensive use of labour and health inputs with existing technologies, whereas lasting changes result from technological innovations or expansions in the capital stock that have the potential to ameliorate any costs to health. Individuals are also more likely to defer health investments during temporary than permanent increases in work hours and sustained growth permits the purchase of consumption goods (like safer cars) that benefit health.

Moreover, since it has been proved that the poorest countries also have the worst health indicators, and in these countries income growth has a direct translation into improved health conditions [48], it is tempting to apply the same reasoning to high- or medium-income countries, assuming for instance that the capacity to generate higher earnings “facilitates an increase in the consumption of health-related goods such as adequate food or medicine” and healthy changes in lifestyle [49].

In the field of historical demography, however, expectations about the impact of economic growth in the long-run decline of mortality are generally modest. For instance, according to already classical estimates by Samuel Preston, only between 10% and 25% of the massive international declines in mortality between the 1930s and the 1960s could be attributed to improved standards of living measured in terms of income per capita [15, 50], an estimate that has not been seriously challenged to date.

In each country, large increases in the output and availability of goods and services took place during the transition from an agrarian economy, mainly producing for self-consumption, to an industrial monetary economy in which markets and commerce play a much larger role. That is precisely the process through which Sweden passed during the past two centuries. Population involved in agriculture and subsidiary occupations was about 80% of all Swedes in 1800, still over 50% in 1900, but below 5% at the end of the 20th century. The share of "agriculture and ancillaries" in the Swedish GDP ranged between 35% and 40% from 1800 up to the 1870s, was about 25% in the 1910s, and only 2.5% in 1990 [19, 51, 52].

Because of early development of a statistical registration system, Sweden has historical statistics that are probably the best in the world. Using these statistics it is possible to analyze the long-term relation between economic growth and health progress. The results of the analysis that will be presented herein provide substantial evidence that the relation between economic growth and health progress reversed in Sweden during the last two centuries, from being strongly positive in the first half of the 19th century to being moderately negative in the late 20th century.

The data and methods used in the study are explained in the next two sections. Section 4 presents the results of the statistical analysis, and section 5 discusses the findings and presents the conclusions of the study. The two appendices present and discuss (1) potential pathways connecting harvests, inflation, economic growth and mortality; and (2) results using other GDP figures.

2. Data

Volume GDP for the years 1800–1998, indexed to 100 for the year 1930, and a GDP deflator, indexed to 100 for 1910–1912, were used, respectively, as indices of the size of the Swedish economy, and its general level of prices (figure 1). These series are from Olle Kratz [51], who kindly shared them with us. National account data by Olle Krantz have been considered of high quality [53, 54] Also from Krantz is an unpublished series of annual unemployment rates for the years 1911–2000 (figure 1). The general crop index for the years 1800–1957 has been taken from Swedish official historical statistics [55]. Economic growth and inflation were computed, respectively, as the first difference in natural logs of GDP and the GDP deflator (figure 1).

Demographic statistics from Sweden are taken from the Human Mortality Database, a common project of the University of California and the Max Planck Institute, available online (http://www.mortality.org/). Infant mortality rates, and age-specific annual mortality rates for large age strata of youngsters (15-24), mid-age adults 35-54, and elderly individuals (70-89), for the whole population and for both males and females separately, were computed from the crude annual death and population counts in each specific age stratum.

Life expectancy at birth (e_0), herein considered synonym with longevity, is a direct indicator of population health, while age-specific mortality rates are inverse indicators. As it was shown by Sen [56], neither the absolute nor the relative increase in e_0 can be considered appropriate indicators of health progress. The absolute change in e_0 makes equally worth a 1-yr gain no matter if the change is from 40 to 41 (rapid, early progress), or from 80 to 81 (slower, more advanced progress), while considering the relative change, transitions in e_0 from 30 to 33 and from 60 to 66 would be equalized, so that gains in longevity would appear to fall over time, simply because the baseline is rising. To avoid that problem, following Sen [56] we will use here as global indicator of progress in population health the relative decline in mortality shortfall, computing this mortality shortfall as $90 - e_{0t}$, where e_{0t} is life expectancy at birth for year *t,* and therefore assuming that 90 is the target of longevity to be reached.[4] We computed the relative progress in longevity shortfall as the negative difference of the natural logarithm of longevity shortfall, i.e., $-\Delta \ln (90 - e_{0,t}) = -[\ln (90 - e_{0,t}) - \ln (90 - e_{0,t-1})]$. Similarly, the relative progress in population health using age-specific mortality rates as health indicators, was computed as $-\Delta \ln (m_{a,t}) = -[\ln (m_{a,t}) - \ln (m_{a,t-1})]$, where $m_{a,t}$ is mortality at age *a* in the year *t.* Since differences in natural logs are very good approximations to rates of change, the negative difference of natural logs approximates a rate of decline, computed as $(ma,_t - m_{a,t-1})/ma,_t$ for an age-specific mortality rate. Both the longevity shortfall and age-specific mortality rates are inverse indicators of population health, so that referring to decline in these indicators and changing signs after computing the first differences in logs is appropriate to avoid referring continuously to negative

[4] We repeated some analyses with longevity shortfall computed with 100 as the target for longevity. The results were very similar.

numbers. Therefore, when the paper refers to *improvement* or *progress* in health, what is implied is the relative decline in longevity shortfall or in age- or age-and-sex-specific mortality.

During the two centuries under consideration, the Swedish mean annual economic growth as estimated by the difference in log GDP was 2.3% (table 1, figure 1). In the long run, GDP growth accelerated from 1800 to the mid decades of the 20th century, when it reached averages annual levels of 4%, to drop then quite dramatically to levels around 2% in the more recent decades of the second half of the 20th century (figure 1). This was also the most inflationary half century, with the GDP deflator growing on average 5.4% per year, versus 2.4% for the whole two centuries considered.

Life expectancy at birth, e_0, rose from values well below 40 years in the early 1800s to almost 80 years in the 1990s (figure 1). In 1999 e_0 reached 76.9 years for males and 81.7 years for females. Consequently, during the period of study the longevity shortfall was reduced from a maximum of about 64 years to a minimum of about 11 years at the end of the 1990s, declining at a mean annual rate of 0.9% per year (table 1). The infant mortality rate, in deaths before year one per 1,000 births, dropped from 240 in 1800 to 3.4 in 1999, declining about 2.1% per year throughout the period, with the fastest decline, 3.7% per year, in 1951-1999, and the slowest, 0.5%, in 1851-1900. Considering the other health indicators, the best years in terms on health progress were the first half of the 20th century for the decline in longevity shortfall and mortality at ages 15-24 and 35-54 (table 1, figure 2). However, considering the decline in mortality at ages 70-89, the fastest health progress was during the years after 1950. The slowest health progress occurred for all considered health indicators in the second half of the 19th century (table 1).

GDP, the GDP deflator, life expectancy, and mortality rates have obvious trends, and the augmented Dickey-Fuller (ADF) test fails to reject the hypothesis of unit roots for all of them. When these series are converted into logs and then differenced, the ADF test rejects, at high levels of statistical significance, the hypothesis of unit roots. Therefore the series of relative change of these variables which are used in the analysis, are all trend-stationary.

The crop index that was used in some analyses evaluates annual crop yields in a scale from 0.5 for disaster harvest to 4.5 for an excellent one.

Unemployment had in Sweden a strong increase in the 1990s (figure 1) and indeed the ADF test does not rule out the hypothesis of unit roots, i.e., the existence of trends in the unemployment series. As in other market economies, in the sample 1911-1999 of the Swedish economy for which unemployment data are available, economic growth does not correlates strongly with unemployment (– 0.13), though it correlates strongly with the rate of change in unemployment measured by the first difference in log unemployment (– 0.56, $P < 0.001$). For these reasons, for the years available the rate of change in unemployment was used as indicator of the dynamic state of the economy, together with GDP growth and inflation.

