José A. Tapia
The University of Michigan
Institute of Labor and Industrial Relations
1111 East Catherine Street
Ann Arbor, Michigan 48109-0913
USA

Phone: 1-734763-0913
Email: jatapia@umich.edu

Mortality and economic fluctuations in Sweden, 1800 – 1998

Short title: *Mortality and economic fluctuations in Sweden*

JOSÉ A. TAPIA GRANADOS

University of Michigan

Abstract. The analysis of several economic indicators and annual mortality in the period 1800-1998 through cross-correlations, spectral analysis, local regressions and other techniques shows that, in Sweden, from 1800 until the 1880s, mortality fluctuates following quite closely fluctuations of prices, with mortality spurts during peaks of inflation, which follow a bad harvest with a one-year lag. The association of mortality spurts with bad harvests fades after the 1870s, and beginning in the 1890s death rates start to fluctuate with the industrial economy, going up during periods of business expansion and down during recessions. This procyclical oscillation of mortality persists until recent decades, though largely reduced in amplitude after the 1950s. These results are consistent with those of other authors who have shown a procyclical fluctuation of mortality in several industrialized countries. No evidence is found in favor of Brenner's hypothesis that attributes peaks in mortality to lagged effects of previous recession.

Keywords: Sweden; mortality; economic fluctuations; business cycles; demography; spectral analysis; local regression.

1. Introduction

This is a study of the general relationship between the fluctuations of the economy and those of death rates in Sweden during the last two centuries. The short-term fluctuations of mortality as related with the economy are assessed by analyzing through several statistical techniques a number of economic indicators and the 1800-1998 series of the national crude death rate.

The Swedish economy was heavily dependent on agriculture until well into the 19th century. During the last decades of the 19th century and the early 20th century Sweden became a developed industrial economy or, in other terms, a modern capitalist country. A specific purpose of this paper was to look for confirmation of the association between mortality oscillations and harvest conditions previously found by Dorothy Thomas (1941) in Sweden demographic data until the last decades of the 19th century.

Previous work (Ogburn and Thomas 1922; Thomas 1925, Eyer 1977, 1984; Higgs 1979, Ruhm 2000, 2003; Gerdtham and Ruhm 2002; Neumayer 2004) has provided solid evidence of a procyclical link between the expansion-contraction fluctuations of industrial economic activity ("business" or "trade cycles") and demographically significant fluctuations in death rates in Western countries, with the secular decline in death rates being reduced during economic expansions and accelerated during recessions. In this paper this procyclical oscillation of mortality is looked for in Sweden from the start of business cycles associated with industrialization in the late 19th century.

While recent work showing a procyclical oscillation of mortality (Ruhm 2000, Gerdtham and Ruhm 2002; Neumayer 2004) is based on fixed-effect regression models applied to panels of geographical units (provinces, states or countries) throughout a relatively short period of no more than two decades, the present investigation is based on the examination of a long series of national death rates analyzed using spectral analysis, local regressions and cross-correlation techniques. Distributed-lag models were also built to look for specific evidence supporting the Brenner's hypothesis that attributes upturns in mortality coinciding with rapid economic growth to lagged effects of the previous recession.

2. Data and methods

The series of annual crude mortality rates (deaths per 1000 population) from 1800 to the present are available online from Statistics Sweden. As indicators of economic fluctuations for the two centuries, I used four series of annual estimates of a general price index, nominal GDP, volume GDP and volume GDP per capita (Krantz 2002) (see details on data in appendix I). From Thomas (1941), I used two series, a harvest index series (1753-1913) and an industrial investment series (1865-1913). An index of industrial production (available online from Statistics Sweden for the years 1913-2001) and several indices of industrial manufacturing activity—aggregate hours, average hours, employment and output (available online from the US Bureau of Labor Statistics for the last five decades)—were employed for the analysis of the most recent period.

As in most countries of Western Europe, in Sweden crude mortality declined considerably during the 19th and 20th centuries. From levels around 20 to 30 deaths per 1000 in the early 1800s, the death rate declined to levels around 14 per 1000 in the early 20th century, reaching a minimum of 9.4 in 1955. There are however strong deviations from the trend, including for instance peaks of 40.3 in 1809 and 17.9 in 1917—the world influenza epidemics. In the mid-20th century, mortality levels off and starts to increase gradually, revealing the strong dependency of crude death rates on the age structure of an aging population.

Since, in the short-run, age structure can be considered constant, the analysis of the relationships between the economy and mortality using crude death rates is not biased by age-structure changes as long as it refers to the short-term oscillations and not the long-term changes (Bengtsson and Lindström 2000). In this paper, I used series of rates of change of crude mortality or detrended death rates series (see appendix II for details on detrending). Both the rate of change of crude mortality and the detrended series of mortality rates are free from the influence of age, revealing only short-term fluctuations of the death rate.

The three indicators of Swedish national output—nominal, volume and per capita GDP—grew steadily and exponentially throughout the 19th and 20th centuries. The price index oscillated without a clear trend throughout the 19th century, grew later to peak in 1920, dropping until the 1930s, and resuming a steady increase thereafter. When in levels (y_t), the series of these four economic indicators and death rates are non-stationary; in first differences ($y_t - y_{t-1}$) neither they are stationary, because of strong heteroskedasticity. Obvious differences in variance for different time periods are also present when in the detrended series. However the transformation into rate of change (or "percent change", i.e., $[y_t - y_{t-1}]/y_{t-1}$) eliminates heteroskedasticity. The augmented Dickey-Fuller test applied to the five series of rates of change of mortality, price index and nominal, volume and per capita volume GDP rejects the hypothesis of unit roots at the 99% confidence level, so these five series can be quite confidently considered stationary. Variables transformed into "yearly percentage changes" to eliminate trends were also used by Ohlsson and Bengtsson (1984) to analyze Swedish demographic movements with spectral analysis.

Since the series of volume GDP and volume GDP per capita fluctuate almost in perfect parallel (the correlation between annual rates of change in volume GDP and volume GDP per capita is 0.963 for the whole period 1800-1998) and both series rendered almost identical results in the initial steps of the analysis, the per capita series was dropped.

3. General results for the period 1800-1998

3.1. Cross-correlations

The correlations (r_g) between rates of change of nominal GDP, volume GDP and the price index reveal strong associations in the oscillations of these variables. The correlation between nominal GDP and the price index is close to 0.8 or 0.9 ($P < 0.001$) for the whole period and the four 50-year subsamples, proving that growth of nominal GDP is associated to rising prices in all periods until the present. The negative correlation between the price index and volume GDP (table 1) is significant for the whole sample 1800-1998 ($r_g = -0.36$, $P < 0.001$), but it is indistinguishable from zero in two of the four subperiods. Only before 1850 is there an intense association of years of high output in real terms with falling prices ($r_g = -0.75$, $P < 0.001$). In every case the lagged cross-correlations between the three economic indicators (not shown) are weaker than the coincidental correlations. The cross-correlations among detrended series (r_d) provide a similar picture to that described for correlations (r_g) between rates of change.

In the whole sample, the rate of change in mortality is correlated positively with the rate of change in the price index, and negatively with the rate of change in volume GDP at zero lag (table 2, last panel). Correlations between mortality and these three economic indicators are statistically significant and strongest at zero lag during the 19th century. During 1901-1950 they are statistically significant at one-year or two-year lags, but they are very weak or zero at any lag after 1950.

