Mortality patterns during crises: Are they different from patterns during normal years? Evidence from 19th century Sweden

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Abstract

Causality is an important but complicated issue not only within social sciences in general but also within economic and historical demography. Here we are dealing with two different, but related, problems of causality. The first is to what extent the impact of food prices on mortality is biased when *selecting* on years with mortality crises. The second concerns the problem of mixing factors that *directly* and *indirectly* have an impact on mortality. Dealing with the first problem, we compare the effects of food prices on child and adult mortality when selecting on mortality crises with a standard approach without selection. When dealing with the second problem we use the *additive hazards model*, in combination with *dynamic path analysis,* which allows for investigating the mediating effect of intermediate covariates in a causal framework. We use individual level data from the Scanian Demographic Database for five rural parishes for the period 1766 to 1865. Data on food prices refers to the local area of these parishes. The statistical analyses are performed in the R statistical computing environment, especially with the aid of the package eha. The main findings are that selecting on mortality crises creates bias in the estimation of the impact of food prices and that the direct effects of food prices are dominating.

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Introduction

Analyses of causes of variations in mortality have basically followed two paths. The first is focusing on years of mortality crises. One question is whether or not these crises are caused by starvation, inflicted by bad harvests or result from market failure. Sen's analyses of the famines in Bengal, Ethiopia, Sahel, and Bangladesh are examples of this approach (Sen 1981, 2001). Analyses of European famines from the sixteenth century onwards (see Walter and Schofield 1989) and of the situation in Warsaw and Amsterdam during the Second World War are other examples (see Livi Bacci 1991). Typical of these studies is the focus on extreme situations. Almost as a rule, only years of excess mortality are selected. Ó Gráda's recent overview of famines all over the world proves the case: out of the twenty-four famines selected, from France in 1693-94 to Malawi in 2002 and Niger in 2005, all but the latter two are associated with excess mortality (Ó Gráda 2009: Table 1.1). Studies focussing on mortality crises have however, short-comings in their analyses of causes since is likely to create a selection bias, as described by Heckman (2008). Their merits are instead *explorative* and in the analyses of consequences.

The second path takes a time series approach, analyzing causes of variation in mortality over a certain period of time, often a hundred years, sometimes more (for an overview, see Bengtsson & Reher 1998). The focus is on testing *hypotheses* of causes of mortality variation such as effects of fluctuations in real wages, food prices, and temperature. Such factors often have a strong time trend as well as a fair degree of fluctuation around this trend. Due to the length of the time periods analyzed, the trend in real wages and food prices itself contains little unique information. The reason is that other factors, such as urbanization and the expansion of schooling and health care, show similar trends, which makes it difficult to establish causality. The focus has therefore been on the effects of the fluctuations of food prices, temperature and other external factors on demographic outcomes. This has been proven very useful since it provides a basis to establish causality as the series after trend removal contains a large amount of variation unique to each of the series.

Numerous studies using the time series approach, based on annual aggregated data from preindustrial populations, show that fluctuations in food prices affect demographic outcomes, particularly fertility, but also mortality and migration (Bengtsson 1993a; Galloway 1988; Lee 1981). The results refer not only to preindustrial Europe but also other parts of the world (Lee 1990; Bengtsson & Reher 1998).

Most of these studies are based on total number of events for the entire population of a certain area, often a country. From an analysis of age-specific mortality for Sweden, we know however, that it was in particular adults and children in ages five years and above that were vulnerable to short-term economic stress (Bengtsson & Ohlsson 1985:317). The mortality among infants seems to follow its own rhythm, likely a result of breastfeeding practices (Bengtsson & Ohlsson 1985:317; Utterström 1957). Not only fluctuations in food prices influence demographic events; cold winters and warm summers also affect demographic outcomes (Lee 1981; Richards 1984; Tromp 1963).

These studies are often estimating distributed lag models with up to five years delay (for other methods, see Bengtsson & Broström 1997). The demographic response was, however, rather instant. A change in food prices typically influence mortality and fertility in the next couple of years, sometimes with a repercussion weaker than the initial impact. Special attention has been taken to the demographic response to extraordinary situations—very high food prices, very low temperature, repeated years of bad conditions—by analyzing thresholds and runs (for example, see Lee 1981). Response patterns of aggregated data may however, conceal great intra-societal diversity in patterns of demographic responses, not only regarding age, as demonstrated by Bengtsson and Ohlsson (1985), but also with respect to other factors, such as socio-economic status and sex.

Advances in data and methods allow for more detailed examination and comparison of demographic responses to economic and environmental pressure. Application of combined event history and time series techniques to longitudinal, individual and household level data allows for identifying demographic responses to changing economic conditions by individual socio-economic and demographic characteristics (Bengtsson 1993b), as well as by household characteristics (Bengtsson, Campbell, Lee et al. 2004). Such analyses show that patterns of demographic responses by socio-economic status, household composition, and individual characteristics to economic fluctuations were diverse (Allen, Bengtsson, & Dribe 2005; Bengtsson, Campbell, Lee et al. 2004; Bengtsson & Saito 2000). The general pattern is that the demographic response is somewhat shorter with no signs of repercussion. The approach also allows for analyses of extreme environmental situations by investigating non-linearity (Bengtsson 2000). This issue was addressed in a recent paper by Bengtsson and Broström (2010), in which the potential effect of both food prices and other external factors, such as temperature, was addressed. One finding was that while food prices affected all age-groups (but infants), temperature and production affected only adults. Another was that while the role of food prices was much stronger than that of temperature and production, it differed between years of mortality crises and all years.

A problem in observational studies is that the interaction between factors at the macro and micro level is not well understood. We know, for example, that mortality for infants and children increases sharply after the loss of a parent. This effect is stronger for infants and stronger if it is the mother who is lost (Bengtsson 2004; for an overview, see Oris, Derosas, & Breschi 2004). We also know that the mortality of both children and parents are affected by external factors, such as food prices. In years of excess mortality, the effects of prices on children might then run two ways; *direct effects* of food shortage and *indirect effects* of losing a parent. In such cases, it is necessary to use methods that avoid the bias that will result from traditional methods based on conditioning. Figure 1 illustrates the problem. Let $X(t)$ be food prices, $Y(t)$ parental deaths, and $dN(t)$ the differential of the counting process, which is child mortality. To be able to address the problem of causality, we have to consider the influence of food prices on parental deaths.