3. Methods

We studied the coincidental or lagged covariations of "the economy" and health by using a variety of correlation and regression models. Though there are many perspectives on causality in economics [57, 58], not to mention social science [59] epidemiology [60, 61], or philosophy[62, 63], a view that is usually agreed by empirical researchers is that statistical results alone cannot establish causality, which is just "suggested" by statistical evidence placed in the context of a theoretical framework. In economics, causal statements do not readily generate consensus agreement. In natural science causal and often in epidemiology, causal judgments are usually the outcome of replicated results that also fit a theoretical model (the classical case is the attribution of causation to the relation between cancer and smoking). Such criteria like time precedence (effects must follow causes), and dose-effect relation or concomitant variation (if the cause is greater, so must be the effect), are also usually accepted criteria for suggesting causation in empirical research. In time series analysis, leaving aside spurious correlations due to common trends, the coincidental or lagged covariation of two time series is strongly suggestive of one series causing the other, or a third factor causing both.[64, 65] The scientific literature on the demographic transition and the so called mortality revolution [2, 6-8, 10-12, 24, 25, 66] provides a theoretical framework suggesting linkages between the process of economic development and the historical decline of mortality rates. Statistical evidence showing coincidental or lagged comovements of mortality rates with respect to “the economy” will therefore suggest a relation of causality between the latter and the former.

In the following sections, when reporting statistical procedures, tests of significance will be provided. Nevertheless, it may be convenient to mention here that we focus on understanding the data, using readily interpretable data analysis methods, rather than leaning too heavily on mathematical models and their resulting *P*-values. Indeed, the concept of statistical significance is based on the theory of statistical inference in which parameters, i.e., population values of a measurement, are inferred from the sample statistics. The data used in this investigation are not a sample in this sense. These time series are computed from economic and vital statistics collected by an excellent system of registration of all Swedish population in the past two centuries. Neither the 200-year series of GDP nor age-specific mortality rates are samples of those variables in the “infinite” Swedish history. They are rather the whole experience of Sweden in its transition from an agricultural society to an industrialized market economy. When, as in this case, mortality rates are not “from a sample” but “from the whole population,” computed with national data, the major issues are not those of statistical stability or statistical significance, but those of systematic errors in data collection or biases in the estimation of parameters [67] (p. 59), and levels of statistical significance are important only to show that the associations are "strong."

4. Results

4.1. Regression modeling of coincidental effects

The historical relation between economic growth and health progress can be modeled with equations such as

$$-\Delta \ln h_t = b_0 + b_1 \cdot t + b_2 \cdot g_t + b_3 \cdot t \cdot g_t + \varepsilon_t,$$

where the progress in health indexed as a relative decline in a mortality-based variable h_t is regressed on a constant, time t, economic growth g, and the interaction of time and economic growth, $t \cdot g$. If economic growth has an impact on health progress, we will expect significant estimates of the parameter b_2. Moreover, if the impact of economic growth on health progress changes throughout time, we will expect a significant estimate of the parameter b_3.

The results for this model, in which time has been rescaled, so that t = year – 1800 (table 2), provide strong evidence that the year-to-year short-term effect of economic growth on health reverses during the considered period. The general pattern of the regression results is that of a positive and significant effect of economic growth on health progress for $t = 0$, i.e., at the start of the 19th century. For instance, considering the models including data for the two centuries, during the early 19th century each percentage point increase in GDP growth reduces the longevity shortfall by 0.76%, and male mortality at ages 15-25 by 2.54%.There is also a pattern of negative effects for the estimated interaction term $g \cdot t$, indicating that the pass of time attenuates the beneficial effect of economic growth. Almost without exception, the interaction term is significant when data for the two centuries, or for the 20th century only, are included in the regression, but not in models including only data for the 19th century.

Using as measure of health progress the longevity shortfall, the model for the two centuries renders statistically significant estimates of 0.76 for the effect of economic growth and – 0.004 for the effect of the interaction between economic growth and time. Therefore, $0.76 - 0.004\, g \cdot t$ is the whole economic growth-related effect on health progress at a year t. This would be zero if a time is reached when there is an effect reversal and economic growth starts having a negative effect on health progress. Solving $0.76\, g - 0.004\, g \cdot t = 0$, we get $t = 0.76/0.004 = 190$, which is the year 1990. Computing this tipping point for other models in which the interaction effect is significant, the tipping point is some year usually in the 20th century, often in its second half. The fact that the interaction is usually not significant when data for the 19th century only are included in the regressions is further evidence suggesting that the reversal happens in the 20th century. The Durbin-Watson d in these models was always above 2.2. Since $d = 2 \cdot (1 - \hat{a})$, where $\hat{a}$ is the estimated autocorrelation of the residuals, d values above 2.0 indicate that the autocorrelation is negative and, therefore, the estimate for the standard error is expected to be enlarged, which will bias the P-values up.

4.2. Cross-correlation models

It is perfectly thinkable that economic growth had lagged effects on health progress. We already mentioned how a whole body of literature by Harvey Brenner's has posed lagged effects of economic growth on health with lags up to 11 years [68-70]. However, Brenner's models have been seriously criticized [71-77] and researchers who have seriously investigated the possibility of lagged macroeconomic effects on health [33, 39, 42] have been unable to find observable lagged effects beyond very few years.

At any rate, we explored the possibility of lagged effects of economic growth on health progress by first computing the cross-correlations between health progress and lagged economic growth. We explored cross-correlation with lags up to 15 or 20 years. Long lags did not reveal any significant correlations beyond those to be expected by chance, so only lags up to 6 years are shown here (table 3). The correlations between economic growth and health progress as measured by the decline in longevity shortfall or in mortality at ages 35-54 show a clear pattern. While in half-century periods during the 19th century there are positive correlations between economic growth and health progress at lag zero, with the pass of time this pattern fades and in the 20th century a pattern of negative correlations appear at lags one and two.

4.3. Lag regression models

Results of regression models with lags (tables 4 and 5) confirm the pattern observed in the exploratory cross-correlation models, showing significant positive effects of economic growth at lag zero and negative and marginally significant negative effects at lags 2 or 3 when data for the two centuries are included in the regression. When the data included in the regression are split by century, the pattern is a quite clear one of positive effects of GDP growth on health progress at zero lag in the 19th century, while in 20th century the significant effects are weaker, appear at lag 2, and are negative. These results show also a reversal of the effect of economic growth on health progress from the 19th to the 20th century, and are consistent with the results already presented of regressions with interactions between time and economic growth.

In the lag regressions the Durbin Watson *d* was consistently above 2.00 (most of the times, between 2.4 and 2.8) indicating again that the residuals have negative autocorrelation and, therefore, the regression results are biased *against* statistical significance.

Results of models including 15 lags (tables 4 and 5 only show the results up to lag 6) or more lags, up to 20 or 40 (not shown) were computed, but they do not reveal long-lagged significant effects. A few statistically significant effects at very long lags appear without any pattern, as is to be expected just because random variability. Increasing the number of lags up to models with 15 or 20 lags, the smaller SBC of models with few lags strongly suggests that it is just noise what is contributed by adding many lags to the explanatory model.

Modeling the impact of economic growth on health progress for half-century samples and sex-specific health indicators (table 6) in coincidental models without lags, and in models including up to two lags, the results again show a general pattern of reversal of signs, though with particularities for different health indicators. For instance, for the longevity shortfall in females, models with two lags indicate a strong positive effect (0.87) at zero lag in 1801-1850. This decreases to 0.62 in 1851-1900, while remaining statistically significant; then in the 20th century there is no significant effect at lag 0 and there are significant negative effects at lag 2 in 1901-1950 (– 0.46), and at lag 1 in 1951-1999 (– 0.25). For infant mortality the reversal seems to happen at the turn of 19th into 20th century, no significant effects of economic growth are observable after 1950. On mortality at specific ages 15-24, 35-54, and 70-89, the results show an impressive positive impact of economic growth in 1801-1850, particularly in the decline of mortality of young men and women aged 15-24. However, for the elderly aged 70-89, effects are no longer significant in the three half-centuries after 1850. In 1851-1900 and 1901-1950, positive effects at lag zero are still predominant for ages 15-24 and 35-43, though many are not significant, and for males aged 35-54 a negative effect marginally significant appears at lag 2. After 1950, negative effects predominate for the decline in mortality at ages 15-24 and 35-54, some of them being statistically significant at the 90% level of confidence.

