The Long-Term Consequences of Exposure to Famines Early in Life: the Health and Socioeconomic Effects of the Dutch 1944-1945 Hungerwinter

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Abstract

This paper uses the famine in the Netherlands during the winter of 1944-1945 to analyze effects of early-life malnutrition on life-course health and socioeconomic outcomes. The well-defined longitudinal and regional variation in famine intensity and both the richness and size of the data allow us to investigate the mechanisms underlying the long-term causal effects of early-life nutrition. The analysis is based on unique historic information of disaggregated consumption levels and register data covering the entire Dutch population. Results show adverse effects of the famine on later life hospitalization rates for both genders. However, we do not systematically find long-term negative effects on income, disability and marital status.

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1 Introduction

This paper analyses long-term effects of early-life malnutrition on health and socioeconomic outcomes by using exogenous variation generated by the Dutch 1944-1945 famine. 65 Years later, this unique natural experiment and exceptional register data, that cover the entire Dutch population, permit us to identify the causal links between early-life caloric restrictions and later-life outcomes.

A growing literature focuses on the determining role of early-life conditions for late-life health and socioeconomic outcomes. Evidence suggests that old-age health is programmed in the fetal stage (Barker 1995). This finding is also confirmed by animal studies (Ozanne and Hales 2004). Furthermore, multiple economic studies find effects of early-life conditions on life-course health and socioeconomic outcomes, see e.g. Van den Berg et al. (2006), Almond (2006) and Chay et al. (2009). However, research focusing on the causal long-term effects of early-life nutrition is up till now scarce, since exogenous variation in initial nutrition is rare and there is a lack of data that covers a sufficiently long time interval. Finally, famines are generally accompanied with poor administrative systems.[1]

The following features of this so-called Hungerwinter are beneficial for its use as a quasi-experiment: first, both the start and the end of this famine had an abrupt and unanticipated nature. The main food shortages also only lasted for four months. Moreover, these shortages merely were a distributional problem between parts of the country, generating variation in the famine's intensity by region, next to the variation over time (Trienekens 1985). Furthermore, the Dutch population was well fed before and afterwards and the public health was among the best of the world (Banning 1945). Finally, the Hungerwinter is well documented, providing detailed information on, for instance, regional (infant) mortality rates and food consumption (Stein et al. 1975).

This is the first study to assess the long-term impact of this famine on health and socioeconomic outcomes of the whole Dutch population.[2] Moreover, our data contains unique information on disaggregated consumption levels, i.e. the daily caloric values of the official food rations, enabling us

[1] Most reseach is based on proxies for the early nutritional environment, such as birth weight. Correlations between initial nutrition and later-life health outcomes are found by most studies (Van den Berg et al. 2007). See Doblhammer (2004) and Koletzko et al. (2005) for reviews. Furthermore, we refer to Curry and Almond (2010) for a survey of the economic literature on the long-run effects of early-life conditions.

[2] Epidemiologic studies, like Roseboom et al. (2006). and Lumey et al. (2007), rely on subsamples of individuals born in famine-affected hospitals and focus on health outcomes.

to make inferences on causal links between initial nutrition and later-life outcomes.[3]

Our analysis is based on register data covering the entire population of the Netherlands, including over 1.6 million births in the period 1941-1949. First, we merge databases of municipalities, tax files, social security records, hospital records and death registers covering the period 1999-2006. Then, the locations and dates of birth are identified and the probabilities that someone has a job, is entitled to disability benefits, has been hospitalized or has deceased are constructed. Finally, this information is combined with historic information on centrally organized food rations, black market prices and regional (infant) mortality rates.

The empirical analysis consists of the following parts. First, the mean outcomes of the treatment cohorts, who are exposed in the first two years of life or prenatally, are compared with the post-famine born control group. Beforehand, we expect to find the most pronounced effects for the fetally exposed individuals, given the estimated importance of the in utero environment.[4] Then, we graphically analyze whether the outcomes of the treatment groups deviate from the cohort trends. At last, both the between and within cohort variation is exploited and the outcome variables are regressed on indicators of the famine intensity, while adopting individual specific controls, like age, province of birth, month of birth, urbanization level and contemporaneous macroeconomic conditions.

The descriptive analysis points at adverse effects of the famine on later-life income, disability and hospitalization rates. Furthermore, the analysis using both the between- and within-cohort variation in famine intensity, also indicates effects of exposure to the famine in the earliest stages of life on the amount of later-life hospitalization rates. However, the findings do not show systematic adverse effects of the famine on later-life income, disability and marital success. Possibly, selection and competition effects conceal adverse effects of the famine.

Studies on the long-term effects of early-life malnutrition remain relevant for the following reasons. First, caloric restriction still is a widespread phenomenon in developing countries. The United Nation's have estimated that 38 million Africans were living under the threat of famine in 2002 (Meng and Qian 2009). Furthermore, variation in early-life nutrition could explain part of the well-documented correlation between health and socioeconomic status between and within countries (Case and Paxson 2010). Finally, this famine could also be the reason for the impairments of health and socioeconomic

[3]This analysis is still in progress and not adopted in this version of the paper.

[4]See e.g. Almond (2006).

status of a currently aging cohort in the Netherlands.

The remainder of this paper is structured as follows. Section 2 discusses the background of the famine. Part 3 discusses the related literature. Section 4 describes the data and provides summary statistics. The descriptive analysis, the model and the regression analysis are treated in section 5. Finally, section 6 concludes.

2 The famine

The famine originated towards the end of World War II due to a combination of the following events: the Allied failure to liberate the northern part of the Netherlands, a Nazi-imposed transport embargo and a general railway strike. Moreover, the within-country allocation of food was disturbed due to the winter's early arrival and, subsequently, the freezing of the waters. Hence, the famine has been caused by allocation problems instead of an overall food shortage (Trienekens 1985). [5]

Figure 1 shows the peak in mortality in the period January-April 1945. Moreover, Figure 2 indicate that public health had only deteriorated slightly during the pre-famine Nazi occupation, i.e. from May 1940-December 1944, and that it has fallen below its pre-war level after liberation in May 1945. The peak in 1945 does not fully show the impact of the Hungerwinter, because the famine was restricted to the first four months in 1945 and its severity was strongly regionally dependent (Banning 1945) (Trienekens 1985). The peak in infant mortality rates in 1945 also points at the severity of conditions (Table 3). The age composition of mortality implies that males were more heavily affected than females and most of the mortality was concentrated among the very young and the elderly (Figure 4). The official food rations dropped to 500 kilocalories per day, which is very low in comparison with the recommendation of 2500 kilocalories for males from the Oxford Nutritional Surveys (Ravelli 1999) (Figure 6). The black market prices (Figure 5) rose steeply as well during the famine because of the food situation. Furthermore, the severe hunger was restricted to the urban areas, because of their dependence on the official food rations and the lack of access to alternative food sources (Stein et al. 1975).

The country was basically split up in three regions during the famine. The Southern-Netherlands, i.e. the part beneath the Rhine, was liberated and, subsequently, saved from serious food shortages. The Northeastern-Netherlands was sparsely populated and contained a large agricultural sector.

[5] We refer to De Jong (1980a),De Jong (1980b) and De Jong (1980c) for an elaborate discussion of the Hungerwinter and the end of the Second World War in the Netherlands.

Hence, food shortages did arise, but the famine was less severe than in the West. Finally, the urbanized Western-Netherlands faced the most severe famine due to its dependence on food imports, which were seriously limited because of the mentioned logistical problems. (Trienekens 1985) (Burger et al. 1948).