- Figure 1 here -

In order to approach this problem, this paper expands into the area of causal inference (see Hernan, Lanoy, Costagliola, & Robins 2006, and references therein) as well as a dynamic path analyses (Aalen et al 2008).

Context and Data

Longitudinal demographic data on individuals and household socio-economic data have been combined with community data on food prices. The individual level data comes from the Scanian Demographic Database, which covers nine rural parishes and one town situated in Scania in the southernmost part of Sweden. Five of the rural parishes are included in this study: Hög, Kävlinge, Halmstad, Sireköpinge, and Kågeröd. The material for two of the parishes dates back to 1646 and for the others to the 1680s. While the publicly available records end in 1895, we end in 1865 when industrial activities evolved in this part of the country. Our interest in socio-economic position further limits our dataset. The data for the 18th century show some gaps, which is why we chose 1766 as the starting year.

The parish register material is of high quality and shows no gaps for births, deaths, or marriages. Migration records are less plentiful but a continuous series exists from the latter part of the eighteenth century. Information concerning farm size and property rights, in addition to various sorts of information from poll-tax records, land registers, and household examination records, are linked to family reconstitutions based on the parish records of marriages, births, and deaths. Taken together, we have very rich information on the household size and structure as well as socio-economic conditions. In addition, we have good information on food prices and temperature. Data on food prices is available for the local area and refers to the beginning of October. We are using the price of rye, since this was the most common grain in this part of the country (Bengtsson and Dribe 1997).

The selected parishes are compact in their geographical location, showing the variations that could occur in peasant society with regard to size, topography, and socioeconomic conditions, and they offer good source material. Life expectancy at birth follows the same development as the entire country, but is about one year higher (Bengtsson & Dribe 1997; Bengtsson 2004). The entire area was open farmland, except for northern Halmstad and parts of Kågeröd, which were more wooded. Halmstad, Sireköpinge, and Kågeröd were predominantly noble parishes, while freehold and crown land dominated in Kävlinge and Hög. The parishes each had between 400 and 1,700 inhabitants in the latter half of the nineteenth century. The agricultural sector in Sweden, and Scania, became increasingly commercialized during the early nineteenth century. New crops and techniques were introduced. Enclosure reforms and other reforms in the agricultural sector took place on large scale, which is why we split up the study period into two parts, with 1815 as the dividing year. In Kävlinge, the establishment of several factories and railroad communications led to rapid expansion from the 1870s onwards, which is we end in 1865.

Land was the most important source of wealth in these societies. The social structure of the agricultural sector is often difficult to analyze since differences in wealth between various categories of farmers and occupations are unclear and subject to change with the passage of time. Data from land registers on different types of tenure must be combined with information from poll-tax records concerning farm size in order to arrive at a better understanding of each household's access to land. Here we only differentiate between two social groups; (1) the landed, which includes freeholder and tenants on noble land with farms large enough to support a family, and (2) landless, which not only include landless day-labourers and artisans but also peasants with small plots of land, so small that they would have to work outside their farm to be able to support their families. The dividing line between peasants who can and cannot support a family on their land is set to 1/16 *mantal,* based on well-founded arguments from numerous studies in this field of research stating that peasants with smaller farms were not self-supporting (for an overview, see Bengtsson 2004; Bengtsson & Dribe 2005).

The nineteenth century was a period of considerable social change in the countryside. It has been described as a period of proletarization and pauperization. The share of landless increased (Carlsson 1968). Downward mobility was significant since many children of farmers were unable to obtain a farm themselves. This was true both for Sweden in general and for the area we study (Lundh 1998). Not only did the share of the landless strata increase, but their economic situation worsened. They became, for example, more vulnerable to short-term economic stress, as shown by their mortality and fertility responses to food prices (Bengtsson 2000, 2004; Bengtsson & Dribe 2005). What actions where then taken to reduce the negative impact of high food prices?

The Swedish poor relief system involved the state, the county administration, the local community and church, the employer and the family (Skoglund 1992; Åmark 1915). As stated by laws from the 1760s, local communities were obliged to take care of those very poor people that were permanently sick, handicapped or elderly without relatives or former employers to take care of them. On average, only a small fraction (2.1 percent) of the population received parish relief, as shown by a public investigation in 1829 (Skoglund 1992); the figure for Malmöhus County, in which the five parishes in this study are located, was even lower (1.4 percent). The poor relief system at the beginning of the nineteenth century was obviously not designed to take care of large groups of people in temporary need during years of high food prices. Furthermore, the granary system, which was abolished in 1823, was intended to provide loans to producers, not consumers (Olofsson 1996:26). Social tensions grew and efforts were made by the state to create work in years of bad harvests. Finally, a new poor law system was introduced in 1847 (Skoglund 1992; Banggaard 2002) after which time individuals and families could receive some temporary assistance. Before that time, while the poor might be granted a temporary tax exemption, they were not given any direct support (for more details on the area we study, see Banggaard 2002; Bengtsson 2004).

Thus, most families in the area and during the period we study had to rely on themselves when conditions worsened. While farmers with land were able to obtain loans, the situation for the landless was bleak. An alternative was to get help from networks of kin and others, generally available to the families that had been residing for generations in the same parish. Immigrants, consequently, had smaller social networks. Outmigration was not really an option as conditions were similar throughout this part of the country (Dribe 2000) due to the limited size of the industrial sector and the low degree of urbanization.

Famines and Mortality Crises

Various methods have been suggested for identifying mortality crises (for example, see Dupâquier 1989). Here we have simply selected pairs of succeeding years in which the number of deaths was at least 25 percent above the average since the previous crisis, and most often much more. This occurs five times in the period 1766 to 1860 in the five rural parishes in Scania included in this study, namely in 1772/3, 1785/6, 1831/2, 1846/7, and 1852/3. The number of deaths exceeds the 25 percent threshold in a single year in another seven years (Figure 2). In detecting the first crisis years we used data back to 1750.

- Figure 2 here -

While the infant mortality during the seven single year crises was 48 percent above the values for non-crises years, it was only 18 percent above in double year crisis, as shown in Table 1. Instead, children in ages 1-15 year are most vulnerable in crisis years with an excess mortality of between 87 and 101 percent. Mortality in working ages and among elderly is high too in crisis years and more so in double year crises. Although some overlap with mortality in other age-groups did occur, like in 1772/3, 1831/2 and 1852/3, infant mortality often differed not only with respect to its annual changes but also causes of death. While peaks in infant mortality were typically due to outbreaks of smallpox and whooping cough, mortality crises among children and adults were primarily due to various fevers, typhus, pneumonia, malaria (1831/2), scarlet fever (1852/3) and others, several of which have a fatal outcome only for weak persons (Rotberg & Rabb 1985; for a discussion of causes of deaths in Scania, see Bengtsson & Lindström 2003).