Models using as indicator of the dynamic status of the economy the annual rate of change of unemployment (table 7) confirm that in the 20th century "the economy" has a lagged effect on health progress, with the lag being two years in the first half of the century and just one year after 1950. Each percentage point increase in the unemployment rate raises one or two years later the rate of decline of the longevity shortfall by about 1%. Models using as economic indicator the rate of change of unemployment produce very similar results, but when unemployment in levels is used as the explanatory variable no effects appear.

For the Swedish economy the correlation between annual economic growth and the annual rate of change in the GDP deflator used as inflation index is – 0.76 ($P < 0.001$) in 1801-1850,

– 0.21 (P = 0.15) in 1851-1900, – 0.32 (*P* = 0.02) in 1901-1950, and – 0.26 (*P* = 0.07) in 1951-1998. That means that, generally, recessionary years are inflationary and expansionary years are deflationary (the correlation for the whole two-centuries sample is – 0.35, $P < 0.001$), but the relation is very intense in the first half of the 19th century, intense in the first half of the 20th century, and quite weak in the second half of both centuries.

Models in which health progress is regressed on inflation (table 8) reveal a strong negative impact of inflation on the rate of improvement in health at lags 0 and 1 in the years 1851-1900 and 1901-1950. However, in both half-centuries at the extremes of the study period, inflation does not seem to have significant effect on health progress. This is also consistent with a regime change during the mid-decades of the 20th century.

4.4. Models with moving averages

It might be that the average level of economic growth during *k* years had an impact on the average progress of health during these *k* years, or that the average economic growth during *k* years had an impact on the rate of change of health at the end of that period. It seems theoretically conceivable that that kind of averaged effects would not appear in the regression models already presented. With this rationale, economic growth and health progress were averaged with centered moving means in periods of 5, 11, and 15 years and the correlations between these moving averages were computed (table 9, panel A). Confirming the evidence already presented, the pattern of such correlations provides strong evidence of a reversal in the relation between economic growth and health progress, since for all averaging lengths and for all health indicators considered, the correlations are strongly positive in 1801-1850, negative in 1951-1999, and show intermediate values in the other two half centuries. For mortality at ages 70-89, the pattern is, again, much weaker. The graphs showing economic growth and, for instance, the rate of change of mortality at ages 35-54 (figure 3) show clearly how the relation between the two variables is opposite in the first half of the 19th century and in the second half of the 20th century.

If we consider that the effect of economic growth in *k* consecutive years will have an impact in health conditions at the end of that period, then what we need to look at is the correlation between average economic growth in periods of *k* years and health progress at the end of that period. However, the correlations of 5-, 11-, and 15-year moving averages of GDP growth with the progress in health at the end of the considered period (table 9, panel B) are very close to zero and rather seem to reflect only noise. If there is any pattern in these correlations, it is precisely in the second half of the 20th century, where the correlations are slightly stronger, but showing, if anything, a negative association between economic growth and improvement in health.

The windows chosen for computing the moving averages are of course arbitrary, but if lagged effects of economic growth on health exist, it would be hard to conceive that those effects are beyond 15 years. At any rate, such an effect appeared neither in cross-correlations nor in lag regressions, and therefore, there is no evidence to support its existence.

5. Discussion and conclusions

The consistency of results using different statistical models and different economic and health indicators makes very unlikely that the described reversal of the relation between economic growth and health progress be a spurious finding. All the models are consistent with a weakening of the strong positive association between economic growth and health progress found in the first half of the 19th century, and with a reversal of the relation between economic growth and health progress, that becomes negative in the last half of the 20th century.

Therefore, this investigation shows that, year-to year, economic growth was strongly associated to health progress in Sweden in the first half of the 19th century, with the association becoming weaker and weaker in the next hundred years, to be substituted by a negative lagged association in the second half of the 20th century, in which economic growth has a negative effect on health progress with a short lag of about one or two years. There is no evidence of effects of economic growth on health at longer lags in any of the periods of the two centuries included in the study.

What might be the reasons why the decline in mortality, strongly stimulated by economic growth in 19th century Sweden, becomes negatively affected by economic growth in the last half of the 20th century? A brief answer may be that economic growth and affluence strongly reduce mortality at the population level when most deaths are due to infectious disease (as in largely agricultural 19th century Sweden), but increased business and industrial activity induce higher death rates when most fatalities are due to such ailments or injuries like cardiovascular diseases, cancer, traffic injuries, diabetes, liver cirrhosis, and other pathologic processes related to work, consumption, or the environment. A more detailed examination of potential pathways, is presented in the appendix A.

The negative association found between economic growth and health progress in the most recent half century, though quite at odds with traditional views of the relation between economic growth and health progress, is consistent with modern studies revealing a short-term tendency of death rates to increase during economic expansions in industrialized countries in recent decades [33-35, 39, 42, 43, 78]. Taking into account all these empirical results, it is indeed quite possible that a reversal of the relation between economic growth and health progress like the one described here in Sweden had occurred during the 20th century in other countries. Analyzing the British experience of health progress between 1900 and 1970, Amartya Sen concluded that the rate of decline of mortality in England and Wales during these eight decades was inversely related to economic growth, with decades of stronger growth associated with lower increases in life expectancy [79]. This finding would also be consistent with a reversal of the relation between GDP growth and health advancement in Britain.

Life expectancy and age-specific mortality rates are among the most objective and solid components of that unobservable Holy Grail variously referred to by social scientists as “social welfare,” “societal utility,” “total ophelimity” or, more plainly, “common good.” A famous economist and once governor of the Bank of Greece, Xenophon Zolotas, concluded almost 30 years ago that, in terms of social welfare, economic growth has diminishing and, eventually, negative returns [80]. What this investigation shows is that economic growth can, and in Sweden's recent past did, produce detrimental effects on social welfare.

To consider the implications of the negative relation between economic growth and health advancement in a modern economy like Sweden raises difficult questions that go well beyond the scope of the present paper. Since the stakes are high and the policy implications of these findings are substantial, a key issue is to ascertain if this switch of the relation between growth and health evidenced in Sweden is also observable in other countries. For nations at low or medium levels of income and population health, it becomes a major issue to ascertain if they have reached the threshold where economic growth no longer promotes improvements in health.

Appendix A

Pathways connecting harvests, inflation, economic growth, and health progress

To disentangle the complex relations between health progress, harvest fluctuations, economic growth, inflation, and other many potential factors that may be involved in population health in Sweden during the two centuries included in the study is beyond the scope of this paper, but an outline of these relations will be presented here.

The correlations between economic growth, inflation, and harvest quality (table A1) show clearly the high degree of dependence of the Swedish economy on agriculture during the 20th century, particularly during its first half.

In the 19th century, the quality of harvests affected the economy contemporaneously and with a one-year lag, and had an impact on mortality the same year. Both in year-to-year terms (table A1, figure A1) and in 5- or 11-year moving averages (not shown), the harvest quality and inflation are negatively related, with the correlation being much stronger in the first half of the century. For instance, the correlations between the general crop index and the rate of inflation one year later are respectively – 0.38 ($P < 0.001$) and – 0.14 in the two halves of the century. Lack of ability to store grain from harvests of good years made good harvest years times of waste and falling prices, while scarcity after bad harvests had a strong impact on increasing prices [19]. This link is weakened, however, in the second half of the century, when the development of facilities for grain storage, as well as increasing ability to transport and import grain, considerably weakens the impact of harvests on the level of prices.