Figure 7 depicts the corresponding regional mortality rates: both the Western and the Northeastern mortality rates are at their maxima in 1945 and the Western peak is the largest. Moreover, the Southern mortality is already at its highest point in 1944. This latter peak is presumably caused by the fights towards the end of the war, which did not affect the West. Finally, the mortality patterns mimic each other in the years before and after the famine.[6]

The prenatally exposed 1945 birth cohort is at the measurement moment of the long-term outcomes, i.e. 2004, smaller than the adjacent birth cohorts for the following reasons. First, Figure 8 indicates that fertility fell slightly in 1945 and that it grew in the post-war years, i.e. the baby boom generation. Furthermore, Figure 9 shows that the 1945 cohort a has discontinuously lower probability of surviving until 2004. The survival probability is calculated as the fraction of the amount of individuals present in the Dutch registers in 2004 by birth year and the corresponding historic birth number (source: Statistics Netherlands Archive). Hence, attrition arises because of emigration and mortality between the 1940's and 2004.

The Hungerwinter did not significantly alter the sex ratio of the 1945 prenatally exposed birth cohort (Figure 10). This finding contrasts the hypothesis of Trivers and Willard (1973), which states that as maternal conditions decline, adult females tend to produce a lower ratio of males to females, and evidence based on China's Great Famine (Almond et al. 2007).

3 Context

3.1 Epidemiologic background

Multiple studies have made use of the Hungerwinter to estimate long-term health effects of early-life malnutrition. E.g. Smith (1947) finds short-term effects of the famine on the birth weight and birth length of newborn babies. Contrarily, the results of Stein et al. (1975) do not indicate large effects at early adulthood by using military data. This could be explained by the fetal

[6]The Western-Netherlands contains the provinces Utrecht, Noord-Holland and Zuid-Holland. The Northeastern-Netherlands comprises Groningen, Friesland, Overijssel, Drenthe and Gelderland. South encloses Noord-Brabant and Limburg.

programming hypothesis, which states that effects of adverse early-life effects become visible at advanced ages.[7] In the long run, Painter et al. (2005) find effects on the probabilities of diabetes, cardiovascular diseases, obesity and breast cancer. They also measure higher cholesterol and lower self-perceived health levels, while they do not observe effects on mortality. Furthermore, these effects are dependent on the gestational stage of fetal malnutrition. Finally, Lumey et al. (2007) find, among other things, a modest relationship between prenatal exposure and current blood pressure.

Other famines are also used to identify the long-term health impact of malnutrition early in life. For instance, St. Clair et al. (2005) measure long-term effects of China's Great Famine on schizophrenia. Moreover, Van den Berg et al. (2007), Kannisto et al. (1997) and Stanner et al. (1997) find mixed effects on later-life mortality and morbidity by exploiting, respectively, the 1846-1847 Dutch Potato Famine, the 1866-1868 Finnish famine and the Leningrad Siege during the Second World War. Possible, dynamic selection is the underlying mechanism behind these ambiguous findings.

3.2 Economic background

The long-term socioeconomic impact of the Hungerwinter has not yet been analyzed in contrast to its health consequences. Currently, economic studies on effects of early-life exposure to famines mainly rely on China's Great Famine: Almond et al. (2007), Brandt et al. (2008), Chen and Zhou (2007), Gørgens et al. (2007) and Meng and Qian (2009) find adverse effects on socioeconomic outcomes, like labor market status, literacy, wealth and marital outcomes, and mixed effects on health outcomes, such as weight and height.[8]

Furthermore, Almond and Mazumder (2008) and Van Ewijk (2009) investigate the long-term health consequences of prenatal exposure to maternal fasting during Ramadan. The former study finds effects on vision, hearing and mental disabilities. The latter indicates that exposed are individuals sick more often and have poorer health in general.

4 Data

4.1 Health and Socioeconomic Outcomes

The register data, which are provided by Statistics Netherlands follow the entire Dutch population in the period 1999-2006 and, hence, allow us to an-

[7] See Van Ewijk (2009) for a survey on evidence of the fetal programming hypothesis.

[8] We refer to Almond et al. (2007) for a more thorough discussion of this literature.

alyze the long-term effects of the Hungerwinter. The data identify the exact municipality and month of birth. The sample is restricted to those born in the Netherlands and both the discontinuous nature and the regional variation in the intensity of the famine are used in the analysis. Furthermore, the short duration of the famine and the large sample, which contains more than 1.6 million individuals born in the period 1941-1949, permits the analysis to be based on people born in a narrow time interval.

We merge the registers of the following institutions to obtain the life-course health and socioeconomic outcomes. First, the Municipal Personal Records Database provides the information on gender, marital status and on the place and date of birth. This data is combined with the tax files containing labor market information of all employees in the Netherlands. This file contains over 7.5 million individuals and records, among other things, whether an individual has worked in a certain year and the corresponding taxable income. Then, the register of the social security agency, which is responsible for the disability benefits and covers almost one million individuals, is added.[9] Afterwards, the registration of hospitals, that includes over 9 million hospitalizations in the period 1999-2004, is used. Finally, the data of the death registers, that comprises over 400.000 deaths, is included.[10]

The main part of the analysis considers the 1943-1947 birth cohorts, which corresponds to nearly one million individuals. This time interval covers the prenatally exposed cohort and the two years before and afterwards. Persons born in 1943 (1944) were exposed to the famine in their first (second) year of life. The individuals born in 1945 were prenatally exposed and the post-famine born 1946 and 1947 cohort is the control group. Furthermore, the degree of exposure to the famine also depends on the region of birth: the West was severely hit, the Northeast was modestly affected and the South was saved from serious food shortages.

Summary statistics of the main variables are given in Table 1. Income measures the income from wages earned as an employee in 1999. Not surprisingly, men are more likely to have jobs than women and, subsequently, to earn higher wages. Disability measures whether someone has been entitled to disability benefits in 1999 and this rate is higher for males. This latter finding presumably reflects the fact that eligibility is related to the labor market history. An issue with this outcome is that firms have also used this

[9]Specifically, entitlement to WAO-benefits, which is the Dutch scheme for labor related disability, is considered.

[10]The following files are used: "Geboorteplaats 2004V1" and its corresponding "GBA-selectiebestand" provided by the Municipal Personal Records Database. The file "SSBBanen_1999" contains the labor market information. "SSBAO_1999" comprises the disability information. "LMRBasis_1999-2004" tracks the hospitalization rates.

scheme as a method to remove undesired, mainly aging workers. Therefore, this outcome is an imperfect measure of health.[11] The outcome married or widowed measures whether someone has been married or widowed in 1999. It is adopted as a measure of marital success. Hospitalization measures the number of times a person has been hospitalized in the period 1999-2005. We aim to obtain a good indicator of the long-term health status of individuals by considering a time interval of seven years. Table 1 displays a higher hospitalization rate for women.

4.2 Historic Data

The individuals' later-life health and socioeconomic outcomes are combined with historic data in order to identify the severity of the famine at the moment and location of birth. First, we use the historic database of the Association of Netherlands Municipalities to assess whether someone is born in a village (up to 40.000 inhabitants), a small city (40.000-100.000 inhabitants), a middle-sized city (100.000-500.000 inhabitants) or a large city (>500.000 inhabitants).[12] This relates to the finding that the famine mainly was a phenomenon of the cities. Then, the month of liberation of each specific municipality is identified by means of information from the Netherlands Institute of Military History in the Hague.[13] Afterwards, we combine this data with the statistics from Statistics Netherlands, which are treated in section 2. Finally, we combine this data with the monthly averages of the daily caloric values of the food rations, which are shown in Figure 6.