- Table 1 here -

Food prices in Scania, known as the granary of Sweden, often peaked, as shown in Figure 3. Sometimes it was due to bad harvests in other parts of Sweden, like in 1797, sometimes to demand from abroad, and sometimes to bad local harvests. From the *harvest evaluations*, which are based on official inspections of the fields prior to the harvests, we know that Scania experienced famines in 1771 and 1783 with dramatically increasing prices as a consequence (Weibull 1923:115).

- Figure 3 here -

While the harvests in the part of Scania we analyze here were below average in 1811, 1826, 1837, 1841, 1842, and 1853, these years should still not be defined as weak years, even less as years of crises (Sommarin 1917, Vol 1:208-211). Thus, the last famine was in 1783. This makes the situation quite different from the rest of Sweden, where four famines occurred during the course of the 19th century, namely in 1812, 1816, 1826, and 1841 (Sommarin 1917, Vol 1:208-211).

To summarize, food prices are higher than during preceding years in double-year mortality crisis, except for 1832 and 1852, but very high prices are also found in numerous years with no crises (Figure 3). Likewise, single year mortality crises sometimes follow high food prices, sometimes not. Turning to other factors that may influence mortality, winters were sometimes colder during mortality crises, sometimes not. It was quite cold in many other years as well, like in the beginning of the nineteenth century, with no excess mortality as a consequence. Overall, the impact of temperature on mortality is weak (Bengtsson & Broström 2010). Thus, the economic and climatic conditions during the five double year mortality crises varied and no common bivariate pattern is easily identified. Conditions in other years were sometimes equally bad without causing mortality to peak. Furthermore, succeeding years of high prices, bad harvests and harsh winters were rare and not systematically related to the mortality crises.

Methods

In the analyses, we use mainly two approaches, first a *proportional hazards model* (Cox 1972). It is very important to check the underlying assumptions behind this model, especially the proportionality assumption. We have therefore routinely tested all models for deviations from the proportionality assumption. The test we have used is based on the correlation between log(t) and the Schoenfeld residuals for each covariate. A high correlation indicates that the corresponding coefficient varies with time; in other words, that the hazards are not proportional (for details, see Therneau & Grambsch 2000:127–152). We found no sign of non-proportionality, neither on any of the covariates, nor globally. The only exception is parish of residence, which we consequently stratify on.

The second approach is the *additive hazards model* (Aalen 1980, 1989), in combination with *dynamic path analysis* (see Aalen et al 2008:354).

The additive model allows for investigating the mediating effect of intermediate covariates in a causal framework. Following Aalen et al (2008:354-6), in Figure 1, the regression coefficient in a standard linear model of Y(t) on X(t) is denoted $\Theta_1(t)$. $\beta_1(t)$ and $\beta_2(t)$ are regression functions in the additive model referred to as the direct effects of X(t) and Y(t) on dN(t). The structural equations corresponding to Figure 1 are:

(1) $dN(t) = (\beta_0(t) + \beta_1(t)X(t) + \beta_2(t)\,Y(t))dt + dM(t)$

(2) $Y(t) = \Theta_0(t) + \Theta_0(t)X(t) + \varepsilon(t)$

The first equation is the classical Doob-Meyer decomposition and in the second, the error term $\varepsilon(t)$ is assumed independent of the martingales, denoted M(t) and X(t). Equations (1) and (2) are estimated by least squares at each t where N(t) = 1. Inserting the second equation in the first yields the marginal equation. The total effect of X(t) on dN(t) is the indirect effects added to the direct effect:

(3) $\text{total effect} = (\beta_1(t) + \Theta_1(t)\,\beta_2(t))dt$

The estimation has been performed using the R statistical computing environment (R Development Core Team 2009). Test of non-linearity for the time-varying community variable (food prices) was done by categorizing, coding them as orthogonal polynomials and including them in the models.

Results

Table 2 shows the effects of food prices on mortality in ages 1 to 15 years controlling for year at birth (to pick up a linear trend), sex, parish of residence and whether the person is born outside the parish of residence or not, for all years. We present the results both for the entire period 1766 to 1865, and the two sub-periods, 1766-1814 and 1815 to 1865. We make separate estimations for the two socio-economic groups, that is, whether their parents belong to the landed group or not. The reason is that we expect the price effects to be different for these two groups. The number of deaths in age-group 1 to 15 years is 1,169.

- Table 2 here -

The parameter estimates for the fixed covariates are much as expected. Being born later lowers mortality with 0.3-0.5 percent per year over the entire period. The mortality among children having in-migrated with their parents is about the same as for those born in the parish with one exception. Children of in-migrated upper socio-economic strata have 10 times higher mortality than those born in the parish in the first period. Few children of upper socio-economic belonging are however, born outside the parish in which they grow up in, which is why the estimated risk, extreme as it is, is still not statistically significant.

The effect of food prices is strong and as expected; the higher the price, the higher the mortality in the next twelve months. Our results are in line with our previous analyses of mortality, fertility, and migration; the group of landless suffered from high food prices in the first half of the nineteenth century, less so in the periods before (Bengtsson 2004; Bengtsson & Dribe 2005; Dribe 2000). A doubling of food prices is followed by an increase in child mortality among the landless of 233 percent in the period 1815-65 (Table 2a). The mortality response of their parents was 244 percent in the same period (Table 2b). The question is then to what extent the children died because food prices went up or because their parents died.

Table 3 shows the results when both food prices and deaths of parents are included in the model. Death of a parent doubles the risk of dying in ages 1 to 15 years for both social groups in the first period, but only for the landless in the second period. The effects of food prices remain the same. However, since mortality among parents also is also affected by food prices, we cannot fully trust these estimates, which is why we apply the Aalen's additive hazards model, and continue along the lines of path analysis.

- Table 3 here -

Using the Aalen approach, the *direct* and *indirect* effects can be separated. In Figure 4, the results of such analyses are shown, where the intermediate covariate is *parental death* when studying the effect of *food prices* on child mortality. Note that the figures display *cumulative time-varying regression coefficients*, which means that we can identify not only whether the effect exists but also during what age-interval. The total effects of food prices are quite strong and influence not only younger ages but throughout the entire age span, with a plateau in ages 3-5 years. The indirect effect is small and not significant and the reason might be that the number of parents dying is small relative to the number of their children dying.