These results show that throughout the years 1800-1950 periods of inflation and deflation tend to be associated with periods of positive and negative change in the death rate, respectively. Similarly, periods with prices above or below its secular trend tend to coincide with periods of mortality above or below its secular trend, respectively. The relationship seems to be strongest for contemporaneous (zero lag) measures during the 19th century and lagged one or two years in the first half of the 20th century. The parallel oscillations of the price index and the death rate are quite obvious in the graph of the two variables during the last decades of the 19th century (figure 1).

In the years 1800-1850 GDP growth is intensely associated with drops in the death rate ($r_g = -0.44$, $P < 0.01$, table 2), and deviations of GDP above its trend are associated with mortality below its trend ($r_d = -0.53$, $P < 0.01$). The negative association progressively weakens between 1851 and 1950, and turns positive though not statistically significant thereafter.

3.2. Spectral Analysis

Spectral analysis can provide evidence on the frequency components of time series and the relationship between different oscillating time series, identifying lagged relationships that might be overlooked when looking at contemporaneous cross-correlations. For the rate of change in mortality series most of the cyclical components in the smoothed periodogram correspond to oscillations with a period around 10 years or just under 10 years. Ohlsson and Bengtsson (1984) also found this death rate oscillation with a period of 10 years in what they called stage II of the Swedish demographic experience, 1800-1869 (see further details on the periodogram analysis in appendix II; the periodograms will be provided by the author on demand).

The smoothed periodograms of the rate of change in prices and nominal and volume GDP also reveal high frequency components corresponding to periods from a few to 15–20 years. In the three series the spectral densities for high frequency oscillations with periods around 10 years or less are much larger in the subsamples 1850-1950 than in the other subsamples. These frequencies correspond to the periodicity usually attributed to business cycles (5 to 11 years, as suggested for instance by Roepke 1937:20-27). The stronger oscillatory component of the series in the period 1850-1950 would be consistent with the emergence of an industrial business cycle in the second half of the 19th century and the reduction of intensity of business cycles after World War II.

The squared spectral coherency of two time series may be interpreted as the proportion of variance that both series share at a particular frequency band. The cross-spectrum of rates of change in mortality and the price index (figure 2) reaches a squared spectral coherency $k^2 = 0.75$ (95%CI 0.66 to 0.85) for business cycle frequencies of around 8 years in the 1851-1900 subsample.[1] Since the periodograms of both series reveal a peak at that frequency, that implies that around 75% of a major business-cycle frequency is shared by the two series. This strongly suggests that one variable is causing the other or that there is a third factor causing both of them.[2]. Squared coherence also peaks at business-cycle frequencies in the other three subsamples, but the corresponding k^2 is 0.56 (95%CI: 0.43 to 0.71) in 1901-1950 and only 0.12 in 1951-1998. The cross-spectra of mortality with either nominal or volume GDP reveal much smaller values of k^2 for business-cycle frequencies, except in the subsample 1901-1950 where the k^2 of nominal GDP with mortality is 0.71 (95%CI: 0.61 to 0.82).

The phase of the cross-spectrum provides information on the degree of overlapping or lead-lag oscillation between the two series (Warner 1998). In the case of mortality and the price index, the phase for frequencies corresponding to a period around 10 years reveal that, with respect to peaks of inflation, peaks in the rate of change in mortality would tend to coincide or lead for one-two years in 1851-1900 and follow one year later in 1901-1950. These results from spectral analysis, with high spectral power for oscillations at business-cycle frequencies in all the series, and very high coherence only

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[1] Since the null hypothesis is $k^2 = 0$, the estimates are statistically significant at the 95% level when the 95%CI excludes zero. The 95% confidence interval (95%CI) for the parameter value of k^2 is computed from tables in Koopmans (1974) and the algorithm in Brockwell and Davis (1991:362-365, 450). The square roots of the 95% confidence limits for k^2 are given by $\hat{k} \pm 1.96 \cdot S \cdot (1 - \hat{k}^2)/\sqrt{2}$, where $\hat{k}$ is the estimate for k, and S is the sum of the squared normalized weights used in the kernel.

[2] The method of concomitant variation, often used in modern epidemiology (Last 2001) was stated as fifth canon to infer causal relationships by John Stuart Mill in *A system of logic*: "Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation" (Mill 1881:287).

between the oscillations of mortality and prices from 1850 to 1950, are quite consistent with those of cross-correlations (table 2).

3.3. Local Regressions

Local regression (sometimes called *loess*) provides a means to study the relationship between variables of non-stationary series (S-P4-GS, 1997). *Loess* models in which detrended mortality is regressed on the detrended series of an economic indicator provides confirmation of the results already presented (see details on *loess* analysis in appendix II).

The estimated regression coefficient relating death rates to the price index obtained from local regressions (figure 3, first panel) is positive and statistically significant at a 95% confidence level between the 1830s and the early 1900s. In the following decades the coefficient is much smaller, though still significant, then becomes indistinguishable from zero. For the *loess* in which mortality is regressed on volume GDP (figure 3, second panel), the coefficient estimate is negative until the early 20th century, statistically significant for most of the 19th century and non significant from the 1880s on. These results, quite consistent with those of cross-correlations and spectral analysis seem to suggest a dampening of the effect of the economy on death rates after the first decades of the 20th century.

4. Links between prices, output, harvests and death rate fluctuations until the early 20th century

The statistical evidence presented shows a clear connection between death rate fluctuations and the fluctuations of the Swedish economy between 1800 and the early decades of the 20th century. In the first half of the 19th century, spurts of mortality coincided with periods of increasing prices, but mortality increases were even more strongly associated with years of real GDP growth below the trend (table 2). In the second half of the 19th century the relation between fluctuations of mortality and real GDP considerably weakens, although death rates continue to be strongly related to prices. This link inflation-mortality persists during the first half of the 20th century, although the relationship between GDP and death rate seems to disappear.[3]

Thomas (1941) proved that in Sweden the harvest was a major factor influencing death rates before the 20th century. Negative correlations of the harvest index with death rates (table 3) show that during most of the 19th century bad harvests were associated with rising mortality one year later. During the period 1800-1840 there is also a strong association between the harvest index and price movements. Years of better harvest than the previous year translate into accelerated growth of volume GDP ($r_g = 0.69$ and $r_d = 0.59$ in 1800-1840), though nominal GDP tends to drop ($r_g = -0.33$ and $r_d = -0.49$),

[3] The $r_g = -0.31$ for the period 1901-1950 between the rate of change in mortality and GDP growth three years before (table 2) is statistically significant at the 95% confidence level and might be interpreted as suggesting a lagged effect of intense economic growth on mortality in that period. However this correlation does not seem to be part of a pattern (correlation coefficients are positive though not significant for both lags of 2 and 4 years), so probably must be interpreted as a chance finding.

probably because of the strong deflation. The effect of harvests on prices and nominal GDP is reduced dramatically after 1840, but there is still a strong association between periods of good harvest and volume GDP growth ($r_g = 0.53$, $P < 0.01$, $r_d = 0.40$, $P < 0.05$). The association of bad or worsening harvests with high or rising mortality and good or improving harvests with low or diminishing death rates is maintained throughout the 19th century, achieving its highest level in the mid-decades of the century, when the correlation between the harvest index and the rate of change in mortality is $r_g = -0.38$ ($P < 0.05$). This impact is not surprising given the large share of population involved in agriculture and subsidiary occupations: 78% of the total Swedish population in 1850 and still 55% in 1900 (Thomas 1941), with GDP composition data (Krantz 2002) proving that "agriculture and ancillaries" made up close to 40% of GDP until the 1870s. Before industrialization the inability to store food over long periods after good harvests generated overconsumption and waste, and seriously limited the reserves that were available to face the food scarcity following bad harvests (Thomas 1941). These periods of overabundance or dearth of food and agricultural commodities translated into dramatic deflation or inflation of prices, respectively (table 3).