The effect of harvests on health progress is revealed by the positive correlations between the crop index and the progress in health as measured by different indicators (table A2). The crop index is associated at statistically significant levels with the decline in infant mortality in 1801–1850 ($r = 0.36$), and 1825–1974 ($r = 0.47$), and with mortality of the very old in 1801–1850 ($r = 0.29$). As explained almost a century ago by the Swedish demographer Gustav Sundabärg, in the early 19th century, "if the harvest was good, marriage and birth rates were high and death rates comparatively low... when the harvest failed ... death devastated the land, bearing witness to need and privation and at times even to starvation" —cited in [19].

The impact of inflation on mortality during the 19th century (tables A1 and A2, figure A1) may be therefore largely explained by the link between the quality of harvests and the rate of inflation. That link between harvests and inflation weakens throughout the century, and then seems to reassert itself in the first half of the 20th century, when, on the other hand, the connection between harvests and mortality no longer operates (table A2), at least at the strong levels observable in infant mortality and mortality of the elderly up to the 1870s.

In summary, during the first half of the 19th century the Swedish economy was highly dependent on agriculture as proved (table A1) by the degree in which good harvests expanded the economy ($r = 0.31$, $P < 0.05$), diminished the level of prices ($r = -0.38$, $P < 0.01$), and reduced mortality (table A2), for instance of infants ($r = 0.36$, $P < 0.05$) and the elderly aged 70–89 ($r = 0.29$, $P < 0.05$). On the other hand, increases in prices raised mortality less than in 1851-1900 (table 8), probably because the food supply depended little on markets and much more on production for self-consumption. In the second half of the 19th century, the general level of economic activity was less dependent on harvests, probably because of a higher capacity to save food from years of good harvest and the ability to import [19].

Appendix B

Results with other GDP estimates

GDP is always an imprecise measure of the size of the economy, much more so when historical data implying many rough estimates are considered. It could therefore be argued that the pattern of correlations found may be just a figment produced by a series of volume GDP not measuring appropriately the growth of the Swedish economy. However, errors in measurement tend to blur relations between variables, not to create patterns like those found in this investigation. On the other hand, another series of historical GDP values for Sweden is available, though this one, by

Angus Maddison [54], covers the 19th century from 1820 only. The correlation of annual economic growth computed with data from the series by Maddison (who used estimates by Krantz as one of his sources) and GDP growth computed with Krantz's values is 0.59 for all the overlapping years, 1821–1998; for subperiods (table A3), the correlations are stronger as we get closer to the present. Taking into account that the correlations between economic growth rates computed from the two sources are as low as 0.34 in some subperiods, it might be expected that when GDP growth from Maddison data is used for the analysis, the estimates of the economic impact on health will change considerably. That was indeed tested and found (table A3). However, the correlation values, though quite different, reveal a similar pattern of change through the subperiods of the study. With data either from Krantz or from Maddison, economic growth associates positively with health progress in the 19th century, with the association weakening as time passes and switching to negative after 1950.

Table 1. Statistics of the variables in the study period and its half centuries. All numbers are percentages

Variable	Years	Mean	Standard deviation	Minimum	Maximum
Economic growth	1801– *ca.* 1998	2.3	3.5	– 8.9	11.7
	1801– 1850	1.1	3.4	– 7.0	7.0
	1851– 1900	2.3	3.4	– 8.8	11.7
	1901– 1950	3.0	4.2	– 8.9	10.9
	1951– *ca.* 1998	2.6	2.4	– 2.4	8.6
Inflation	1801– *ca.* 1998	2.4	6.5	– 25.0	36.9
	1801– 1850	1.6	5.9	– 10.1	21.3
	1851– 1900	0.7	4.9	– 13.2	12.1
	1901– 1950	2.1	9.3	– 25.0	36.9
	1951– *ca.* 1998	5.4	3.9	– 1.9	19.4
Rate of decline in longevity shortfall	1801– *ca.* 1998	0.9	5.1	– 25.5	18.3
	1801– 1850	0.5	6.4	– 15.3	18.3
	1851– 1900	0.4	5.5	– 14.6	14.3
	1901– 1950	1.4	5.5	– 25.5	18.2
	1951– *ca.* 1998	1.2	1.5	– 1.9	5.2
Rate of decline in infant mortality	1801– *ca.* 1998	2.1	8.6	– 26.8	24.4
	1801– 1850	1.0	11.0	– 26.8	20.6
	1851– 1900	0.8	9.8	– 20.7	24.4
	1901– 1950	3.1	7.1	– 10.6	23.3
	1951– *ca.* 1998	3.7	5.0	– 5.5	14.0
Rate of decline in mortality 15– 24	1801– *ca.* 1998	1.5	13.7	– 82.5	72.5
	1801– 1850	0.5	15.9	– 47.1	44.1
	1851– 1900	– 0.1	10.8	– 38.9	23.9
	1901– 1950	3.6	17.8	– 82.5	72.5
	1951– *ca.* 1998	1.8	7.7	– 10.9	18.8
Rate of decline in mortality 35– 54	1801– *ca.* 1998	1.1	10.0	– 42.8	50.8
	1801– 1850	0.5	15.1	– 33.7	50.8
	1851– 1900	0.9	9.3	– 20.2	28.8
	1901– 1950	1.9	8.9	– 42.8	33.8
	1951– *ca.* 1998	1.2	2.4	– 3.3	7.3
Rate of decline in mortality 70– 89	1801– *ca.* 1998	0.5	7.1	– 18.8	18.8
	1801– 1850	0.7	10.0	– 18.8	18.8
	1851– 1900	0.3	7.7	– 15.6	15.1
	1901– 1950	0.3	6.1	– 11.6	16.3
	1951– *ca.* 1998	0.9	2.6	– 4.5	7.5

Table 2. Parameter estimates of models in which annual health progress, measured as $-\Delta \ln h_t$, is regressed on a constant, time t, economic growth g, and the interaction of time and economic growth, $g \cdot t$. Standard errors are in parenthesis following parameter estimates. For the explanation of the tipping point, see text.

Sample	Health indicator, h	Economic growth, g	Interaction $g \cdot t$	Tipping point
19th & 20th centuries	Longevity shortfall	0.76*** (0.20)	– 0.004* (0.002)	1990
	Infant mortality	0.91** (0.35)	– 0.005 (0.003)	
19th century	Longevity shortfall	0.73* (0.32)	– 0.003 (0.006)	
	Infant mortality	0.86 (0.56)	– 0.000 (0.010)	
20th century	Longevity shortfall	1.55* (0.66)	– 0.009* (0.005)	1972
	Infant mortality	– 0.09 (1.04)	– 0.001* (0.007)	1890
19th & 20th centuries	Longevity shortfall males	0.75*** (0.20)	– 0.004* (0.002)	1988
	Mortality 15-24 males	2.54*** (0.56)	– 0.012* (0.005)	2012
	Mortality 35-54 males	1.49*** (0.41)	– 0.009* (0.003)	1966
	Mortality 70-89 males	0.82** (0.27)	– 0.007* (0.003)	1917
19th century	Longevity shortfall males	0.73* (0.31)	– 0.004 (0.006)	1983
	Mortality 15-24 males	3.44*** (0.74)	– 0.038** (0.013)	1891
	Mortality 35-54 males	1.88** (0.68)	– 0.021 (0.012)	
	Mortality 70-89 males	1.03* (0.48)	– 0.011 (0.009)	
20th century	Longevity shortfall males	1.67* (0.63)	– 0.010* (0.004)	1967
	Mortality 15-24 males	6.22** (2.22)	– 0.036* (0.016)	1973
	Mortality 35-54 males	3.56** (1.12)	– 0.023** (0.008)	1955
	Mortality 70-89 males	0.17* (0.73)	– 0.002 (0.005)	
19th & 20th centuries	Longevity shortfall females	0.77*** (0.21)	– 0.004* (0.002)	1993
	Mortality 15-24 females	1.81** (0.57)	– 0.007* (0.005)	2059
	Mortality 35-54 females	1.73*** (0.41)	– 0.011* (0.004)	1957
	Mortality 70-89 females	0.80* (0.31)	– 0.006* (0.003)	1933
19th century	Longevity shortfall females	0.72* (0.33)	– 0.002 (0.006)	2160
	Mortality 15-24 females	2.00** (0.69)	– 0.013* (0.013)	1954
	Mortality 35-54 females	2.12*** (0.69)	– 0.021 (0.013)	
	Mortality 70-89 females	1.06* (0.52)	– 0.011 (0.009)	
20th century	Longevity shortfall females	1.38* (0.70)	– 0.008* (0.005)	1973
	Mortality 15-24 females	4.36 (2.54)	– 0.025 (0.018)	
	Mortality 35-54 females	2.46* (1.08)	– 0.016* (0.008)	1954
	Mortality 70-89 females	– 0.05* (0.87)	– 0.000 (0.006)	