- Figure 4 here -

Turning to mortality crises and food prices again, we have tested for the functional form of the effects in various ways. Here we just display a simple threshold test with a cut point of 0.20. Prices are above this level in about every fifth year. Table 4 shows that indeed, the effect of food prices on mortality among children is non-linear. Same goes for their parents (table not shown). More extended tests shows, however, that while there are some threshold effects, the linear model is quite sufficient (Bengtsson 2004), which is why we refrain from using the non-linear model in our tests how selection on the outcome variable affects the results.

- Table 4 here -

Table 5 shows the effects of food prices on child mortality when selecting on crisis years. First the price effects in double year mortality crises is shown (section a), then in single and double year crises (section b), and finally in all years (section c). Notable is the large difference in the importance of food prices; they have a much higher impact selecting on crisis years than if all years are included.

- Tables 5, 6 here -

For the most vulnerable ones, the children belonging to the lower socio-economic groups, the mortality response to a doubling of food prices is between 280 and 440 percent, depending on whether all crisis years are included or only double year crisis, as summarized in Table 6. When not selecting on the outcome variable, thus including all years, the mortality response is 176 percent. Focussing on the period 1815 to 1865 likewise gives large differences, if not as large as for the entire period. Probablyly, the bias created by selecting on the outcome variable is large, one reason being that all years with high food prices *not* followed by mortality peaks are excluded, in this case about half of them. However, the principle error with this procedure is that conditioning on the future in the Cox regression takes place. The proper way of dealing with this problem is not obvious.

Summary and Discussion

Causality is an important but complicated issue not only within social sciences in general but also within economic and historical demography. Here we are dealing with two different, but related, problems of causality. The first is to what extent the impact of food prices on mortality is biased when selecting on years with mortality crises. The idea of focussing on mortality crises is not only common in historical demography as demonstrated by Walter & Schofield (1989), but also in studies of contemporary crises by Amarthya Sen and others as shown by Ó Gráda (2009). This approach is likely to create a selection bias, as described by Heckman (2008). The question raised in this paper is how big this bias is. The answer is that it is very big indeed. In our analysis of a rural population in pre-industrial Sweden, selecting on mortality crises creates overestimates the impact of food prices with up to a factor of between 160 to 250 percent for lower social strata and around 205 percent for higher social strata. The conclusion is straightforward. One should avoid selecting on mortality crises when analysing its causes. The problem caused by selecting on the outcome variable is not only a theoretical one but a reality.

The second problem of causality, dealt with in this paper concerns the problem of mixing factors that directly and indirectly impact on mortality. From studies both at the macro and micro level, we know that environmental conditions, such as food prices and temperature, had a strong impact both on fertility and mortality in the past. And from micro studies, we know that parents were of outmost importance to the health of their children, since extra-familial resources were few and inadequate. The role of each of these factors is, however, somewhat unclear since environmental conditions might not only influence mortality among children *directly*, but also *indirectly* through the death of their parents. When applying Aalen's additive hazards models to solve this problem, we found that the *direct* effects are totally dominating in this pre-industrial setting.

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References

Aalen, O.O. (1980), A model for non-parametric regression analysis of life times. In W. Klonecki, A. Kozek, & J. Rosinski (Eds.), *Mathematical Statistics and Probability Theory*, Volume 2 of Lecture Notes in Statistics, 1-25.: Springer-Verlag, New York.

Aalen, O.O. (1989), 'A linear regression model for the analysis of life times', *Statistics in Medicine* 7, 1121-1137.

Aalen, O.O., Borgan, O. & Gjessing, H.K. (2008), *Survival and Event History Analysis: A Process Point of View*, Springer, New York.

Allen, R., Bengtsson, T. & Dribe, M. (Eds.) (2005), *Living Standards in the Past: New Perspectives on Well-Being in Asia and Europe*, Oxford University Press, Oxford.

Banggaard, G. (2002), 'Sygdom og Sundhet: Offentlige ingreb og deres virkninger i Sydsverige, c. 1750–1894', Lund Papers in Economic History no. 76, Department of Economic History, Lund.

Bengtsson, T. (1993a), 'A Re-Interpretation of Population Trends and Cycles in England, France, and Sweden, 1751–1860', *Histoire et Mésure* VIII.1, 93–115.

Bengtsson, T. (1993b), Combined time-series and life event analysis: The impact of economic fluctuations and air temperature on adult mortality by sex and occupation in a Swedish mining parish. In D.S. Reher & R. Schofield (Eds.), *Old and New Methods in Historical Demography*, Clarendon Press/ Oxford University Press, Oxford, England/ New York, pp. 239–258.

Bengtsson, T. (2000), Inequality in death: Effects of the agricultural revolution in southern Sweden, 1975–1865. In T. Bengtsson & O. Saito (Eds.), *Population and Economy: From Hunger to Modern Economic Growth*, Oxford University Press, Oxford, pp. 301–334.

Bengtsson, T. (2004), Mortality and Social Class in Four Scanian Parishes. In T. Bengtsson, C. Campbell & J. Z. Lee, et al., *Life under Pressure. Mortality and Living Standards in Europe and Asia 1700–1900*, MIT Press, Cambridge, MA. pp. 37–41.

Bengtsson, T. & Broström, G. (1997), 'Distinguishing Time-Series Models by Impulse Response: A Case Study of Mortality and Population Economy', *Historical Methods* 30:4, 165–171.

Bengtsson, T. & Broström, G. (2009), 'Mortality Crises in Rural Southern Sweden 1766–1860', in Kurosu, S., Bengtsson, T, and Campbell, C. (eds.) (2019), *Demographic Response to Economic and Environmental Crises.* Kashiwa: Reitaku University.

Bengtsson, T., Campbell, C. & Lee, J. Z. et al. (2004), *Life under Pressure. Mortality and Living Standards in Europe and Asia 1700–1900*, MIT Press, Cambridge, MA.

Bengtsson, T & Dribe, M. (1997), 'Economy and Demography in Western Scania', Eurasia Project on Population and Family History Working Paper Series, No. 10, International Research Centre for Japanese Studies, Kyoto.

Bengtsson, T. & Dribe, M. (2005), New evidence on the standard of living in Sweden during the 18th and 19th centuries: Long-term development of the demographic response to short-term economic stress among landless in western Scania. In R. Allen, T. Bengtsson & M. Dribe (Eds.), *Living Standards in the Past: New Perspectives on Well-Being in Asia and Europe*, Oxford University Press, Oxford, pp. 341–371.