Bengtsson and Ohlsson (1985) have shown that up to the mid-decades of the 19th century there was a clear link between real wages and mortality fluctuations, with drops in real wages having a stronger effect on people in working age and the elderly. The influence of real wages on mortality was largely mediated by the outcome of the rye harvest—the major determinant of real wages through its impact on the cost of living during this period (Ohlsson and Bengtsson, 1984). However, the impact of short-term economic stress probably was largely concentrated on mortality in early ages, since the impact on mortality of the aged 55-80 was limited (Bengtsson and Lindstrom 2000). Until the mid-19th century the positive association between price index and mortality and the negative association between real GDP and death rates can be interpreted as being driven by the strong dependence of mortality on harvests, together with the large impact of agriculture on GDP and the dependence of the price level on agricultural output.

From the mid-19th century onward "the standard of living increased in consequence mainly of improvements in agricultural productivity. The old mortality pattern was broken as a result of better nutritional standards" (Ohlsson and Bengtsson 1994). Judging by the relationship between mortality and the GDP deflator (table 2, figures 1 to3), in the second half of the 19th century periods of inflation were clearly associated with spurts in mortality. This connection between inflation and high death rates persists into the first half of the 20th century, despite the fact that the agricultural link explanation seems less and less applicable in the final decades of the 19th century, when industrialization developed quickly. In fact between 1881and 1913 the correlations between the harvest index and mortality become indistinguishable from zero (table 3).

Before World War II, the cycle of inflation-deflation was one of the known characteristics of the business cycle, with inflation developing in the upward swing of the cycle and prices falling with each business cycle contraction (Roepke 1937; Gabisch 1989; Sherman and Kolk 1996). Therefore the association of inflation periods with spurts of mortality during the last decades of the 1900s and first decades of the 20th century can be interpreted as strong evidence of a procyclical movement of mortality during these years. This is confirmed by the relationship between another business cycle indicator (fixed capital investment in manufacturing and mining) and mortality in the period 1865-

1913. The positive correlations of this index of investment in fixed capital with mortality (table 4) prove that in that period peaks and troughs of investment are associated, to a large extent, with peaks and troughs of mortality. The relationship is weak during 1865-1889 but becomes quite strong ($r = 0.48$, $P < 0.01$) during the years 1989-1913, when mortality is correlated with investment in the previous year (see appendix III on Dorothy Thomas's oversight of this).

According to Ohlsson and Bengtsson (1984), in Sweden the connections between economic variables and death rate fluctuations were mostly absent already in the period 1869-1914. However, the association presented above between the fluctuations of the various business cycle indicators and those of mortality leaves no doubt regarding the existence of an association between bad harvests and high mortality until the 1880s, with a procyclical oscillation of mortality arising during the final decades of the 19th century. In the early decades of the 20th century the existence of this procyclical fluctuation of mortality, shown by the strong positive correlations of mortality with price movements and fixed capital investment is also proved by the correlations between mortality and the oscillations of unemployment and industrial production (table 5), as discussed below.

5. Fluctuations of the real economy and mortality in the 20th century

As decades passed there was an intense reduction in the amplitude of the fluctuations of mortality in Sweden. The standard deviation of the detrended series of death rates is 1.49 in 1851-1900, 0.76 in the first half of the 20th century (0.46 discounting the year of the world flu epidemics, i.e. 1918) and only 0.17 in 1951-1998. Were these mortality fluctuations, in spite of their falling intensity, still related to the business cycle? The evidence already presented points to an affirmative answer for the first decades of the 1900s. What about the remainder of the century?

In most industrial countries the association between price movements and business cycles drastically changed during the mid decades of the 20th century. The inflation-deflation fluctuation linked to the traditional trade cycle disappeared, and more or less continuous inflation emerged. In Sweden Keynesianism *avant la lettre* was already orienting economic policy in the early 1930s, in the form of the ideas and practical suggestions of Wicksell, Myrdal, Ohlin, Hammarskjöld and others (Galbraith 1987). After the deflation of the 1920s continuous inflation began in Sweden in the mid 1930s and continued throughout the century.

If there is a relationship between business cycles and mortality fluctuations the disappearance of price fluctuations associated with the business cycle must seriously distort the manifestations of that relationship as shown by money-based economic indicators. This is probably part of the explanation of the different picture shown by the correlations of mortality with the price index and nominal or volume GDP in 1901-1950 and after 1950 (table 2).

Economic indicators that are not money-based, such as unemployment rates or indices of manufacturing or industrial production, offer an alternative to explore the business cycle and its impact on mortality.

Spectral analysis applied to national unemployment rates provides evidence on an associated oscillation in joblessness and death rates. In the years 1911-1998 both detrended unemployment and detrended mortality have peak spectral densities at frequencies corresponding to a period around 10 or 11 years. The corresponding spectral squared coherence of the two series for that frequency is $k^2 = 0.67$ (95%CI: 0.58 to 0.77), and the spectral phase of the cross-spectrum is $\varphi = -2.5$ radians. Since the phase f in fractions of a cycle is $f = \varphi / 2\pi$, we have $f = -2.5/6.28 = -0.4$ and therefore unemployment peaks 4/10 of a cycle—i.e., 4 years— before mortality, for cycles of about 10 years. This implies peaks in unemployment occurring at or slightly before troughs in mortality, i.e., peaks in mortality approximately coinciding or just preceding the lowest unemployment (assuming a symmetrical rise and decline of it along the cycle). Spectral analysis of the series of rates of change in unemployment and mortality provide similar results.

Cross-correlations between unemployment and mortality (table 5) also provide evidence that variations in unemployment are followed by changes in mortality in the opposite direction with a one- or two-year lag. The correlations of an industrial production index with death rates (table 5) suggest that during the 20th century variations in industrial production are followed by variations in mortality in the same direction with a two-year lag.

Results for the second half of the 20th century provide evidence of a weak association of business cycles and mortality fluctuations. Out of four indicators of manufacturing (aggregate hours, average hours, employment and output) available only since 1950, two of them reveal statistically significant correlations with mortality at a 95% confidence level and a third one, shows a significant correlation at a 90% confidence level (see values for r_d in table 6; values for r_g reveal a similar pattern). The periodograms of the detrended series of these three indices show peaks of spectral density at frequencies close to 10 years. Though at these frequencies the cross-spectrum with death rates shows non-statistically significant squared coherences, the spectral phases imply that oscillations of aggregate hours and manufacturing employment are approximately synchronized with death rates while peaks in average hours precede peaks in mortality by some 3 years so that average hours and mortality fluctuate approximately mirroring each other (figure 4).

While the indices of manufacturing aggregate hours and manufacturing employment fluctuate quite in parallel and both have a high correlation with volume GDP at zero lag (table 7), the strongest correlation of average hours with GDP movements is at a two- or three-year lag. Taken together, these relationships suggest that death rates tend to go up in the expansion years of the cycle, when hiring is increasing aggregate hours in manufacturing and reducing both the unemployment rate and average hours in manufacturing.