[11] We consider the labor market outcomes income and disability only in the year 1999 to avoid confounding with early retirement schemes above age 57. A disadvantage is that the time frame of success on the labor market is therefore restricted to one year.

[12] The small cities are Amersfoort, Apeldoorn, Arnhem, Breda, Delft, Dordrecht, Enschede, Heerlen, Hengelo, Den Bosch, Hilversum, Kerkrade, Leeuwarden, Maastricht, Schiedam, Venlo, Zaandam, Zwolle, Leiden, Deventer, Ede, Emmen en Vlaardingen. The middle sized cities are Eindhoven, Den Haag, Groningen, Haarlem, Nijmegen, Tilburg en Utrecht. The large cities are Amsterdam and Rotterdam.

[13] Based on this information the Northeastern part of the province Limburg, i.e. the parts surrounding Roermond and Venlo, is left out of the analysis: this area was, in contrast to the main part of this province, occupied during the Hungerwinter and the food situation is unclear.

5 First Results (to be completed)

5.1 Non-Parametric Analysis of Outcome Differences by Birth Cohort

A ceteris paribus comparison of exposed and non-exposed cohorts is unfortunately infeasible due to the linear dependence of period, age and birth cohort. However, the short duration of the famine enables us to compare outcomes of nearby cohorts. This section contains two parts: first, the outcome means of the cohorts that have been exposed prenatally or in the first or second year of life are compared with the post-famine born control group. Second, we graphically inspect whether the outcomes of the fetally exposed group deviate from the trend-predicted levels.

The outcome means of the various groups are shown in Table 2. The 1944 (1943) cohort corresponds to exposure in the first (second) year of life and the 1945 cohort has been prenatally exposed. The outcomes of these exposed cohorts are compared with the most adjacent post-famine born control group, i.e. individuals born in 1946. The outcomes are averages of each birth cohort 56 year later in time, i.e. income is measured respectively as income in 1999 for the 1943 birth cohort, income in 2000 for the 1944 birth cohort, income in 2001 for the 1945 birth cohort and income in 2002 for the 1946 birth cohort. This adjustment of the measurement date aims to take away age effects, albeit at the expense of time specific effects. We also do not exploit the cross-sectional within cohort variation.

Table 2 provides evidence that famine exposure during any stage early in life negatively affects long-run income. T-tests imply that this difference is significant at 99% for both genders. However, the opposite results hold for the marital status outcome. Possibly, this reflects lower competition on the marriage market. Furthermore, the results are dependent on gender in case of the outcome disability: the famine has a significant adverse effect for men and either an insignificant adverse, i.e. the 1944 and 1945 cohorts, or significant beneficial effect, i.e. the 1943 cohort, for women. Finally, the exposed cohorts face significantly lower hospitalization rates, except for the male 1945 cohort. The lower hospitalization rates possibly imply at a selection effect. We conclude that these inter birth cohort comparisons do not provide an unambiguous finding on the long-term effects of the famine and that time specific effects need to be taken into account.

Therefore, we plot the outcome means by year and quarter of birth in Figure 11. Income, disability and marital status are measured as their 1999 levels and hospitalization reflects the mean number of hospital visits in the period 1999-2005. The dashed vertical lines indicate the prenatally exposed

birth cohort of 1945.

The first chart depicts a clear negative deviation of the famine affected cohort from the increasing income trend. The second panel depicts the trend of the fraction being entitled to disability benefits in 1999 by quarter of birth. A negative trend is visible and the cohorts born in the second and third quarter of 1945 seem to deviate in contrast to the individuals born in the first and fourth quarter of 1945. The third panel shows the fraction of the population that is either married or widowed in 1999. This indicator is a measure of success on the marriage market. There is no clear trend in the cohorts born before 1946 and the prenatally affected famine cohort does not seem to systematically deviate. Finally, the last graph shows a clear discontinuous drop in hospitalization rates between the third quarter of 1945 and the first quarter of 1946. This provides clear evidence that early-life exposure to a famine negatively affects long-term health. However, the mean hospitalization rate of the fourth quarter 1945 cohort is also low, while these individuals were exposed to the famine during the first quarter of gestation. Finally, this graphic analysis points at the presence of negative long-term health and economic effects of the famine.

5.2 Model specification

In this section, we treat the model that is used to systematically analyze how exposure to the famine in different stages of the early life affects later-life health and socioeconomic outcomes. Both the longitudinal variation between cohorts and the cross-sectional variation in famine intensity are exploited. This reduces the probability that the estimates are biased because of confounding effects. Only unobservable factors that exactly resemble the famine pattern remain troublesome. The sample is restricted to all individuals born two years before the famine, i.e. the 1943 birth cohort, to two years after the end of the famine, i.e. the 1947 birth cohort.

Equation 1 represents the main identifying equation.

$$y_i = \beta_0 + \beta_1 * X_i + \beta_2 * Z_i + u_i \tag{1}$$

Y_i comprises the long-term outcomes of interest, i.e. income, disability, marital status and hospitalization. X_i is a vector of individual controls. In specification I it contains age, age^2 and province of birth dummies. Age is measured in months and varies from 1, i.e. a birth in December 1947, to 60, i.e. a birth in January 1943. In the extended model II, we also control for the month of birth, urbanization level and contemporaneous macroeconomic conditions. The month of birth dummies aim to capture season of birth ef-

fects.[14] The urbanization grade is a dummy indicating a birth in a urban or rural municipality of birth. The adopted cut-off number of inhabitants is 40.000, which is in line with the study by Stein et al. (1975). The contemporaneous macroeconomic conditions are measured by the deviation of the 1999 unemployment rate of the province of residence from the national average. Furthermore, the vector Z_i contains the main variables of interest, i.e. six dummies that indicate a birth in either the West or Northeast and in the years 1943, 1944 and 1945. Hence, the β_2-coefficients measure whether the individuals born in the severely affected West and the modestly affected East and at crucial moments have adverse long-term outcomes after controlling for, amongst other things, age and regional effects. Significant estimates of the 1945 cohort indicate importance of the prenatal stage and significant coefficients of the 1944 (1943) cohort point at importance of the first (second) year of life. Beforehand we expect to find the strongest adverse effects of the famine in the West and smaller adverse effects in the Northeast. Finally, the standard errors are clustered at the municipality of birth.

Columns I and II of Tables 3-6 present the results of this simple and more extensive model. Columns III and IV adopt similar specifications, while restricting the sample to individuals born in urban areas. This corresponds to the finding that the famine mainly was a phenomenon in the cities.

5.3 Results

First, Table 3 shows the results for the outcome income. According to column I, there are no significant long-term effects of the famine on female income. However, the signs of the severely affected West indicate that the famine affected cohorts have lower later-life incomes. The estimates for males also do not point at structural negative effects of the famine. The sign of the prenatally affected Northeastern cohort is marginally significant, but this estimate loses significance when modifying the model specification (column II). Restricting the sample to urbanized places of birth (columns III and IV) does not significantly alter the results. Therefore we conclude that this analysis indicates that there are no significant long-term effects of the famine on income.