Bengtsson, T. & Ohlsson, R. (1985), Population and Economic Fluctuations in Sweden 1749–1914. In T. Bengtsson, G. Fridlizius & R. Ohlsson (Eds.), *Pre-Industrial Population Change. The Mortality Decline and Short-Term Population Movements*, Almqvist & Wiksell International, Stockholm, pp. 277–328.

Bengtsson, T. & Reher, D. (1998), Short and medium term relations between population and economy. In C-E. Núñes (Ed.), *Debates and Controversies in Economic History*, Proceedings of the Twelfth International Economic History Congress, Madrid.

Broström, G. (2011), *eha: Event History Analysis*, R package version 1.3-1.

Carlsson, S. (1968), *Yrken och samhällsgrupper. Den sociala omgrupperingen i Sverige efter 1866*, Almqvist & Wiksell, Stockholm.

Cox, D. (1972), 'Regression models and life-tables (with discussion)', *Journal of The Royal Statistical Society, Series B* 34, 187–220.

Dribe, M. (2000), *Leaving Home in a Peasant Society. Economic Fluctuations, Household Dynamics and Youth Migration in Southern Sweden, 1829–1866*, Almqvist & Wiksell International, Södertälje.

Dupâquier, J. (1989), 'Demographic crises and subsistence crises in France, 1650–1789', In J. Walter & R. Schofield (Eds.), *Famine, disease and the social disorder in early modern society,* Cambridge University Press, Cambridge, pp. 189–200.

Galloway, P.R. (1988), 'Basic patterns in annual variations in fertility, nuptiality, mortality, and prices in pre-industrial Europe', *Population Studies* 42, 275–303.

Heckman, J. J. (2008). 'Econometric causality.' *International Statistical Review* 76, pp. 1-27. International Statistical Institute.

Hernan. M.A., Lanoy, E., Costagliola, D. & Robins, J.M. (2006), 'Comparison of dynamic treatment regimes via inverse probability weighting', *Basic & Clinical Pharmacology & Toxicology,* 98:237-242.

Lee, R.D. (1981), Short-term variation: Vital rates, prices and weather. In E.A. Wrigley & R. S. Schofield (Eds.), *The Population History of England, 1541–1871. A Reconstruction*, Edward Arnold, London, pp. 356–401.

Lee, R.D. (1990), 'The demographic response to economic crises in historical and contemporary populations', *Population Bulletin of the United Nations* 20, 1–15.

Livi Bacci, M. (1991), *Population and Nutrition. An Essay on European Demographic History.* Cambridge: Cambridge University Press.

Lundh, C. (1998), 'Servant migration in the early nineteenth century', *Journal of Family History* 24, 53–73.

Ó Gráda, C. (2009), *Famine. A Short History.* Princeton: Princeton University Press.

Olofsson, J. (1996), *Arbetslöshetsfrågan i historisk belysning. En diskussion om arbetslöshet och social politik i Sverige 1830-1920,* Lund University Press, Lund.

Oris, M., Derosas, R, & Breschi, M. (2004), Infant and Child Mortality. In T. Bengtsson, C. Campbell & J. Z. Lee, et al., *Life under Pressure. Mortality and Living Standards in Europe and Asia 1700–1900*, MIT Press, Cambridge, MA. pp. 359–398.

R Development Core Team (2011), *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. *http://www.R-project.org

Richards, T. (1984), Weather, nutrition and the economy: The analysis of short run fluctuations in births, deaths and marriages, France 1740–1909. In T. Bengtsson, G. Fridlizius & R. Ohlsson (Eds.), *Pre-Industrial Population Change. The Mortality Decline and Short-Term Population Movements*, Almquist & Wiksell International, Stockholm, pp. 357–390.

Rotberg, R. & Rabb, T.K. (Eds.) (1985), *Hunger and History: The Impact of Changing Food Production and Consumption Patterns on Society*, Cambridge University Press, Cambridge.

Sen, A. (1981), *Poverty and Famines: En Essay on Entitlements and Deprivation.* Oxford: Oxford University Press.

Sen, A. (2001), *Development as Freedom*. Oxford: Oxford University Press.

Skoglund, A-M. (1992), *Fattigvården på den svenska landsbygden år 1929*, School of Social Work, Stockholm.

Sommarin, E. (1917), *Det skånska jordbrukets ekonomiska utveckling 1801-1914*, Del I, Skrifter utgivna av Skånska Hushållningssällskapen. Berlingska boktryckeriet, Lund.

Therneau, T.M., & Grambsch, P.M. (2000), *Modeling Survival Data: Extending the Cox Model*, Springer, New York.

Tromp, S. (1963), *Medical Biometeorology*, Elsevier, Amsterdam.

Utterström, G. (1957), *Jordbrukets arbetare*, Tidens Förlag, Stockholm.

Walter, J. and Schofield, R. (eds.), (1989), *Famine, disease and the social order in early modern society*. Cambridge: Cambridge University Press

Weibull, C-G. (1923), *Skånska jordbrukets historia intill 1800-talets början*, Skrifter utgivna av Skånska Hushållningssällskapen. Gleerups, Lund.

Åmark, K. (1915), *Spannmålshandel och spannmålspolitik i Sverige 1710–1830*, Isaac Marcus, Stockholm.

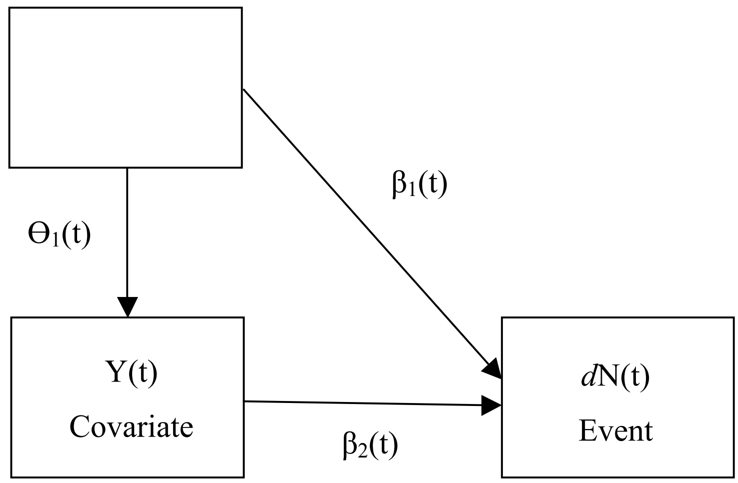

Figure 1. Path diagram for a single jump in a counting process illustrating problems of causality in the presence of an intermediate covariate (Y).