In summary, spectral analysis and cross-correlations of unemployment and industrial production with mortality provide evidence supporting the procyclical oscillation of mortality from the 1910s to the end of the century. The smaller cross-correlations for period after the mid-century (table 5) indicate a weakening of the procyclical oscillation of mortality in these years. In the period after 1950 cross-correlations at zero- or few-year lags between death rates and economic indicators are statistically significant for two business cycle indicators and marginally significant for the other three, including the unemployment rate ($r_d = -0.28$, P < 0.05, table 5) and volume GDP ($r_d = 0.27$, $P < 0.1$, table 7). It can be concluded that death rates continued fluctuating procyclically with the business cycle during the most recent decades, although the business-cycle associated fluctuation is much weaker than before.

6. The question of lags

An important problem in the analysis of the relationship between economic fluctuations and mortality is the issue of lags. In fact, in the results of major investigations in the field (Ogburn and Thomas 1922; Thomas 1925; Eyer 1977, 1984; Ruhm 2000) there is general agreement on the coincidence of periods of rapid economic growth with spurts of mortality—i.e., a procyclical oscillation of the death rate. However, in a series of papers published in the 1970s and 1980s Harvey Brenner exposed the view that recessions increased mortality with a lag. The Brenner's hypothesis, at least as has been most recently stated (Brenner 1995), attributes the spurt in mortality during rapid economic growth to a long-lagged effect of the previous high levels of unemployment, that would have effects extending for 10 to 15 years later. Though this theory has been strongly criticized, for many it has intuitive appeal because it seems obvious that recession must be bad for health and, therefore, that any relationship between economic growth and mortality must result from the lagged effect of a prior recession.

In Swedish working-age population, Starrin et al. (1990) found a procyclical oscillation of the death rate in the years 1963-1983 for particular causes of death like liver cirrhosis and cardiovascular disease. In modern times, most deaths in industrialized countries are due to chronic diseases that develop over years—though traffic injuries, the third cause of death after cardiovascular disease and cancer, have an "instantaneous" causation. Since in a country like Sweden most deaths correspond to retired people, to think that there is a *direct link* of this fluctuation in mortality to business and working conditions is wrong, though a direct link may exists for particular causes of death such as traffic fatalities and occupational illnesses or injuries. It is an old observation that during business expansions high work-pace, overtime, and increasing business-related and recreational traffic raise the incidence of industrial injuries and traffic fatalities (Kossoris 1939; Arno 1984; Robertsson 1992). However, the model of stress-related mortality that was developed by Eyer (1984) implies indirect economy-mortality relationships that may impact on the whole population and are coincidental or just briefly lagged (figure 5). Alcohol and tobacco consumption increase during economic expansions, also associated with rising levels of overweight and obesity, decreased levels of exercising (Ruhm 2003), reduced levels of sleep (Biddle and Hamermesh 1990), and drops in time and opportunity for social interactions—with the consequent deterioration of social support, a major preventive factor of death (Seeman and Berkman 1988). Direct effects of unhealthy consumption, increased levels of industry- and traffic-related atmospheric pollution, stress-related direct causation of cardiovascular events (Kalimo et al. 1987; Sparks et al 1996; Sokejima and Kagamimori) and indirect effects on immunity and infectious disease (including microepidemics) might lead to the precipitation of death in persons with underlying chronic disease (Kiecolt-Glaser et al 2002). In the US heart attacks in working individuals peak on Mondays (Ruhm 200) and during the first week of the month there is a significant increase of deaths by external causes, circulatory disorders, cancer and other causes (Phillips et al 1999). In Israel, Sunday is the day of the week when there are more deaths among Jews—among Arabs there is no clear pattern (Anson 2000). These patterns prove that the concrete timing of death, even when its underlying cause may be due to chronic diseases, is subject to influences that have a very short lag. These are precisely the lags (up to two years) that spectral analysis or cross-correlograms reveal in these Swedish data for the 20th century.

Cross-correlations of detrended death rates with lagged detrended volume GDP, in each 25-year period between 1800 and 2000 reveal maximum cross-correlations between mortality and lagged GDP for lags never longer than five years, and usually much shorter (table 8). The correlations between detrended mortality and lagged detrended GDP seem to show a pattern of change around the 1870s. In the years 1851-1875 the relationship between economic activity, indexed by the GDP, and fluctuations in mortality is coincidental and strongly negative, probably reflecting, as previously noted, the impact of good/bad harvests on economic growth/slowdown and high/low mortality. However, from the period 1876-1900 onward the relationship becomes positive (with above-trend mortality associated with above-trend GDP), and lagged one or two years. After 1950 this relationship is weakened, although it remains positive and most intense for a one-year or two-year lag.

In cross-correlograms of death rates in the period 1800-1998 with economic indicators lagged up to 50 years, for lags larger than a few years the cross-correlation drops to zero (not shown). The highest correlations are for zero lag or for a short lag of one or two years. For detrended mortality and lagged detrended unemployment the strongest correlation, $r_d = -0.34$, is between unemployment at year $t - 2$ and mortality at time t. In the cross-correlograms of rates of change the strongest correlation of mortality with prior unemployment is that for unemployment lagged three years ($r_g = -0.33$). These cross-correlations are largely at odds with the possibility of the economy having effects on death rates with long lags of 10 to 15 years, as Brenner (1995) maintains.

Support for Brenner's hypothesis of lagged effects of recession on mortality is not provided by local regressions of mortality on lagged economic indicators or by regressions with detrended death rates as the dependent variable and sets of lagged values (from 0 to 15) of detrended volume GDP and GDP deflator as regressors. I also tried regressions with lagged unemployment rates as explanatory variables, including and excluding different sets of variables, in different combinations, and also regressions with the variables in rates of change. For variables with lags over 5 years all these regressions rendered coefficient estimates with *t*-values under 2, except a few cases in which marginally significant coefficients suggested mutually inconsistent long-lag effects of the economy on mortality rates.

In Sweden the largest unemployment rates during the 20th century were present in 1921-1922 and 1932-1934 (figure 6), when joblessness reached levels of 15% and 13%, respectively. If Brenner's hypothesis fits these data, mortality should have deviated above its trend around the years 1931-1937 and 1942-1949. In these two periods mortality oscillated above and below trend, and was in fact *below* its trend most of the time.

7. Conclusion

Variables like GDP or unemployment estimates are largely inaccurate and conclusions based on them have to be viewed with skepticism. However, errors in measurement generating relationships as those shown in this paper are hard to imagine, since measurement errors would very likely dampen any relationship between economic indicators and mortality rates. The relationship between mortality fluctuations and harvest results in Sweden during the 19th century had already been found by Thomas

(1941) and Ohlsson and Bengtsson (1994). The present results confirm previous findings using other indicators and statistical techniques.

In her pioneering demographic work on Sweden, Dorothy Thomas concluded that in the last decades of the 19th and early decades of the 20th century "the welfare of the people was independent of fluctuations in business conditions," because "[economic] depression—unlike harvest failure—brought no consistent increases in the death rate, and in fact, there was no significant correlation [...] and *such insignificant correlation as existed was in the positive direction*" (Thomas 1941:162; emphasis added). It has been shown here that Thomas was right in that the correlation between the economy and the death rate fluctuations was in the positive direction (procyclical), though she was wrong about this correlation being insignificant. Thomas own data and other data used here show that business cycles had a powerful influence on mortality movement in Sweden during the last years of the 19th and early decades of the 20th century, with a procyclical fluctuation that considerably dampened in the period after the World War II. This result is consistent with the one found for recent decades in several Western countries by a number of authors.