Second, the findings for the outcome eligibility to disability benefits is presented in Table 4. The main model does also not provide strong evidence for adverse long-term effects of the famine. There are no significant estimates in the main model in case of females (column I). For males, exposure to the famine in the first two years of life is related to lower levels of disability in

[14] See Doblhammer and Vaupel (2001) for the importance of seasonal effects.

both the West and the Northeast. This surprising finding is possibly caused by selection effects, i.e. the lower fertility and the higher life-course mortality up to 2004 result in a relatively strong sample of individuals. Finally, the sign of the estimate of the prenatally exposed (1945) Western cohort points at higher disability rates for both genders in the reduced, urbanized sample (columns III and IV). However, this result is insignificant.

Furthermore, marital status is adopted as outcome variable in Table 5. Being married or widowed is interpreted as a measure of success on the marriage market. The famine does also not seem to have a significant adverse long-term impact on this outcome. For females the estimates of both exposure in the first two years of life in the West and exposure in the second year of life in the Northeast seem to have a positive effect on marital outcomes (column I). Modifications of the model do not point at adverse effects of the famine (columns II-IV). For males, a birth in the severely affected West in any of the three critical years is related positively to success on the labor market in the main model (column I). This result remains significant for exposure in the first two years of life, when changing the specification of the model (column II-IV). The underlying mechanism behind these findings is still unclear. Two possible explanations are selective mortality and lower marriage market competition.

Finally, the analysis considering the outcome hospitalization is depicted in Table 6. These findings point at the importance of the fetal environment on later life health. The male estimate of the Western 1945 cohort is positive and highly significant (column I). Furthermore, this finding is robust to alternative specifications of the model (II-IV). This result is in line with the severity of the famine in the Western-Netherlands and the estimated importance of the fetal environment. The female Western estimate corresponding fetal stage in the West is also significant and positive in the main and extended model (columns I and II). However, it loses significance when restricting the sample to urban-born individuals (III and IV). Moreover, the Western female results point at importance of the first year of life (the 1944 and West variable) and this result is robust to all modifications of the model. Finally, the marginally significant estimate in the opposite direction for the interaction between the birth year 1943 and birth region Northeast provides modest evidence for a selection effect towards more healthy individuals (columns I and II). However, this finding loses significance when restricting the sample to individuals born in urbanized regions (columns III and IV).

To conclude, the previous results provide evidence indicating that exposure to the famine in the earliest stages of life affects later-life hospitalization rates. Contrarily, we do not find adverse effects on the outcomes income, disability and marital status. Finally, selection effects possibly cover the

adverse effects of the Hungerwinter.

5.4 Discussion

The treatment and control groups have to be comparable in terms of characteristics, except for exposure to the Hungerwinter, in order to assign the previously discussed findings to the adverse early-life conditions. However, the previous analysis indicates the presence of selection effects for certain outcome variables.

The famine has affected the size of the prenatally exposed cohort born in 1945 in the following ways: the slightly lower fertility (figure 8) and the lower survival probability (Figure 9) have resulted in a smaller cohort in 2004. The 1944 and 1946 birth cohorts are respectively 5.7 and 42.9 percent larger than the 1945 cohort.[15] Furthermore, Figures 12 and 13 display that the discontinuous drops in fertility and in the probability of survival of the 1945 cohort are, as well, most pronounced in the West. Hence, it seems plausible to assume that the famine has resulted in a more selective sample of survivors in 2004 and, subsequently, estimates of the adverse effects of the famine are downward biased.

Contrarily, selective fertility is a larger concern if weaker individuals were more likely to have children during the famine: this would bias the results in an upward way. However, the following findings reduce this concern: first, menstruation ceased for a substantial number of women, making it impossible to become pregnant and it seems likely that this effect was the strongest for the weaker women (Burger et al. 1948). Moreover, the number of illegitimate births, i.e. no father was present to register the baby, does not increase disproportionately in the West in 1945 (Figure 14). Furthermore, Stein et al. (Stein et al. 1975) find that fathers of children conceived in the Hungerwinter were more likely to be working in non-manual occupations. Finally, the absence of wide-spread birth control measures also made it difficult to control pregnancy.

Unfortunately, the data does not allow to further investigate whether the parents of individuals conceived during the famine have unfavorable characteristics. We also cannot analyze whether these individuals have a relatively large number of siblings, which could indicate that parents were comparatively more interested in the quantity than in the quality of their children (Becker and Lewis 1973). However, Almond et al. (Almond et al. 2007) do not find evidence of such effects in the Chinese Great Famine.

[15] Please notice that the large difference between the 1945 and 1946 cohorts is mainly caused by the large increase in fertility in 1946.

There also have been no major educational reforms that could confound the results (Dodde 1983). Finally, the benefit of exploiting between- and within-cohort variation is that potential confounders would have to resemble this pattern to bias the results.

6 Conclusion

This paper uses the Dutch 1944-1945 Hungerwinter as a natural experiment to assess effects of early-life malnutrition on later-life health and socioeconomic outcomes. The results point at the presence of long-run effects of exposure to famines on hospitalization rates for men and women. However, no consistent adverse effects on the outcomes income, disability and marital status are found. Finally, we also find evidence of selection effects, which could cover the adverse effects of the famine.

This study is the first to analyze the long-term health and socioeconomic consequences of the Hungerwinter for the entire Dutch population. Hence, it contributes to the existing knowledge on long-term effects of early-life conditions. Furthermore, the high quality documentation of this unique quasi-experiment and the richness and magnitude of the contemporaneous register data enable us to make inferences on the causal links between initial undernutrition and health and socioeconomic outcomes later in life.

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Appendix

Figure 1: Monthly mortality per 1.000 inhabitants, the Netherlands, 1944-1945 (source: Statistics Netherlands Archive)

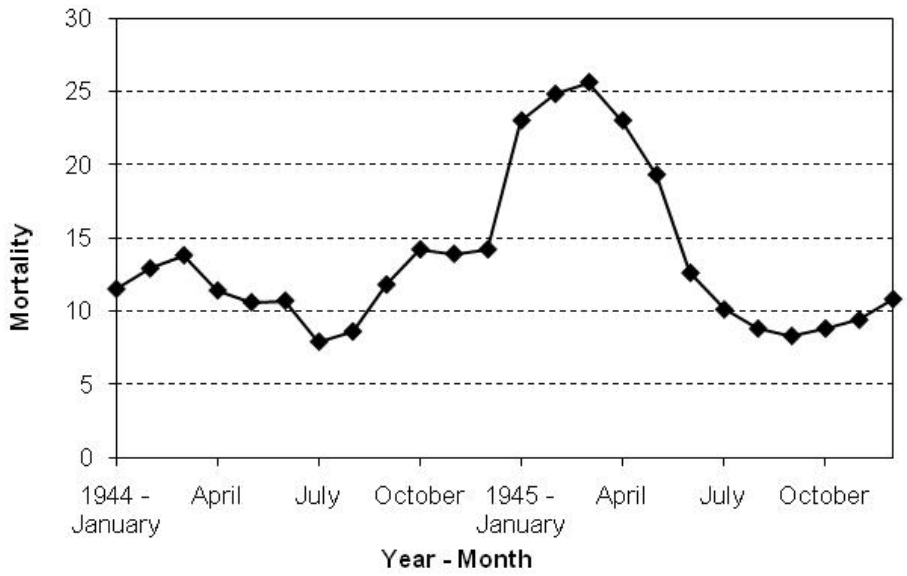

Figure 2: Annual mortality per 1.000 inhabitants, the Netherlands, 1935-1949 (source: Statistics Netherlands, statline.cbs.nl)