$^*P < 0.05$ $^{**}P < 0.01$ $^{***}P < 0.001$. Durbin-Watson $d > 2.2$ in all 27 regressions

Table 3. Correlations between health progress and economic growth at lag 0 and other lags, during overlapping half-centuries in Sweden

Years	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
A —Health progress as measured by the relative decline in longevity shortfall ($90 – e_0$)							
1801-1849	0.33*	0.10	0.01	– 0.27	– 0.04	0.08	– 0.17
1825-1874	0.32*	0.26	– 0.16	– 0.31*	– 0.05	0.02	0.09
1850-1899	0.34*	0.16	– 0.21	– 0.14	– 0.23	0.07	0.18
1875-1924	0.32*	– 0.03	– 0.43**	0.15	– 0.06	– 0.15	0.06
1900-1949	0.27	– 0.06	– 0.37**	0.17	0.09	– 0.25	0.10
1925-1975	– 0.05	– 0.28*	– 0.05	0.17	0.25	– 0.17	0.08
1950-*ca.*1998	– 0.10	– 0.24	– 0.02	– 0.21	– 0.10	0.00	– 0.10
B — Health progress as measured by the relative decline in mortality at ages 35-54							
1801-1849	0.36*	0.13	– 0.07	– 0.20	– 0.01	0.01	– 0.10
1825-1874	0.20	0.18	0.02	– 0.35*	– 0.03	– 0.02	– 0.02
1850-1899	0.15	0.11	– 0.04	– 0.17	– 0.16	0.03	0.28
1875-1924	0.32*	– 0.07	– 0.36*	0.13	0.01	– 0.17	0.18
1900-1949	0.27	– 0.09	– 0.30	0.10	0.13	– 0.24	0.09
1925-1975	– 0.16	– 0.42**	0.10	– 0.02	0.31*	– 0.21	0.13
1950-*ca.*1998	– 0.26	– 0.21	0.00	– 0.23	– 0.20	– 0.15	– 0.08

* $P < 0.05$ ** $P < 0.01$

Table 4. Regression estimates of the effect of economic growth on health progress (as measured by the decline in longevity shortfall or in mortality at ages 35-54) in lag models

	Effects on the decline of longevity shortfall							Effects on the decline of mortality 35-54						
	Sample centuries 19 & 20													
	Number of lags included in the regression							Number of lags included in the regression						
	0	1	2	3	4	5	15	0	1	2	3	4	5	15
β_0	0.41***	0.45***	0.42***	0.42***	0.42***	0.42***	0.30**	0.68***	0.73***	0.70***	0.70***	0.70***	0.69***	0.42***
β_1		0.05	0.09	0.08	0.08	0.08	0.11		0.09	0.12	0.10	0.09	0.11	0.10
β_2			–0.19†	–0.19†	–0.20†	–0.20†	0.25†			–0.23	–0.23	–0.23	–0.21	–0.16
β_3				–0.06	–0.05	–0.05	–0.13				–0.22	–0.24	–0.26	–0.49*
β_4					–0.10	–0.10	–0.02					–0.08	–0.05	0.09
β_5						–0.03	–0.06						–0.16	–0.17
β_6							0.06							0.11
	Sample 19th century													
β_0	0.56***	0.64***	0.62***	0.58**	0.58**	0.59**	0.43**	0.98***	1.12***	1.11***	1.02**	1.01**	1.03**	0.49
β_1		0.23	0.27	0.24	0.19	0.19	0.26		0.45	0.50	0.45	0.37	0.40	0.44
β_2			–0.08	–0.09	–0.13	–0.14	–0.26			– 0.04	– 0.09	– 0.11	– 0.15	– 0.01
β_3				–0.21	–0.24	–0.25	-0.45*				– 0.40	– 0.48	– 0.53	–1.08*
β_4					–0.26	–0.26	–0.15					– 0.27	– 0.26	– 0.03
β_5						–0.06	–0.16						– 0.26	– 0.20
β_6							–0.12							–0.08
	Sample 20th century													
β_0	0.25*	0.26*	0.20†	0.19	0.20	0.17	0.08	0.37	0.40*	0.33	0.32	0.32	0.27	0.15
β_1		–0.12	-0.08	-0.05	–0.05	–0.05	0.05		–0.24	–0.18	– 0.17	–0.18	–0.17	–0.03
β_2			–0.33*	-0.34**	-0.35**	–0.33*	-0.35*			–0.41†	–0.42*	-0.40*	–0.36	–0.43†
β_3				0.13	0.13	0.11	0.03				0.05	0.04	– 0.01	– 0.10
β_4					–0.02	0.00	0.14					0.07	0.12	0.29
β_5						–0.15	-0.22						– 0.31	– 0.40
β_6							0.06							0.11

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$

Table 5. Regression estimates of the effect of economic growth on health progress, as measured by the infant mortality, and mortality at ages 15-24, and 70-89

	Sample 19th century							Sample 20th century						
	Number of lags included in the regression							Number of lags included in the regression						
	Dependent variable: decline of the infant mortality rate													
	0	1	2	3	4	5	15	0	1	2	3	4	5	15
β_0	0.79**	0.92**	0.85**	0.80*	0.81*	0.79*	0.45	0.08	0.10	0.03	0.02	0.04	0.05	0.00
β_1		–0.29	–0.26	–0.28	–0.34	–0.34	0.33		–0.06	–0.02	0.03	0.02	0.01	0.17
β_2			–0.44	–0.47	-0.51†	–0.48	-0.67†			–0.40*	-0.40*	-0.42*	-0.41*	-0.37†
β_3				–0.22	–0.24	–0.22	–0.53				–0.29	–0.28	–0.29	0.08
β_4					–0.27	–0.25	–0.07					–0.11	–0.11	0.08
β_5						–0.17	–0.17						–0.05	–0.06
β_6							–0.22							0.20
	Dependent variable: decline of age-specific mortality at ages 15-24													
β_0	1.45***	1.59***	1.51***	1.44***	1.43***	1.45***	1.01*	1.06**	1.08**	0.93*	0.85*	0.85*	0.78†	0.83
β_1		0.46	0.49	0.47	0.33	0.34	0.47		–0.23	–0.11	–0.01	–0.01	0.01	0.16
β_2			–0.46	–0.54	–0.60	–0.62	- 0.83†			-0.87*	- 0.95	-0.95*	-0.91*	-1.15*
β_3				–0.28	–0.39	–0.41	-0.66				0.49	0.49	0.42	0.30
β_4					–0.54	–0.55	-0.06					0.00	0.05	0.25
β_5						–0.10	-0.19						–0.42	–0.43
β_6							-0.02							0.31
	Dependent variable: decline of age-specific mortality at ages 70-89													
β_0	0.51†	0.65*	0.63*	0.58*	0.55*	0.56*	0.33	– 0.10	–0.08	– 0.11	–0.17	–0.16	–0.19	-0.31*
β_1		0.02	0.03	– 0.01	– 0.07	– 0.04	-0.08		–0.14	–0.09	–0.06	–0.09	–0.07	–0.10
β_2			–0.14	-0.14	-0.15	–0.16	0.01			-0.24†	-0.28†	-0.24†	–0.23	–0.23
β_3				-0.29	-0.37	–0.40	-0.60				0.17	0.14	0.11	0.04
β_4					–0.14	-0.11	-0.27					0.18	0.20	0.33
β_5						–0.14	0.08						–0.18	-0.32*
β_6							-0.04							0.17