Appendix I — Economic indicators

The four series of annual estimates of a general price index, nominal GDP, volume GDP and volume GDP per capita and a series of national unemployment rates from 1911 to 1999 are unpublished data, kindly provided to me by Olle Krantz (University of Umeå). The price index is a GDP deflator, indexed to make the 1910-1912 price level index equal to 100. The nominal GDP is estimated in nominal million Swedish crowns or *kronen*

(SEK), and the volume GDP is the nominal GDP adjusted for the price change and indexed to make volume $GDP_{1930} = 100$, so that, $V = (N/d) \bullet 100 \bullet (d_{1930}/N_{1930})$, where V is volume GDP, N is nominal GDP and d is the deflator.

Appendix II — Details on statistical procedures

Detrended series were computed with the Hodrick-Prescot filter with a smoothing factor $\gamma = 100$, except in the case of the index of investment in fixed capital (table 4). For this index of investment in mechanical equipment in manufacturing and mining (in Swedish *kronen* adjusted by a price index of industrial raw materials), the detrended data where taken from Thomas (1941), who used the percentage deviations from a third degree parabola.

All correlations reported in the paper are product-moment Pearson correlation coefficients.

In the spectral analysis, for the smoothing of periodograms I used a Parzen kernel, a common option. The periodograms did not change much when using triangular, quadratic spectral or Tukey kernels. However the periodogram profile is quite different for different bandwidths of the kernel. After trying different bandwidths I chose a bandwidth $L = 1.2\ [\mathrm{F}(n/2) +1]^{1/2}$, where $\mathrm{F}(n)$ represents the *floor* of $n/2$ (i.e., the largest integer $k \leq n/2$), and n is the number of observations in the series. *Grosso modo,* the bandwidth L of this Parzen kernel is equal to the square root of n, an option that Gottman (1981: chap. 17) considers appropriate, so approximately $L = 12$ for the periodograms of the whole period 1800-1998 and $L = 6$ for the subsamples of 50 years. These bandwidths substantially reduce the number of peaks of the unsmoothed periodogram, but not as much as to render a flat profile.

To check that only long-cycle and trends of the original series (in levels) are removed by the process of transforming the data into rates of change, I used the squared coherence k^2 of the cross-spectra of the two series (levels and rates of change), for different subsamples, as suggested by Bengtsson and Ohlsson (1985). The k^2 of mortality and the rate of change of mortality is very high, around 90%, for high frequencies corresponding to short-period oscillations. The results for the economic indicators, especially for nominal and volume GDP were not so good, implying a considerable distortion of short period oscillations of the variables in levels when the data are transformed into rates of growth.

In the cross-spectral analysis of mortality and the price index, the phase for frequencies corresponding to a period around 10 years reveal values between –1 and 0 radians for the phase of change in mortality by change in the price index for the subsample 1851-1900, and around 0.5 to 0.7 in the 1901-1950 subsample. Since $f = \varphi / 2\pi$, where φ is the phase in radians and f is the phase in fractions of a cycle, these values represent an approximate f in the interval from – 0.16 to 0 cycles in the subsample 1851-1900, and from 0.08 to 0.11 cycles in the subsample 1901-1950. Therefore, with respect to peaks of inflation, peaks in the rate of change in mortality would tend to coincide or lead for one-two years in 1851-1900 and follow one year later in 1901-1950.

For the local regressions I used a window of 51 observations symmetrically weighted from 0.05 to a peak of 13.9 for the 26th observation and back to 0.05 for the

51st observation. The profile of these weights resembles closely that of the Parzen kernel. The series of weights that I used is as follows: 0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 0.9, 1.2, 1.5, 1.9, 2.5, 3.2, 4.0, 5.0, 5.9, 7.0, 8.0, 9.0, 10.2, 11.3, 12.2, 13.0, 13.6, 13.8, 13.9, 13.8, 13.6, 13.0, etc., down to 0.1.

Appendix III — Dorothy Thomas's oversight of the correlation between investment and mortality

For the correlation of her index of investment in fixed capital with mortality (both as deviation from trend), Thomas (1941) reported non-statistically significant coefficients of 0.13 ± 0.14 for the period 1865-1913 and 0.06 ± 0.22 for the subperiod 1893-1913. In my computations with SAS these values are 0.15 ± 0.15 and – 0.01 ± 0.21, respectively—assuming that Thomas' standard error for *r* is computed as in Blalock (1960). Thomas would have found that the weak correlation 0.06 ± 0.22 in 1890-1913 increases to 0.48 ± 0.21 by simply lagging investment one year—*as she had done with the harvest index*. But it is not likely to look much for what you don't want to find. Judging by her publications, Thomas probably was quite troubled by her remarkable discovery (in the 1920s) of mortality going up in "good times."

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José A. Tapia Granados is a researcher and lecturer at the Institute of Labor and Industrial Relations and School of Social Work, University of Michigan, Ann Arbor, Michigan (jatapia@umich.edu).

Table 1. *Coincidental correlations between volume GDP and price index (GDP deflator) in rates of change (r_g). Sweden, 1800-1998*

Time period	r_g
1800-1850	–0.75***
1851–1900	0.21
1901–1950	–0.35*
1951–1998	–0.26
1800–1998	–0.36***

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$.

Table 2. *Correlations (times 100) between three economic indicators and death rates, computed both among detrended series (r_d) and among year-to-year rate of change (r_g) of the variables, for the same year and for the economic indicator lagged up to four years with respect mortality*

	r_d for mortality at year					r_g for mortality at year				
	t_0	t_1	t_2	t_3	t_4	t_0	t_1	t_2	t_3	t_4
1800-1850										
Price index	24	9	–10	6	28	32*	9	–17	5	30*
Nominal GDP	1	–1	–4	10	22	10	6	–1	18	21
Volume GDP	–53***	–24	16	13	–14	–44**	–11	29**	13	–31*
1851–1900										
Price index	46***	–5	–35*	–22	3	38**	–18	–33*	–17	17
Nominal GDP	24	–9	–31*	–23	–9	17	–17	–24	–3	8
Volume GDP	–26	–17	–5	2	–7	–26	–2	12	17	–12
1901–1950										
Price index	30*	51***	47***	16	–2	31*	24	12	0	–12
Nominal GDP	24	49***	51***	8	–9	17	24	25	–13	–12
Volume GDP	– 1	–2	4	–16	–18	–22	–5	23	–31*	6
1951–1998										
Price index	0	– 2	18	–17	–19	–1	8	18	–10	7
Nominal GDP	5	21	21	–4	–14	3	5	23	–13	12
Volume GDP	8	25†	9	1	–7	6	–6	9	– 5	9
1800–1998										
Price index	8	7	5	3	2	27***	7	–6	–2	9
Nominal GDP	1	0	1	1	0	12	5	4	–2	3
Volume GDP	–1	–1	0	–1	–2	–28***	–6	19**	–1	–12

† $P < 0.10$ * $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$.