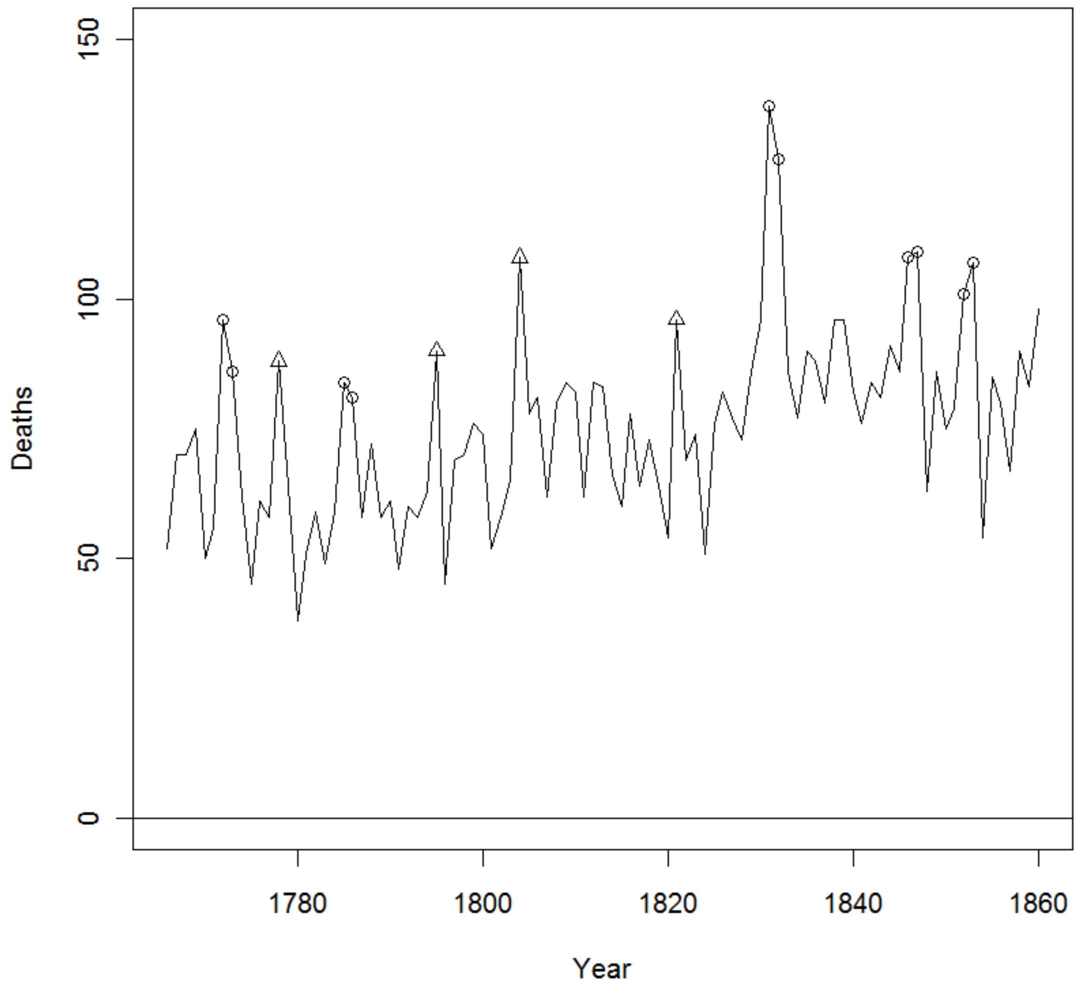

Figure 2. Total number of deaths by year in five parishes, 1766-1865. Circled years are pairs of successive years having very high mortality. Single bad years are marked with a triangle.