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$

Table 6. Regression results in models $-\Delta \ln H_t = \alpha + \sum_{i=0}^{k} \beta_{t-i} \cdot g_{t-1}$ in which health progress (as measured by the rate of decline in infant mortality or a sex-specific health indicator H) is regressed on a constant and economic growth g in the same year (k = 0) or lagged up to two years (k = 2) . M and F indicate if the sex-specific mortality used as outcome variable is for males or females, respectively

	19th century, first half				19th century, 2nd half				20th century, 1st half				20th century, 2nd half			
k =	0		2		0		2		0		2		0		2	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Infant mortality rate[1]																
β0	0.80†		0.97†		0.82*		0.78†		0.15		0.11		−0.04		−0.01	
β1			−0.45				−0.13				−0.01				−0.02	
β2			−0.23				−0.31				−0.45†				−0.08	
Longevity shortfall																
β0	0.59*	0.65*	0.78**	0.87*	0.50*	0.58*	0.53*	0.62*	0.37*	0.33†	0.31†	0.25	−0.10	−0.03	−0.04	0.08
β1			0.19	0.23			0.24	0.34			−0.08	−0.05			−0.12	−0.25†
β2			0.27	0.31			−0.31	−0.30			−0.39*	−0.46*			−0.02	0.11
Mortality ages 15-24																
β0	2.68***	1.78**	3.11***	2.17**	0.57	0.98*	0.57	1.11*	1.72**	1.28*	1.55*	1.14†	−0.48	−0.40	−0.57	−0.43
β1			0.31	0.47			0.11	0.67			−0.24	0.10			0.29	0.69
β2			0.34	0.46			−0.69	−1.03*			−0.95	−0.79			−0.65	−1.38†
Mortality ages 35-54																
β0	1.41*	1.81	1.78*	2.20**	0.35	0.44	0.35	0.45	0.71*	0.45	0.60†	0.35	−0.39*	−0.19	−0.34†	−0.10
β1			0.35	0.65			0.31`	0.36			−0.20	−0.17			−0.13	−0.18
β2			0.30	0.32			−0.13	0.06			−0.61†	−0.46			−0.11	0.25
Mortality ages 70-89																
β0	0.88*	0.96*	1.11*	1.15*	0.16	0.11	0.05	−0.01	−0.11	−0.10	−0.18	−0.20	−0.13	0.04	−0.01	0.21
β1			−0.07	0.23			−0.18	−0.13			−0.13	−0.08			−0.01	−0.34
β2			−0.27	−0.24			0.09	0.24			−0.31	−0.44			−0.27	0.17

[1] Infant mortality is the only not sex-specific health indicator in this table.

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$

Table 7. Regression results in lag models $-\Delta \ln H_t = \alpha + \sum_{i=0}^{k} \beta_{t-i} \cdot \Delta u_{t-1}$ in which health progress—as measured by the rate of decline in longevity shortfall *H*—is regressed on a constant and the change in the unemployment rate (Δu_t) in specifications with *k* lags, $k \leq 3$

	1911-1999				1911-1950				1950-1999			
k =	0	1	2	3	0	1	2	3	0	1	2	3
β_0	0.001	0.001	0.003	0.003	0.001	0.001	0.004	0.002	0.002	–0.002	–0.002	–0.002
β_1		0.001	0.000	–0.001		0.001	0.000	–0.002		0.007*	0.009†	0.011*
β_2			0.007**	0.008**			0.008†	0.008†			–0.001	–0.005
β_3				–0.004				–0.005				0.006

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$

Table 8. Regression results in lag models $-\Delta \ln H_t = \alpha + \sum_{i=0}^{k} \beta_{t-i} \cdot \Delta \log d_{t-1}$ in which health progress—as measured by the rate of decline in longevity shortfall *H*—is regressed on inflation as measured by the log difference in *d,* the GDP deflator, in specifications with *k* lags, $k \leq 2$

	1801-1850			1851-1900			1901-1950			1950-1999		
k =	0	1	2	0	1	2	0	1	2	0	1	2
β_0	–0.24	–0.23	–0.21	– 0.48**	–0.26	–0.24	– 0.17*	– 0.41***	– 0.49***	0.00	– 0.03	– 0.02
β_1		–0.08	–0.11		–0.45**	–0.47		0.34**	0.54***		0.04	0.04
β_2			0.01			0.04			–0.19†			– 0.06

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$

Table 9. Correlations between health progress and economic growth both smoothed with centered moving means in periods of 5, 11, and 15 years

		A — Health progress and economic growth both averaged from $t-(k\text{-}1)/2$ to $t+(k\text{-}1)/2$				*B* — Economic growth averaged from $t-k+1$ to t, correlated with health progress at t			
Health progress as measured by the decline in	*k*	1801-1850	1851-1900	1901-1950	1950-1999	1801-1850	1851-1900	1901-1950	1950-1999
Longevity shortfall	5	0.56	0.27	0.17	− 0.49	−0.04	−0.04	0.04	−0.25
	11	0.53	0.00	0.44	− 0.40	− 0.07	0.07	0.07	− 0.15
	15	0.55	0.12	0.37	−0.49	−0.10	0.06	0.01	−0.25
Mortality 15-24	5	0.60	0.18	0.42	− 0.53	0.08	−0.09	0.17	− 0.19
	11	0.63	−0.08	0.54	−0.18	0.04	0.00	0.09	− 0.07
	15	0.63	0.08	0.49	−0.03	0.02	0.01	0.09	− 0.13
Mortality 35-54	5	0.48	0.25	0.14	− 0.48	0.03	−0.06	0.05	− 0.39
	11	0.41	0.00	0.35	− 0.46	−0.02	0.00	0.08	− 0.28
	15	0.50	−0.10	0.31	− 0.37	−0.04	0.04	0.00	− 0.27
Mortality 70-89	5	0.31	0.29	−0.31	−0.24	−0.10	−0.12	−0.02	− 0.06
	11	0.04	−0.02	0.08	−0.16	−0.15	−0.04	0.00	0 06
	15	0.03	−0.03	0.12	−0.19	−0.17	0.01	− 0.05	− 0.02

Table A1. Correlations between economic growth, inflation, and harvest quality

Variables correlated	Period	Correlation
Economic growth and inflation	1801-1850	– 0.76***
	1825-1874	– 0.49***
	1851-1900	– 0.21
	1875-1924	– 0.28†
	1901-1950	– 0.32*
	1925-1974	– 0.25
	1951-*ca.* 1998	– 0.26†
Economic growth and crop index	1801-1850	0.31*
	1825-1874	0.16
	1851-1900	0.08
	1875-1924	0.14
	1901-1950	0.36**
Economic growth and crop index lagged one year	1801-1850	0.64***
	1825-1874	0.52***
	1851-1900	0.56***
	1875-1924	0.50***
	1901-1950	0.13
Inflation and crop index	1801-1850	– 0.38**
	1825-1874	– 0.10
	1851-1900	– 0.23
	1875-1924	– 0.16
	1901-1950	– 0.29
Inflation and crop index lagged one year	1801-1850	– 0.57***
	1825-1874	– 0.35*
	1851-1900	– 0.14
	1875-1924	– 0.31*
	1901-1950	– 0.40**

* $P < 0.05$ **$P < 0.01$ ***$P < 0.001$ † $P < 0.1$

Table A2. Correlations between the general crop index and health progress as measured by different indicators