Table 3. *Correlations (times 100) of a price index (GDP deflator), nominal GDP, volume GDP and death rates, as detrended series (r_d), or in rates of growth (r_g), with a harvest index of the previous year (0 = disaster harvest, 9 = excellent harvest)*

	Price index		Nominal GDP		Volume GDP		Mortality	
Period	r_d	r_g	r_d	r_g	r_d	r_g	r_d	r_g
1800-1840	–68***	–60***	–49**	–33*	59***	69***	–17	–13
1841-1880	–7	–17	9	13	40*	43**	–28	–38*
1881-1913	–16	–16	–12	13	10	34	–18	6

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

Table 4. *Correlations (times 100) between detrended series of death rates and a detrended investment index at different lags of the investment index. Sweden, 1865-1913*

Lag	1865-1913	1865-1889	1890-1913
0	15	20	– 1
1	29*	23	48**
2	25^{+}	20	44*
3	24	24	25
4	12	19	– 9

† $P = 0.087$ * $P < 0.05$ ** $P < 0.01$

Table 5. *Correlations (times 100) of death rates with unemployment rates and an index of industrial production (IPI), as detrended series (r_d), or in rates of growth (r_g), at zero lag and with the economic indicator lagged up to five years. Sweden, years as indicated*

		Unemployment rate		Industrial production index	
Period	Lag	r_d	r_g	r_d	r_g
1911-1955	0	-26	-6	0	– 22
(1914-	1	-30†	5	12	– 13
1955 for	2	-36*	-32*	27†	35*
IPI)	3	0	14	8	3
	4	15	12	-12	–18
1956-1996	0	–17	1	1	0
(1956-	1	–28*	–20	16	4
2000 for	2	–11	–5	24	10
IPI)	3	2	–12	20	12
	4	16	10	1	– 10
1911-1996	*0*	*–24**	*-6*	*0*	*-19†*
(1914-	*1*	*–29****	*2*	*6*	*-10*
2000 for	*2*	*–34***	*-29**	*11*	*31***
IPI)	*3*	*0*	*11*	*6*	*4*
	4	*15*	*12*	*-2*	*-17*

† $P < 0.10$ * $P < 0.05$ ** $P < 0.01$

Table 6. *Correlations between detrended series of death rates and three indices of manufacturing, lagged up to five years. Sweden, 1950-1998*

Lag	Aggregate hours	Average hours	Employment index
0	0.13	–0.37**	0.25†
1	0.17	–0.11	0.20
2	0.31*	0.20	0.24
3	0.12	0.21	0.06
4	–0.14	0.07	-0.14

† $P < 0.10$ * $P < 0.05$ ** $P < 0.01$

Table 7. *Correlations r_d between detrended series of three manufacturing indices, national unemployment rate and death rate with coincidental and lagged volume GDP. Sweden, 1950-1998*

GDP lag	Aggregate hours	Average hours	Employment index	Unemployment rate	Death rate
0	0.74***	0.07	0.74***	–0.70***	0.12
1	051***	0.21	0.59***	–0.67***	0.27†
2	0.04	–0.42**	0.18	–0.42**	0.11
3	–0.31*	–0.38**	–0.19	–0.15	0.0 2
4	–0.39**	–0.25†	–0.30*	0.16	–0.06
5	–0.35*	–0.12	–0.30*	0.34*	–0.09

† $P < 0.10$ * $P < 0.05$ ** $P < 0.01$ *** $P < 0.01$

Table 8. *Correlation* r_d *between detrended series of volume GDP and detrended mortality, for the same year or for GDP lagged up to five years. Sweden, 1850-1998*

Lag	1851-1875	1876-1900	1901-1925	1925-1950	1951-1975	1976-1998
0	–0.46*	0.18	–0.33	0.34^{+}	–0.04	0.18
1	–0.30	0.44*	0.11	0.39^{+}	–0.04	0.45*
2	0.12	0.35^{+}	0.62**	0.09	–0.26	0.25
3	0.32	0.05	0.32	–0.30	–0.06	0.03
4	0.36	0.07	0.30	0.38^{+}	–0.19	–0.03
5	0.06	–0.25	0.39^{+}	–0.12	–0.39†	–0.01

† $P < 0.10$ * $P < 0.05$ ** $P < 0.01$

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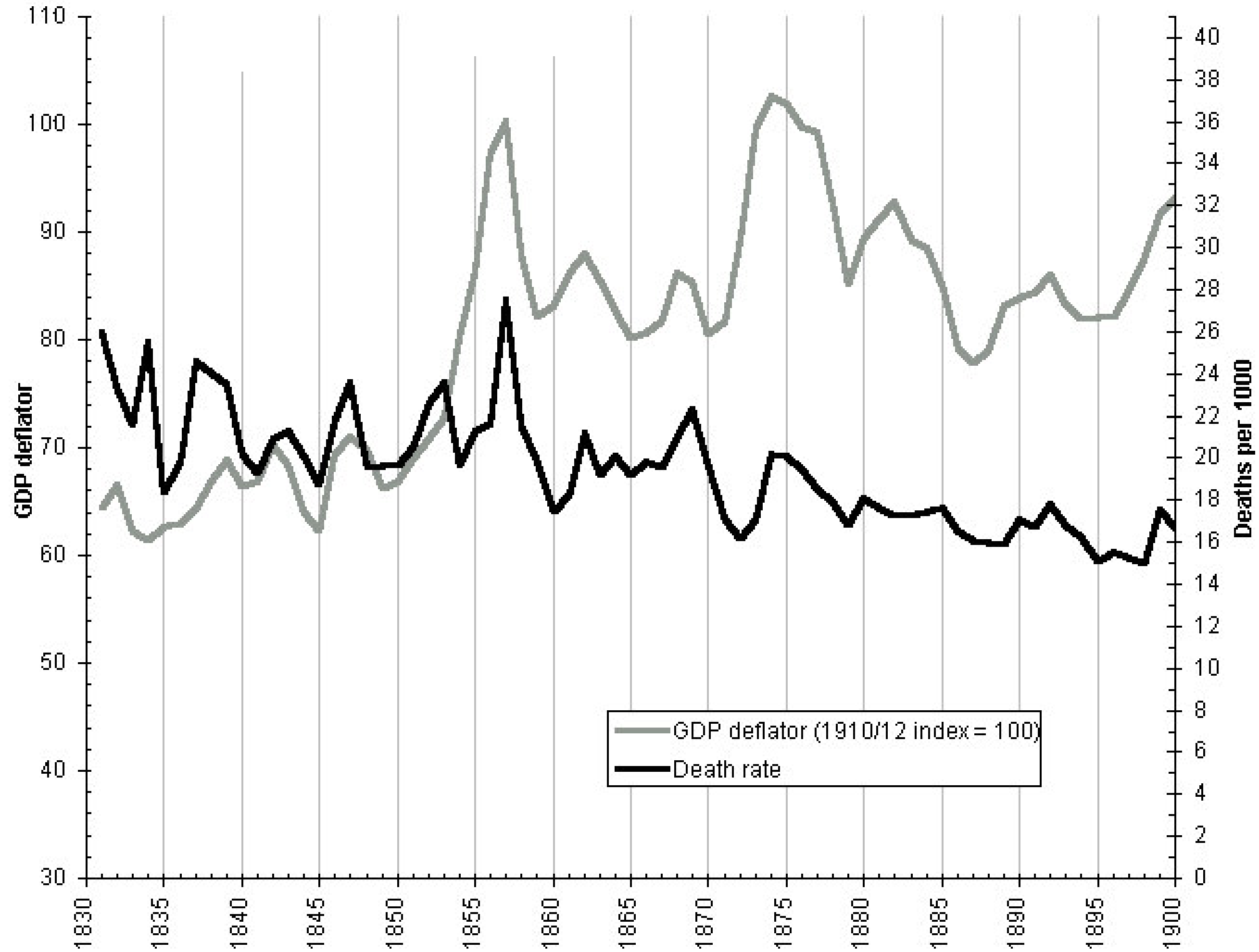
Figure 1. Crude mortality and price index (GDP deflator). Sweden, 1830-1900