Figure 3: Deaths within the first year of life per 1.000 live births, the Netherlands, 1940-1949 (source: Statistics Netherlands, statline.cbs.nl)

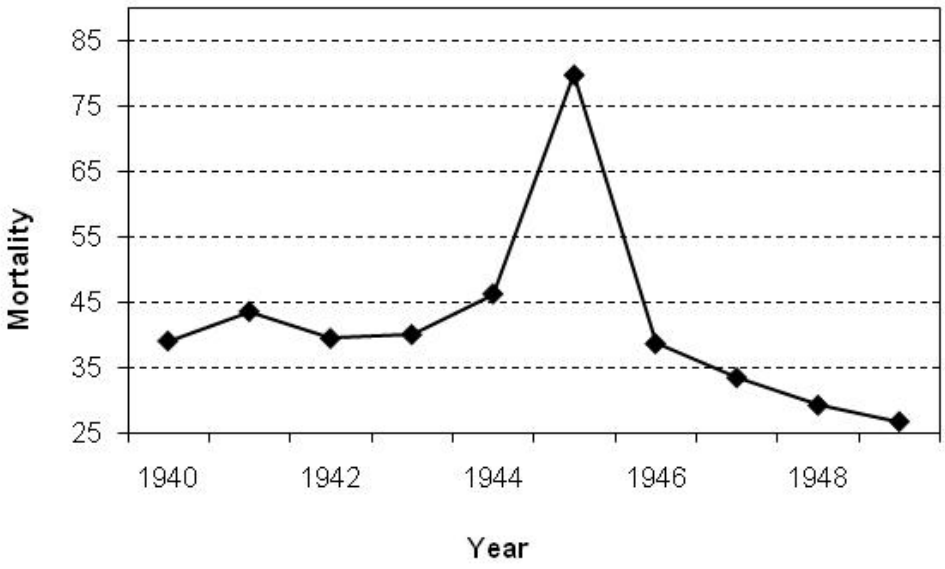

Figure 4: Composition of mortality by age group, the Netherlands, 1945 (source: Statistics Netherlands Archive)

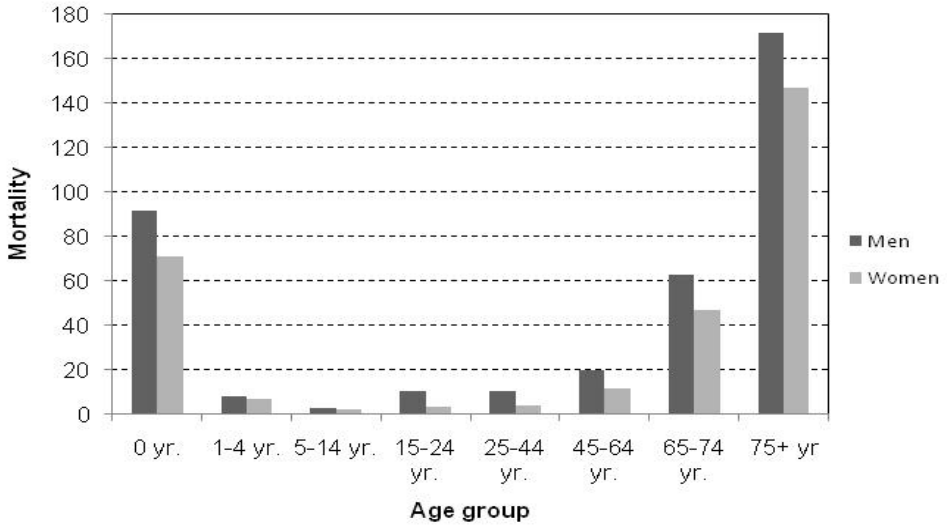

Figure 5: Black market prices in the famine area, 1938=100, 1938-1948 (source: Klemann, 2000)

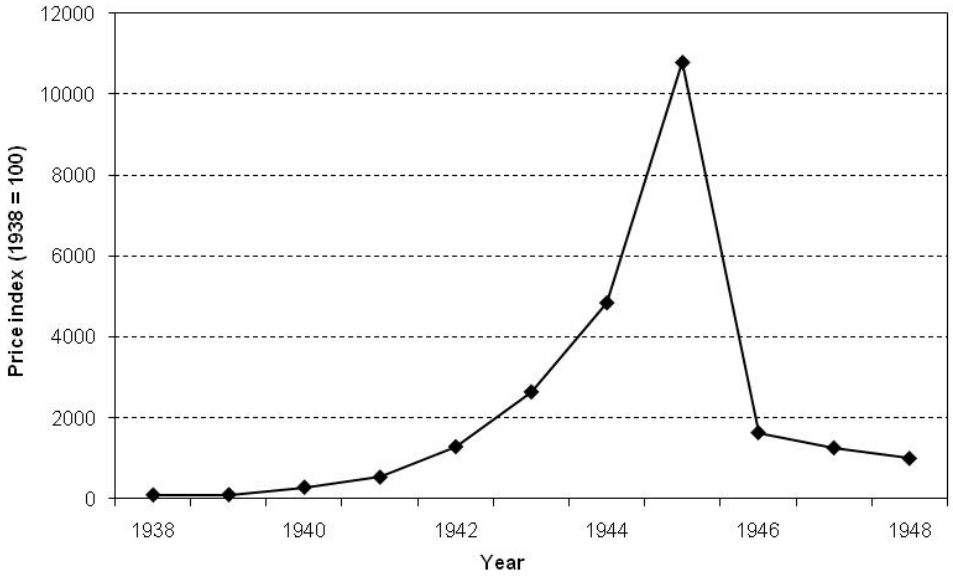

Figure 6: Daily caloric averages of the official food rations, the Western-Netherlands, 1941-1945 (source: Rijksbureau voor de Voedselvoorziening in Oorlogstijd, National Archive)

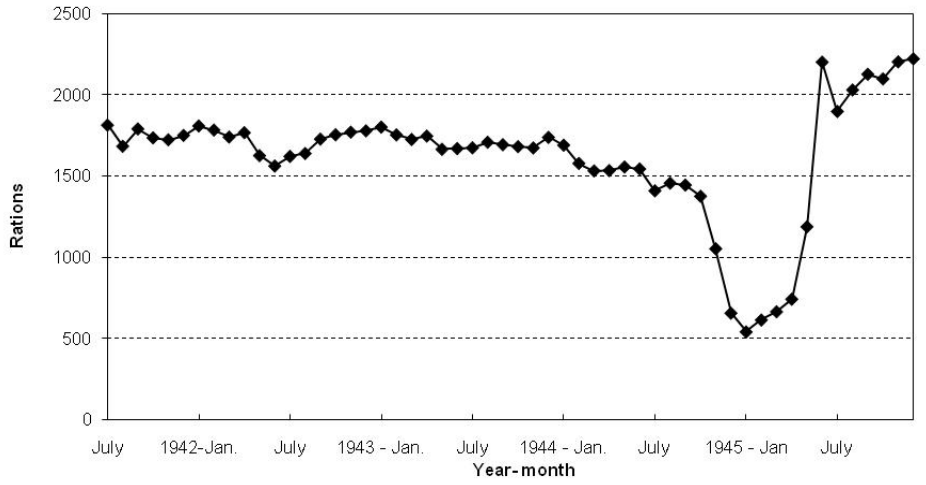

Figure 7: Annual regional mortality per 1.000 inhabitants, 1935-1949 (source: Statistics Netherlands Archive)