		Crop index	
Health indicator	Period	Same year	Lagged one year
Longevity shortfall	1801-1850	0.15	0.09
	1825-1874	0.22	0.09
	1851-1900	0.17	0.28†
	1875-1924	0.22	0.12
	1901-1950	0.24	0.02
Infant mortality	1801-1850	0.36*	– 0.06
	1825-1874	0.47**	– 0.16
	1851-1900	0.22	0.09
	1875-1924	– 0.04	0.18
	1901-1950	– 0.09	– 0.08
Mortality ages 15-24	1801-1850	0.18	0.21
	1825-1874	0.13	0.17
	1851-1900	0.00	0.24
	1875-1924	0.21	0.08
	1901-1950	0.25†	0.06
Mortality ages 35-54	1801-1850	0.20	0.15
	1825-1874	0.20	0.06
	1851-1900	0.03	0.11
	1875-1924	0.16	0.04
	1901-1950	0.24†	0.02
Mortality ages 70-89	1801-1850	0.29*	0.12
	1825-1874	0.23	0.19
	1851-1900	– 0.06	0.11
	1875-1924	0.03	0.12
	1901-1950	0.15	– 0.17

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$

Table A3. Correlations between health progress—as measured by the annual progress in three health indicators—and economic growth as computed with GDP data from Olle Krantz [51] and Angus Maddison [54]

	Longevity shortfall		Infant mortality rate		Mortality ages 35-54		Annual rates of GDP growth from the two sources
	Krantz	Maddison	Krantz	Maddison	Krantz	Maddison	
1820-1900	0.27*	0.12	0.22*	0.27*	0.27**	0.19†	0.40***
1901-1999	0.21*	0.12	0.05	0.03	0.20†	0.10	0.77***
1851-1900	0.33*	0.11	0.29*	0.10	0.15	0.13	0.34*
1901-1950	0.27†	0.16	0.09	0.05	0.28†	0.16	0.76***
1951-1999	– 0.11	– 0.11	– 0.02	– 0.05	– 0.32*	– 0.28†	0.84***

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ † $P < 0.1$.

Figure 1. GDP growth, inflation, unemployment (as percent of economically active population), and life expectancy at birth (females, total, and males) in 19th and 20th century Sweden. Except for the line plot for the unemployment rate, all plots are 15-year centered moving averages.

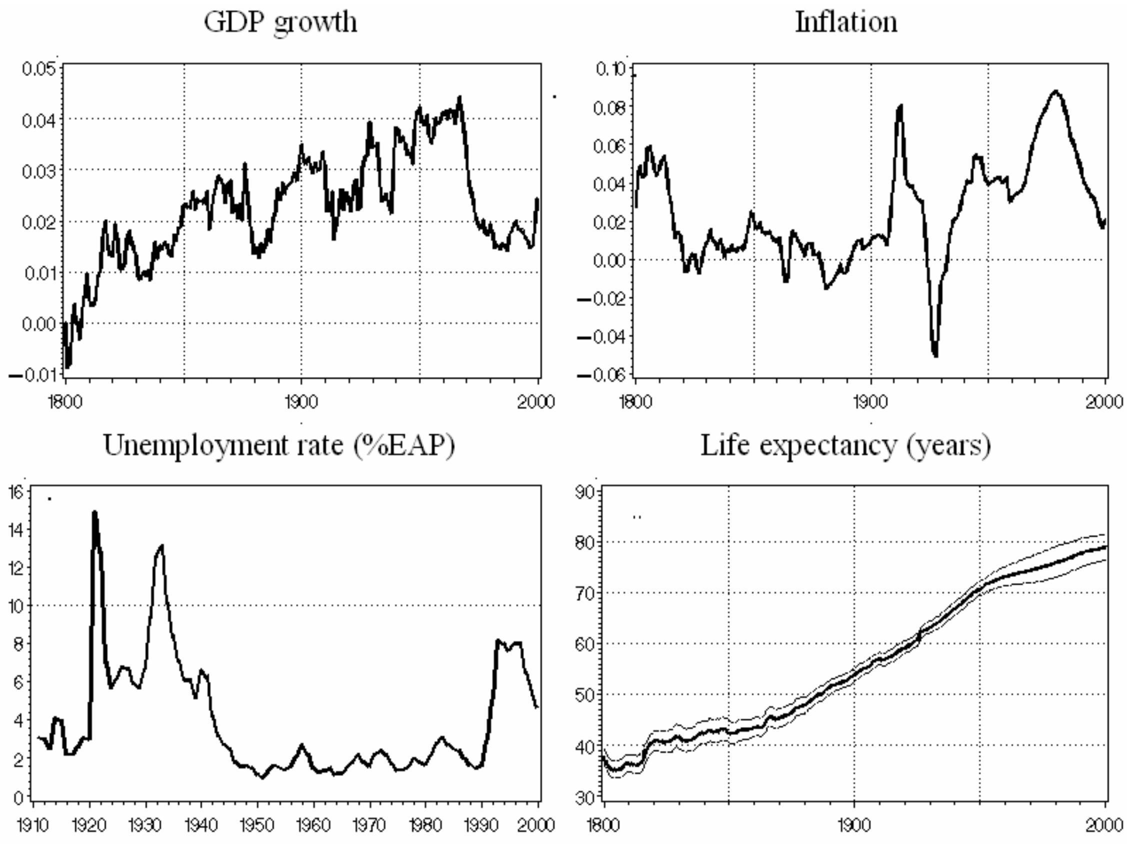


Figure 2. Health progress in 19th and 20th century Sweden as measured by the annual decline in the natural logarithm of four health indicators: the longevity shortfall (the difference between 90 and life expectancy at birth), and age-specific mortality rates at ages 15-24, 35-54, and 70-89.

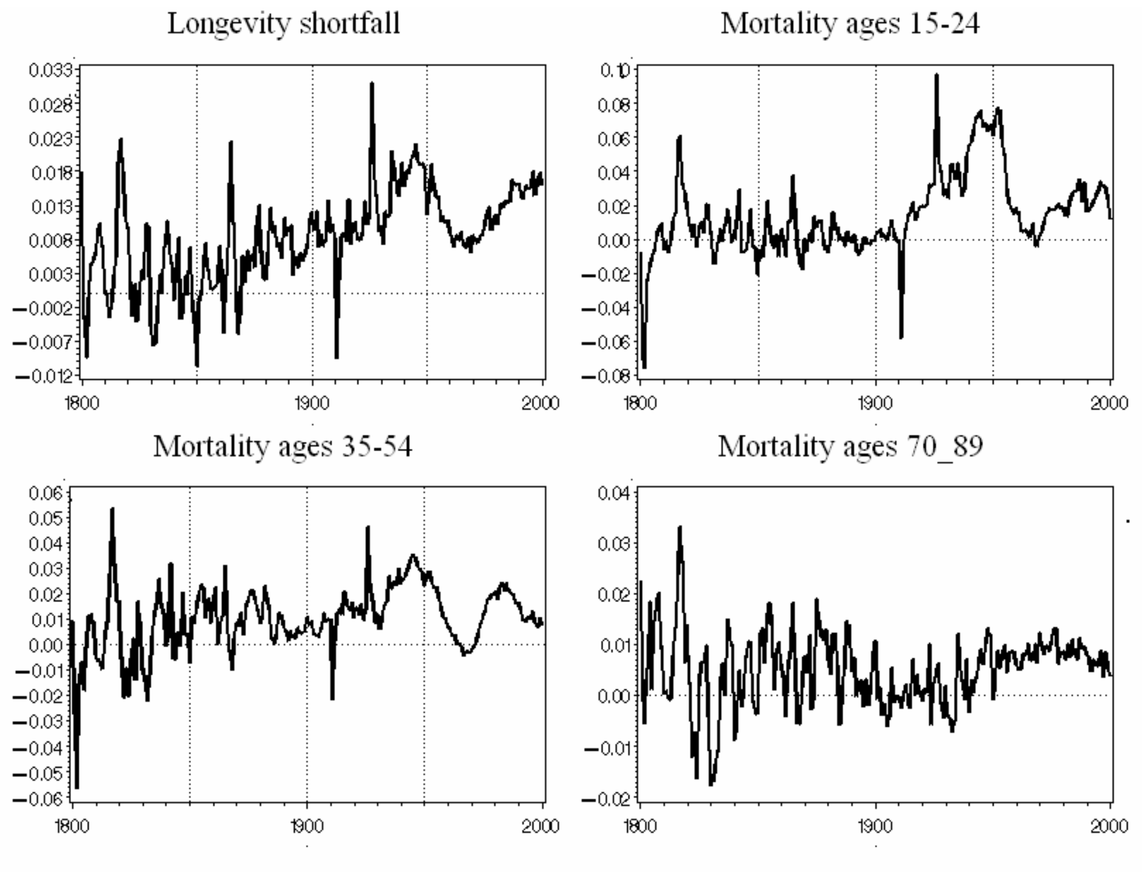


Figure 3. Economic growth (*g,* thick line) and rate of change of mortality at ages 35-54 in 19th and 20th century Sweden. Both variables are transformed into 5-year centered moving means. Scales in percentages.