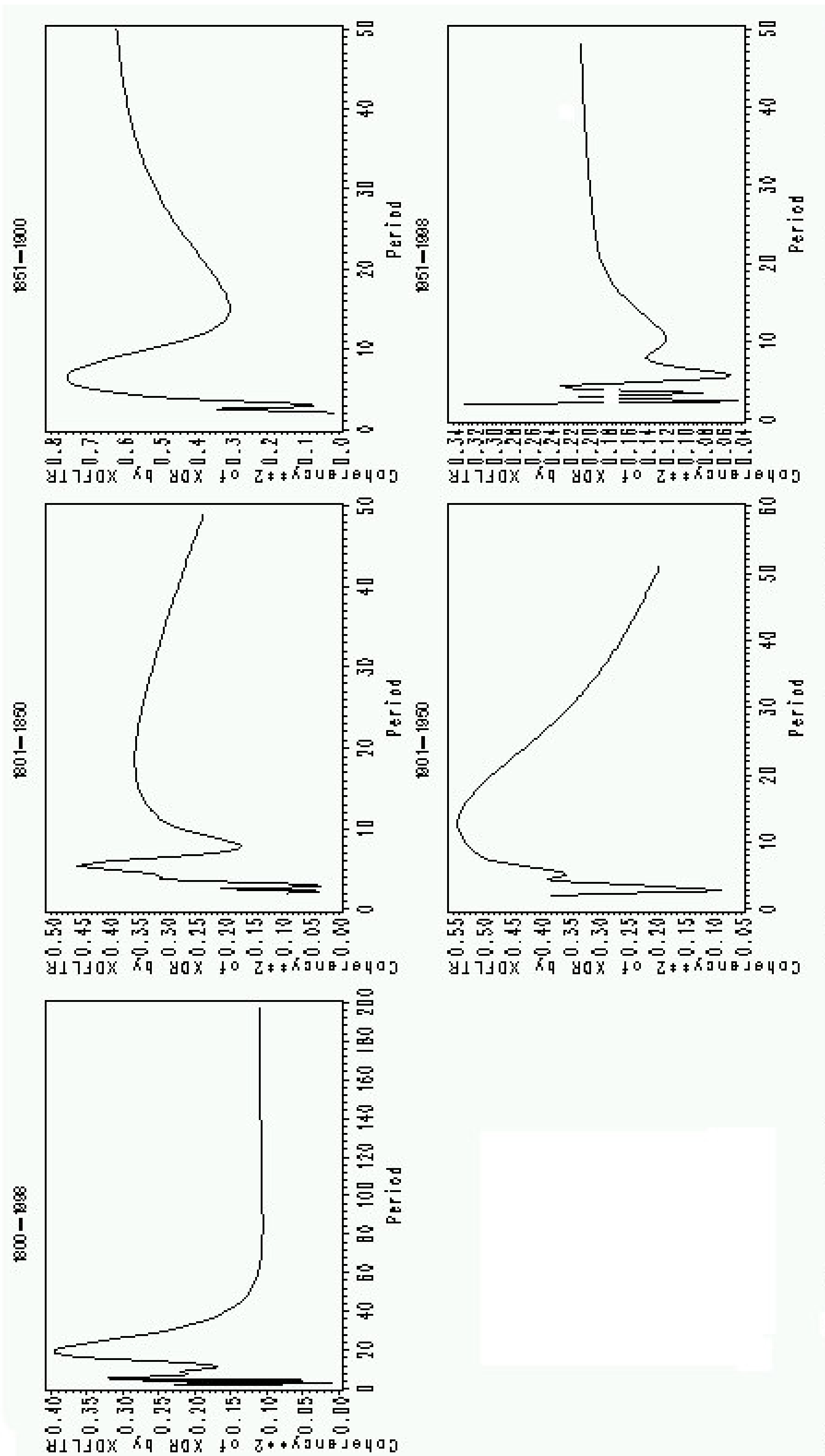


Figure 2. Squared coherence of the cross-spectrum of the annual rate of change in mortality with the rate of change of the price index (GDP deflator). Smoothing with Parzen kernel. Sweden, 1800-1998.

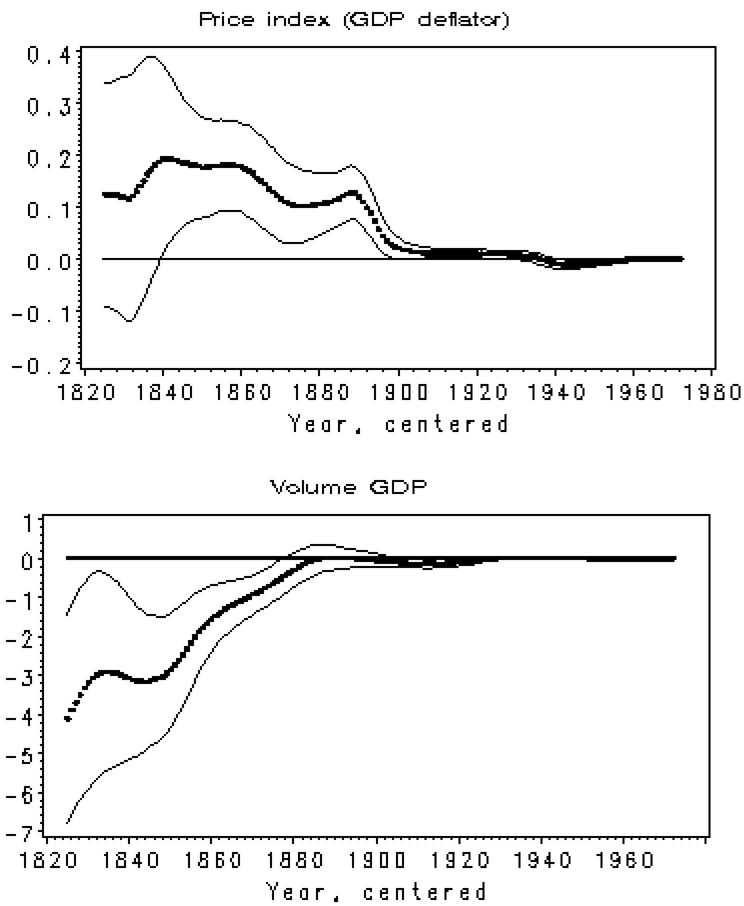
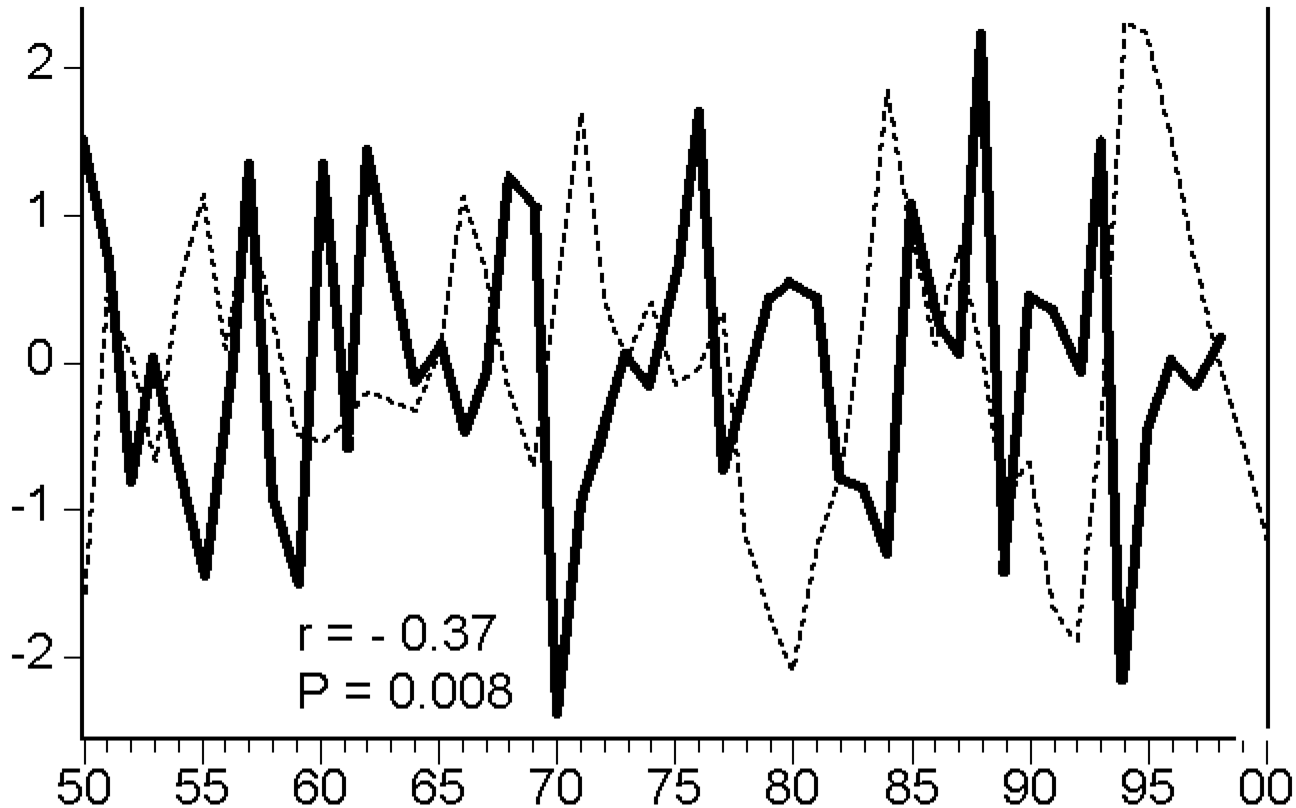