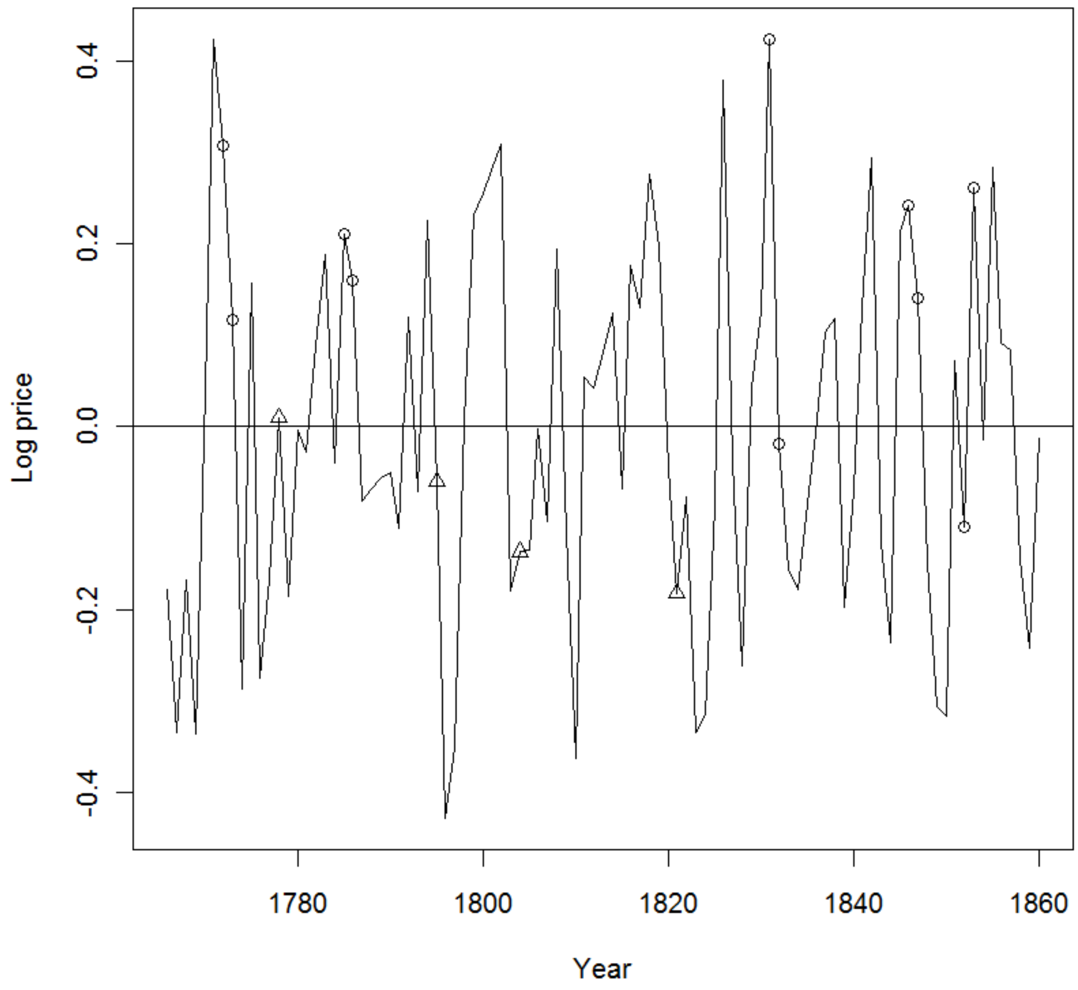

Figure 3. Yearly local food prices, 1766-1865. Logged, detrended prices of rye. Circled years are pairs of successive years having very high mortality. Single bad years are marked with a triangle.

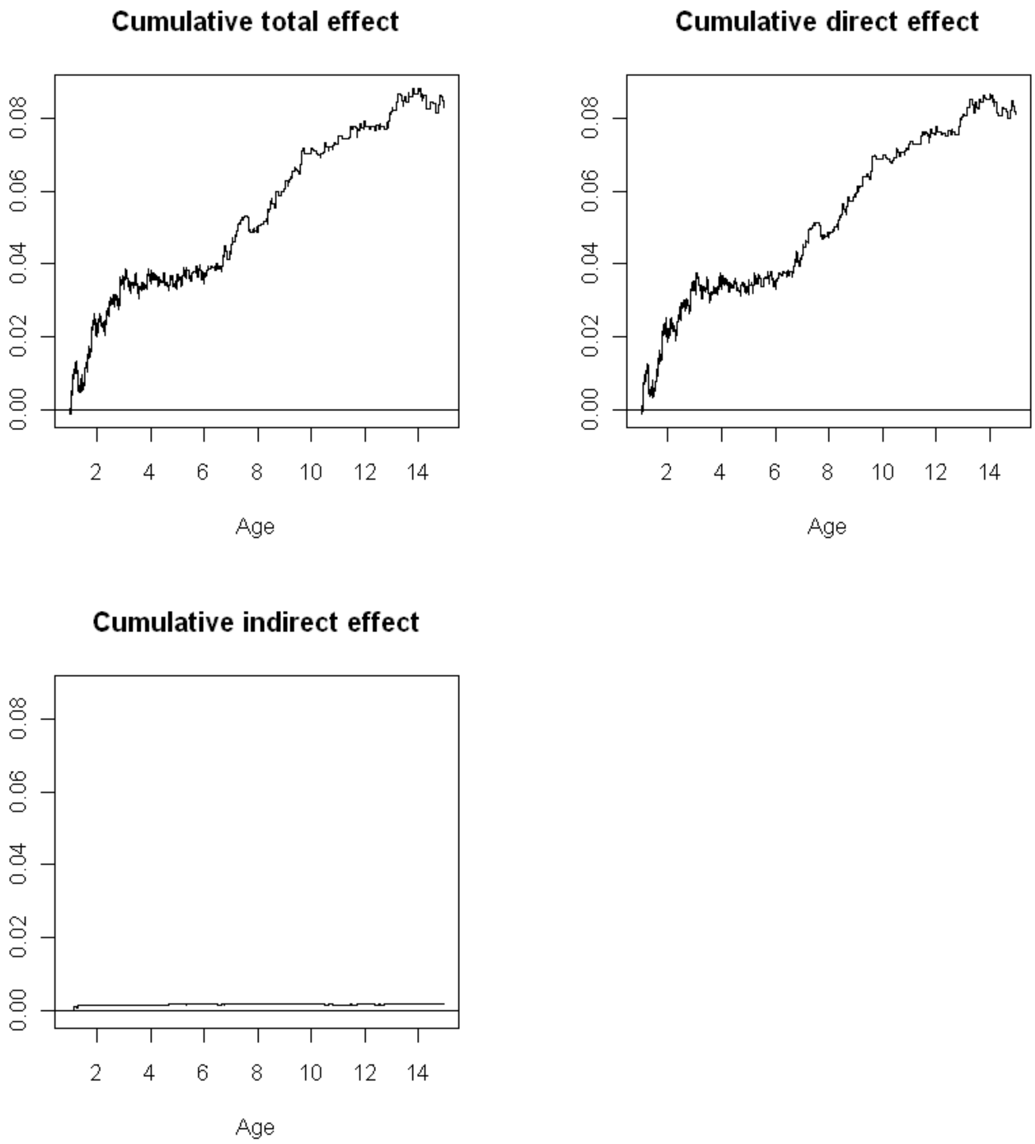

Figure 4. Effect of food prices on mortality, mediated by parent's death. All years.

Table 1. Excess mortality in various age-groups in single and double years of mortality crises relative to other years.

Ages	Single bad	Double bad	Other
0-1	48.4	18.3	23.5
1-15	100.8	87.3	1.2
25-55	42.0	62.3	1.1
55-90	23.3	46.0	5.6

Note: Mortality in single and double bad years is calculated as mortality relative to other years.

Table 2. Effects of food prices, sex, immigration and birth date on mortality for lower and higher socio-economic groups.

a. Children, 1-15 years

	birth date	immigrant	male	food prices	events
lower:(1766-1866)					
relative risk	0.995	1.113	0.931	1.802	722
p-value	*0.001*	*0.490*	*0.337*	*0.002*	
lower:(1766-1815)					
relative risk	0.991	0.855	0.995	1.196	256
p-value	*0.043*	*0.873*	*0.969*	*0.571*	
lower:(1815-1866)					
relative risk	1.001	1.025	0.904	2.326	466
p-value	*0.854*	*0.875*	*0.277*	*0.000*	
upper:(1766-1866)					
relative risk	0.997	0.872	1.084	1.415	447
p-value	*0.128*	*0.760*	*0.393*	*0.151*	
upper:(1766-1815)					
relative risk	0.999	10.212	1.342	2.097	249
p-value	0.773	0.095	0.021	0.024	
upper:(1815-1866)					
relative risk	0.998	0.697	0.806	0.846	198
p-value	*0.746*	*0.456*	*0.131*	*0.644*	

b. Married, 25-50 years

	birth date	immigrant	male	food prices	events
lower:(1766-1866)					
relative risk	0.992	1.305	1.069	1.695	592
p-value	*0.000*	*0.004*	*0.421*	*0.014*	
lower:(1766-1815)					
relative risk	0.987	1.810	1.171	1.094	239
p-value	*0.004*	*0.000*	*0.226*	*0.782*	
lower:(1815-1866)					
relative risk	0.994	1.083	1.016	2.435	353
p-value	*0.117*	*0.490*	*0.882*	*0.002*	
upper:(1766-1866)					
relative risk	0.993	1.137	0.991	1.561	305
p-value	*0.001*	*0.289*	*0.935*	*0.130*	
upper:(1766-1815)					
relative risk	0.993	1.443	1.088	1.760	173
p-value	*0.209*	*0.027*	*0.585*	*0.140*	
upper:(1815-1866)	0.991	0.833	0.872	1.272	132
p-value	*0.141*	*0.324*	*0.433*	*0.602*	