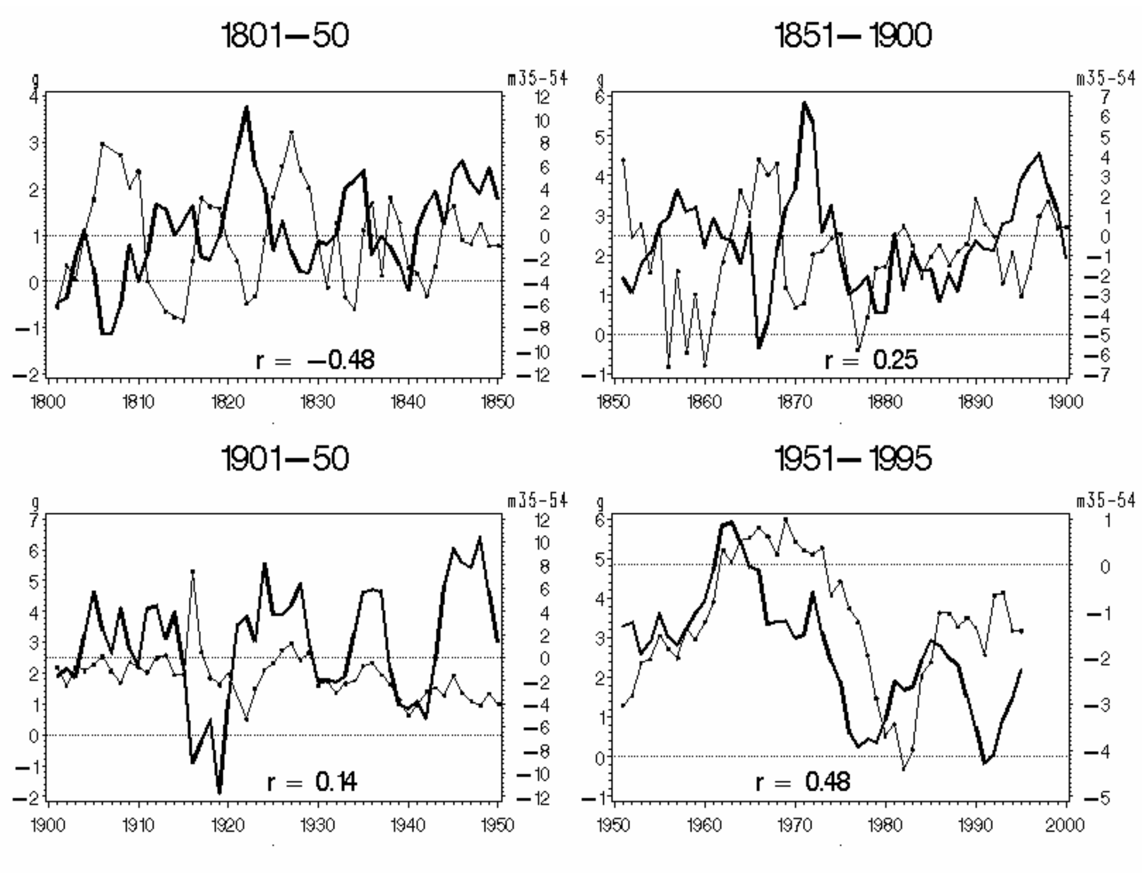
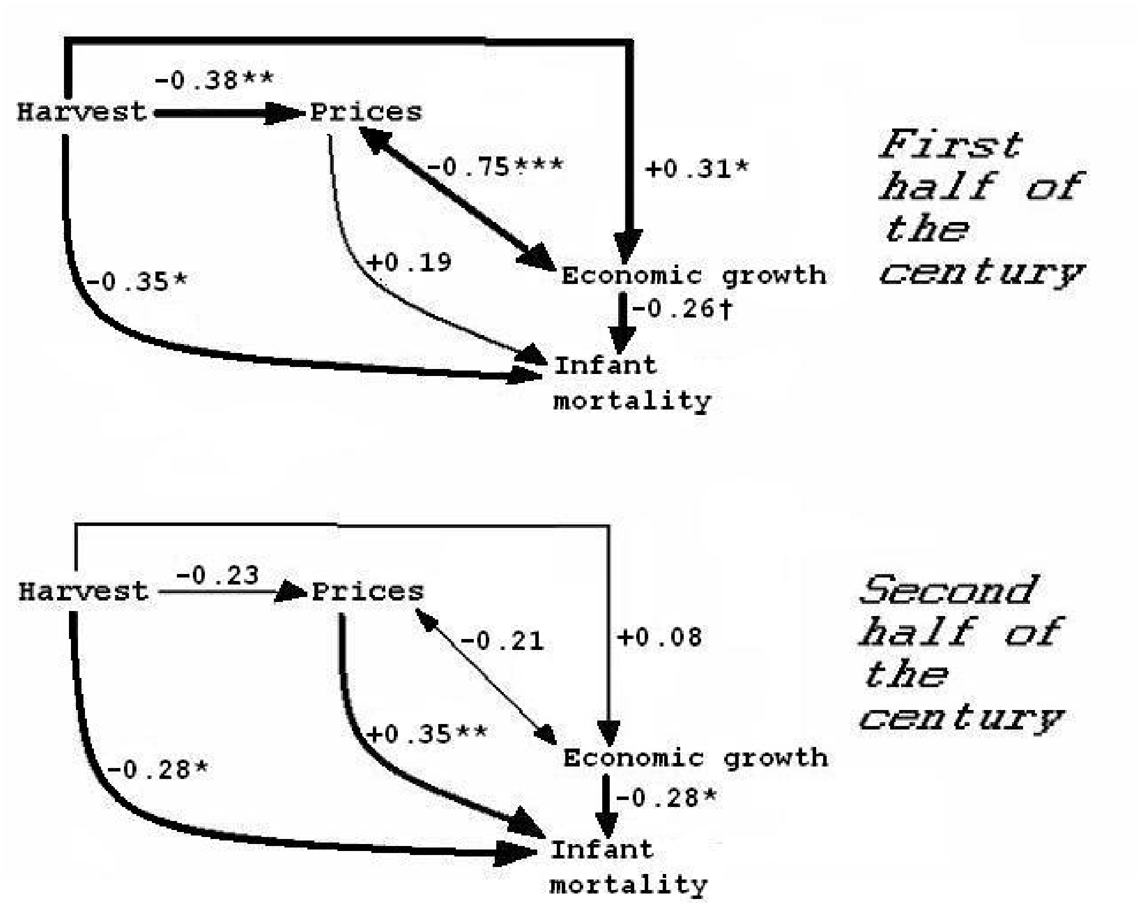


Figure A1. Pathways between harvests, price levels, economic growth, and infant mortality in Sweden during the 19th century. Correlations are computed between annual series of a general crop index in levels (harvest) and the GDP deflator (prices), volume GDP (economic growth), and infant mortality, these three variables in annual rate of change. Thick lines indicate statistically significant correlations.



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