Figure 3. Regression coefficient estimates and 95% confidence bands obtained from local regressions of mortality rates on a price index and volume GDP. All data detrended with the Hodrick-Prescott filter. Local regression window of 51 years, weights Parzen-like. Annual data for Sweden, 1900-1998.

Figure 4. Index of average hours in manufactuting and death rate (solid line), both series detrended with the H-P filter, and normalized. Sweden, 1950-1998



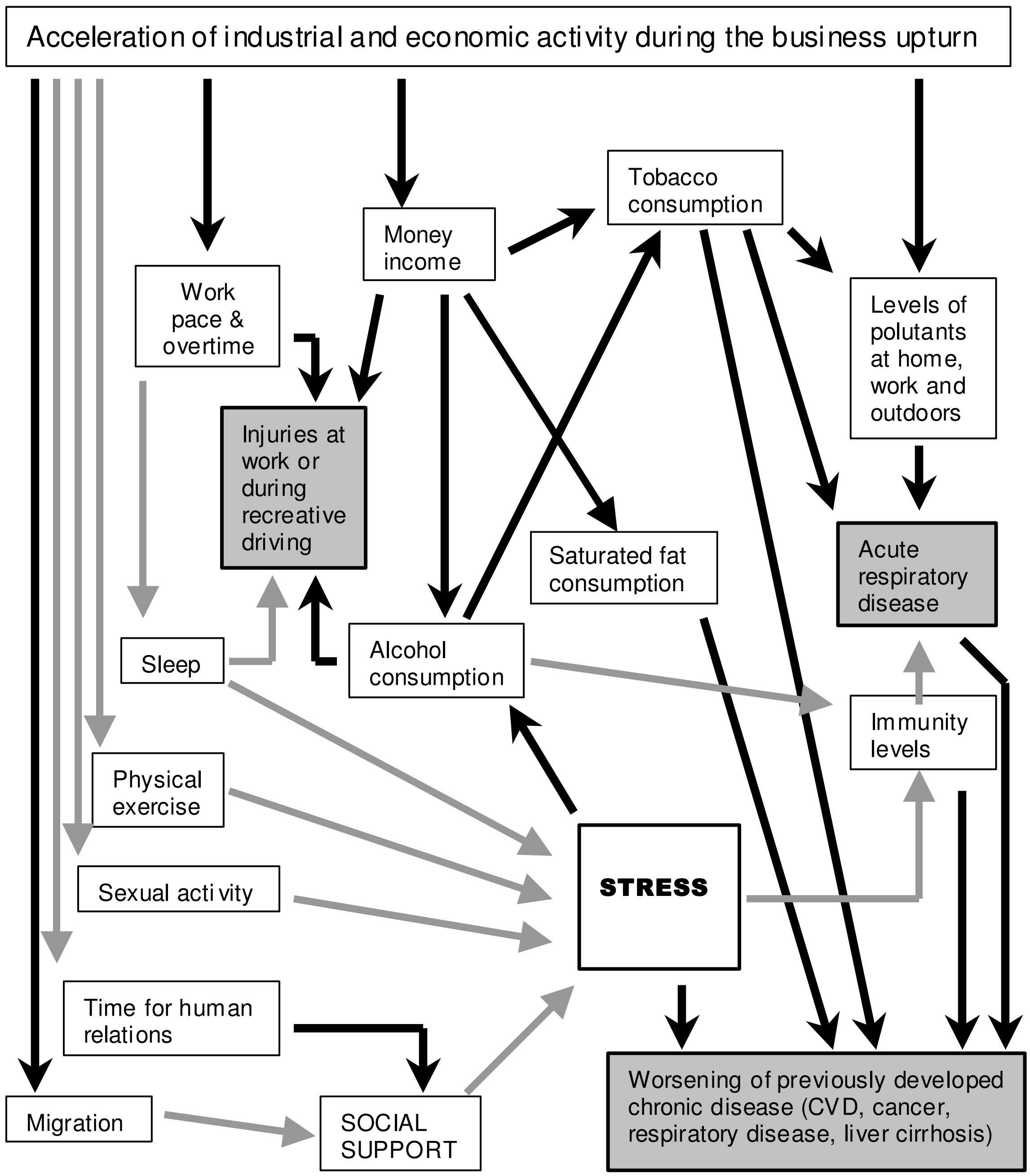


Figure 5. Causal pathways in a stress-mediated model of procyclical mortality. Black thick arrows and thin gray arrows represent positive and negative effects, respectively. For instance, a business upturn increases work pace and overtime which in turn tend to reduce sleep, which raises both injury risk and stress levels, etc. For many of these pathways (most of which, but not all, were proposed by Eyer in the 1970s) there is strong empirical evidence. The three shaded rectangles represent the final steps leading to death—through worsening of a chronic condition, a new acute disease or an injury. Some direct links (e.g. stress increasing tobacco consumption) and bi-directional pathways that are known (for instance alcohol consumption increasing tobacco consumption *and vice versa*) have been omitted to simplify the model.

Figure 6. Death rate (upper black curve, right scale in deaths per 1000 population) and unemployment (lower thick gray curve, left scale in percent of labor force) in Sweden, 1910-1960. The thin line on the death rate curve is a Hodrick-Prescott trend (gamma = 100)