Table 3. Effects of parental deaths, food prices, sex, immigration and birth date on mortality among children in ages 1-15 years for lower and higher socio-economic groups.

	birth date	par.death	migrant	male	food prices	events
lower:(1766-1866)						
relative risk	0.995	2.120	1.131	0.932	1.797	722
p-value	*0.001*	*0.000*	*0.430*	*0.343*	*0.002*	
lower:(1766-1815)						
relative risk	0.991	2.233	0.876	0.998	1.193	256
p-value	*0.042*	*0.021*	*0.893*	*0.986*	*0.577*	
lower:(1815-1866)						
relative risk	1.001	2.082	1.042	0.905	2.318	466
p-value	*0.845*	*0.006*	*0.795*	*0.281*	*0.000*	
upper:(1766-1866)						
relative risk	0.997	2.060	0.884	1.087	1.406	447
p-value	*0.144*	*0.009*	*0.784*	*0.378*	*0.158*	
upper:(1766-1815)						
relative risk	0.999	2.642	10.734	1.347	2.043	249
p-value	*0.838*	*0.005*	*0.090*	*0.019*	*0.029*	
upper:(1815-1866)						
relative risk	0.998	1.412	0.701	0.807	0.848	198
p-value	*0.746*	*0.473*	*0.464*	*0.133*	*0.648*	

Table 4. Threshold effects of food prices, sex, immigration and birth date on mortality among children 1-15 years for lower and higher socio-economic groups. Cut point 0.20.

	birth date	immigrant	male	food prices	events
lower:(1766-1866)					
relative risk	0.995	1.116	0.931	1.260	722
p-value	0.001	0.479	0.336	0.012	
lower:(1766-1815)					
relative risk	0.991	0.864	0.995	1.083	256
p-value	0.045	0.883	0.966	0.627	
lower:(1815-1866)					
relative risk	1.000	1.032	0.904	1.336	466
p-value	0.897	0.845	0.276	0.010	
upper:(1766-1866)					
relative risk	0.997	0.869	1.084	1.232	447
p-value	0.121	0.754	0.394	0.089	
upper:(1766-1815)					
relative risk	0.998	11.733	1.338	1.594	249
p-value	0.732	0.082	0.022	0.003	
upper:(1815-1866)					
relative risk	0.999	0.697	0.806	0.842	198
p-value	0.831	0.456	0.129	0.381	

Table 5. Effects of food prices, sex, immigration and birth date on mortality for lower and higher socio-economic groups in single and double year mortality crises.

a. Children 1-15 years, double year mortality crises

	male	food prices	events
lower:(1766-1866)			
relative risk	1.091	4.397	153
p-value	*0.593*	*0.003*	
lower:(1766-1815)			
relative risk	1.102	69.485	25
p-value	*0.815*	*0.004*	
lower:(1815-1866)			
relative risk	1.108	3.220	128
p-value	*0.564*	*0.028*	
upper:(1766-1866)			
relative risk	1.094	2.858	64
p-value	*0.723*	*0.193*	
upper:(1766-1815)			
relative risk	1.283	2.635	30
p-value	*0.506*	*0.436*	
upper:(1815-1866)			
relative risk	0.890	2.991	34
p-value	*0.737*	*0.317*	

b. Children 1-15 years, single and double years mortality crises

	male	food prices	events
lower:(1766-1866)			
relative risk	1.059	2.798	192
p-value	*0.692*	*0.009*	
lower:(1766-1815)			
relative risk	1.003	2.366	54
p-value	*0.990*	*0.199*	
lower:(1815-1866)			
relative risk	1.090	3.119	138
p-value	*0.613*	*0.021*	
upper:(1766-1866)			
relative risk	0.994	2.231	95
p-value	*0.976*	*0.142*	
upper:(1766-1815)			
relative risk	0.998	2.859	54
p-value	*0.995*	*0.127*	
upper:(1815-1866)			
relative risk	0.941	1.795	41
p-value	*0.847*	*0.517*	

c. Children 1-15 years, all years

	male	food prices	events
lower:(1766-1866)			
relative risk	0.936	1.763	722
p-value	*0.374*	*0.003*	
lower:(1766-1815)			
relative risk	0.989	1.154	256
p-value	*0.930*	*0.653*	
lower:(1815-1866)	0.903	2.325	466
p-value	*0.274*	*0.000*	
upper:(1766-1866)	1.082	1.392	447
p-value	*0.406*	*0.172*	
upper:(1766-1815)			
relative risk	1.342	2.100	249
p-value	*0.021*	*0.024*	
upper:(1815-1866)			
relative risk	0.805	0.851	198
p-value	*0.127*	*0.656*	

Table 6. Summary of effects of food prices in mortality crises and in all years.

	double crises	all crises	all years
lower:(1766-1866)			
relative risk	4.397	2.798	1.763
p-value	*0.003*	*0.009*	*0.003*
lower:(1766-1815)			
relative risk	69.485	2.336	1.154
p-value	*0.004*	*0.199*	*0.653*
lower:(1815-1866)			
relative risk	3.220	3.119	2.325
p-value	*0.028*	*0.021*	*0.000*
upper:(1766-1866)			
relative risk	2.858	2.231	1.392
p-value	*0.193*	*0.142*	*0.172*
upper:(1766-1815)			
relative risk	2.635	2.859	2.100
p-value	*0.436*	*0.127*	*0.024*
upper:(1815-1866)			
relative risk	2.991	1.795	0.851
p-value	*0.317*	*0.517*	*0.656*

Note: Summary of Table 5.