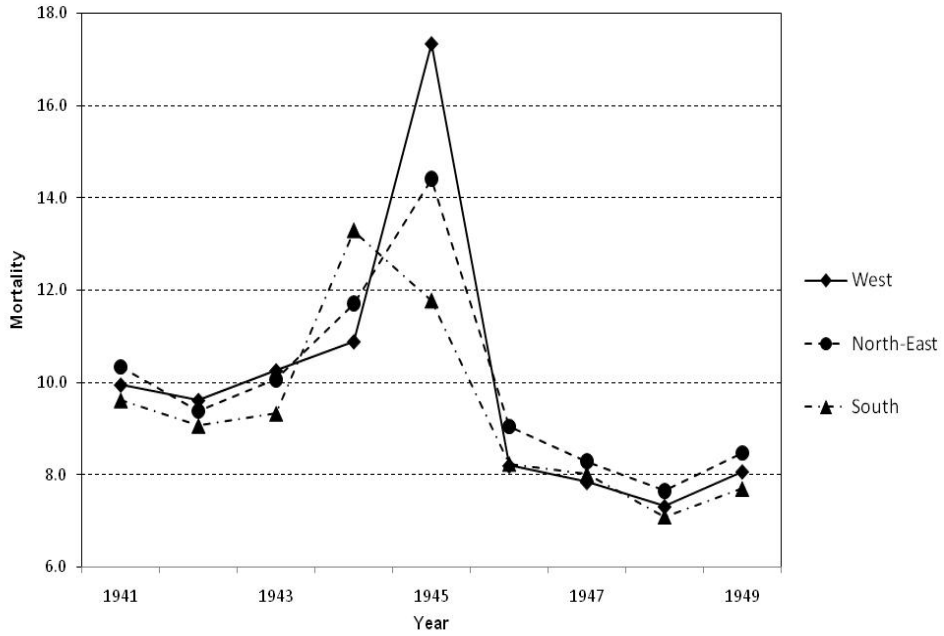

Figure 8: Live births per 1.000 inhabitants, the Netherlands, 1940-1949 (source: Statistics Netherlands, statline.cbs.nl)

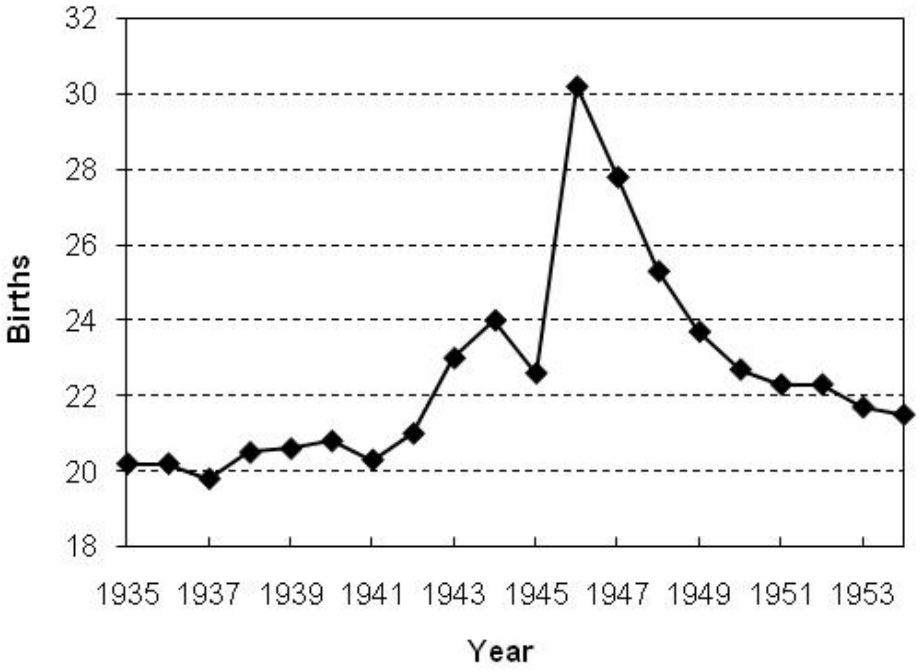

Figure 9: Probability of survival until 2004 by birth year, 1941-1949 (source: Municipal Personal Records Database and Statistics Netherlands Archive)

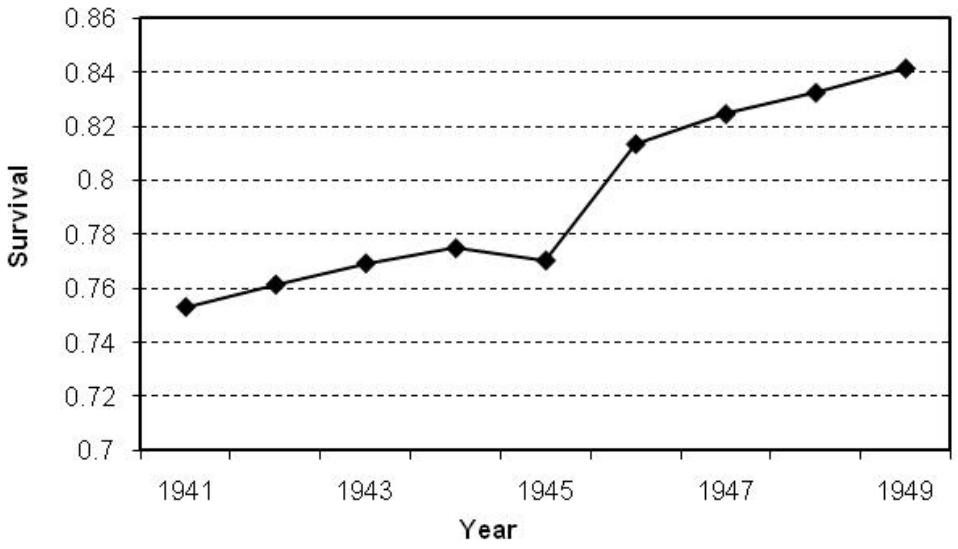

Figure 10: Boy/girl ratio at birth, the Netherlands, 1940-1949 (source: Statistics Netherlands, statline.cbs.nl)

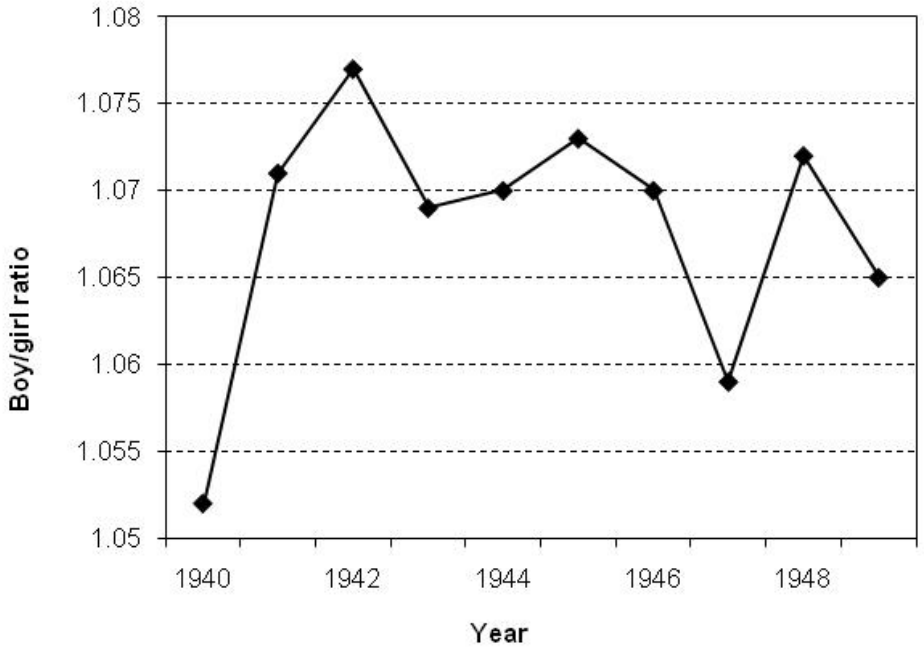

Figure 11: Outcomes by year and quarter of birth, 1942-1948 birth cohorts (source: SSB_Banen1999, SSB_AO1999, GBA, LMR_Basis1999-2005; Statistics Netherlands)

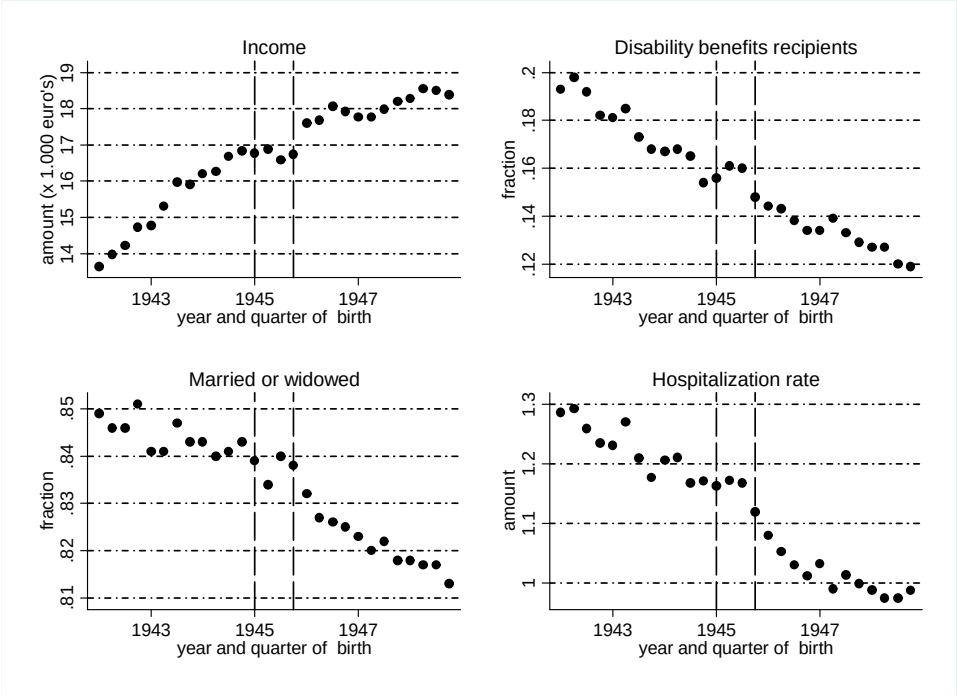

Figure 12: Live births per 1.000 inhabitants by region, the Netherlands, 1940-1949 (source: Statistics Netherlands Archive)

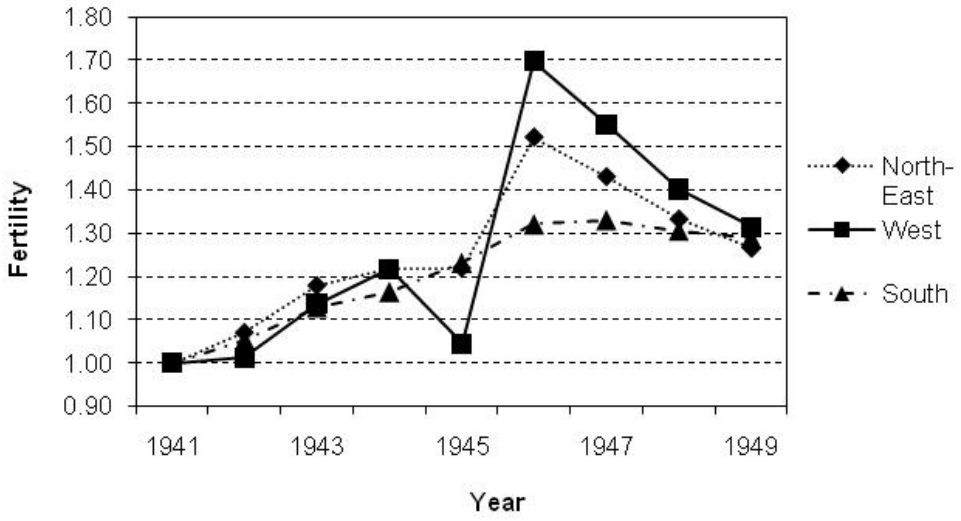

Figure 13: Probability of survival until 2004 by birth region and birth year, 1941-1949 (source: Municipal Personal Records Database and Statistics Netherlands Archive)

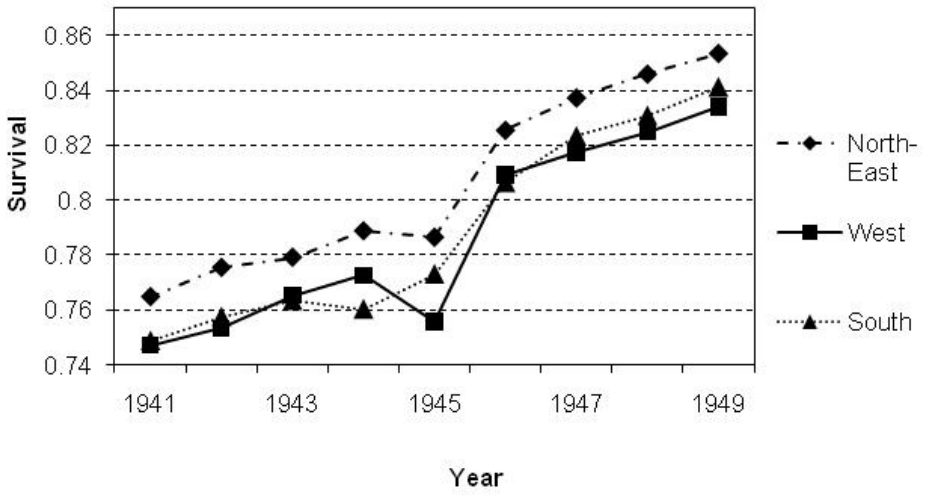

Figure 14: Illegitimate births by region, 1941=1, 1941-1949 (source: Statistics Netherlands Archive)

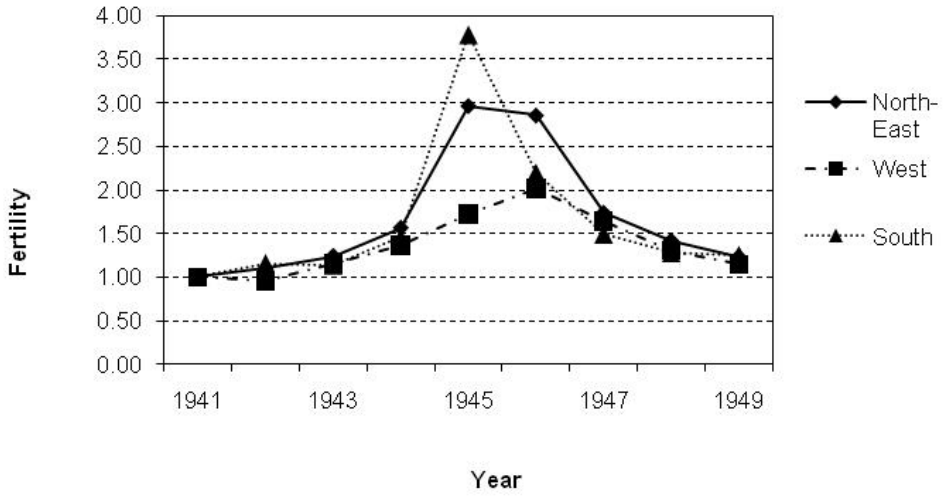

Table 1: Descriptive statistics

	Women	Men
Income	6287	27649
Disability	0.117	0.186
Marital or Widowed	0.834	0.831
Hospitalization	1.129	1.094
Nurb	196449	200998
Nwest	209368	212765
Nnortheast	132754	134989
Nsouth	102656	104028
Ntotal	444778	451782

Table 2: Cohort means of the 1943-1946 birth cohorts

		N	Income		Disability		Married/Widowed		Hospitalization	
			Mean	P-value	Mean	P-value	Mean	P-value	Mean	P-value
Women	1943	76156	5167	0.000	0.133	0.020	0.842	0.000	0.087	0.000
	1944	80694	5695	0.000	0.137	0.504	0.841	0.000	0.090	0.006
	1945	76246	6345	0.000	0.137	0.591	0.838	0.000	0.092	0.128
	1946	108317	7359		0.136		0.831		0.094	
Men	1943	76717	25836	0.000	0.219	0.000	0.844	0.000	0.082	0.001
	1944	81493	27149	0.000	0.212	0.002	0.841	0.000	0.082	0.001
	1945	77221	27883	0.000	0.220	0.000	0.837	0.000	0.087	0.791
	1946	110960	29826		0.201		0.824		0.086	

P-values behind the means correspond to two-sided T-tests with the 1946 birth cohort mean

Table 3: Outcome I: income

	Women								Men							
	I		II		III		IV		I		II		III		IV	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
1943 & West	−187.66	115.20	−191.77*	115.26	99.38	152.06	−99.05	185.01	−430.30	471.77	−454.55	542.90	−998.29	1143.45	−1214.78	1357.71
1944 & West	−120.64	93.88	−95.27	97.76	34.85	115.66	−99.00	127.34	50.16	290.67	90.74	335.32	−438.13	639.44	−581.47	773.13
1945 & West	−76.10	98.08	23.04	100.38	100.54	123.26	50.51	137.44	−309.10	262.74	−170.60	272.99	−512.36	441.49	−553.70	469.09
1943 & Northeast	146.99	149.91	177.94	114.76	93.45	193.51	−96.68	197.14	−179.54	469.06	−176.36	537.34	−568.69	1180.46	−848.17	1373.77
1944 & Northeast	35.13	120.60	86.79	95.04	78.96	155.45	−50.15	162.44	178.52	309.28	239.80	341.59	73.58	695.28	−108.96	809.82
1945 & Northeast	−86.89	109.86	−9.91	96.52	−216.25	181.17	−297.91	179.11	−404.72*	243.17	−396.54	250.07	−450.31	655.81	−671.06	627.63
Age	−36.058***	4.61	−35.88***	4.75	−46.60***	6.69	−43.07***	7.06	27.56**	13.32	26.96**	13.00	32.373	22.36	32.31	29.70
Age2	−0.85	0.08	−0.07	0.07	−0.02	0.11	−0.01	0.11	−1.27***	0.28	−1.23***	0.28	−1.19**	0.57	−1.10*	0.61
Groningen	576.19	490.04	1467.70***	265.04	1425.99***	195.53	2061.66***	318.71	512.01	816.44	4878.69***	605.02	1312.709	877.52	5014.79***	1163.28
Friesland	560.16*	314.21	1147.03***	201.27	1344.54***	196.13	1643.84***	216.57	584.38	807.94	2676.70***	582.11	2552.68***	876.90	4179.29***	900.18
Drenthe	257.94	251.24	1164.55***	350.90	−500.48**	196.24	163.06	330.32	−115.05	782.00	3902.63***	887.62	−3204.06***	882.34	772.45	1203.69
Overijssel	336.88	277.76	181.96	194.93	894.72**	377.90	873.40**	380.46	943.08	606.40	327.98	483.05	1341.75	1135.03	877.12	1119.50
Gelderland	452.38*	246.80	175.85	175.77	636.92***	280.16	485.36	297.34	741.09	567.59	−557.01	453.41	959.48	1023.10	−152.21	1072.63
Utrecht	1822.69***	282.82	1122.90***	219.20	1747.02***	192.96	1444.67***	267.39	3772.08***	561.27	951.85***	505.44	3300.98***	874.78	1050.72	1009.14
Noord-Holland	2573.36***	395.60	2075.74***	202.20	2574.97***	267.34	2522.11***	294.26	3723.79***	579.68	2493.14***	410.10	3378.71***	853.27	2701.29***	832.97
Zuid-Holland	2122.78***	342.20	1450.73***	266.54	2067.905***	392.65	1949.00***	409.507	5392.02***	555.71	3529.93***	441.13	4876.13***	894.48	3799.20***	898.35
Noord-Brabant	671.86***	255.13	235.30	164.56	1254.54***	213.16	945.60***	265.767	1402.00***	652.73	−713.34	536.38	2185.14***	1012.73	304.06	1147.82
Constant	6127.57***	172.95	5672.13***	156.71	6836.10***	194.05	6827.38***	201.80	25780.23***	481.19	25106.22***	420.65	26777.70***	933.95	26290.57***	959.83
Add. controls	*No*		*Yes*		*No*		*Yes*		*No*		*Yes*		*No*		*Yes*	
Urban Areas	*No*		*No*		*Yes*		*Yes*		*No*		*No*		*Yes*		*Yes*	
No. individuals	444778		444778		196.449		196.449		451782		451782		200998		200998	

The 1944 (1943) cohort has been exposed to the famine in the second (first) year of life. The 1945 has been prenatally exposed and the omitted 1946/1947 birth cohort is born post-famine. The West (Northeast) faced the most severe (modest) famine. The omitted South was saved from serious food shortages. Robust s.e.'s clustered at the municipality level; *** p<0.01, ** p<0.05, * p<0.1; estimated by OLS.

Table 4: Outcome II: disability

	Women								**Men**							
	I		II		III		IV		I		II		III		IV	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
1943 & West	−0.045	0.015	−0.280*	0.015	−0.370**	0.016	−0.020	0.019	−0.029**	0.134	−0.032**	0.015	−0.052***	0.018	−0.055***	0.019
1944 & West	−0.014	0.013	0.003	0.013	−0.004	0.015	0.008	0.016	−0.024**	0.012	0.025**	0.012	−0.029	0.018	−0.028	0.017
1945 & West	−0.009	0.011	0.009	0.011	0.017	0.015	0.023	0.015	0.009	0.012	0.009	0.012	0.018	0.017	0.019	0.017
1943 & Northeast	−0.031	0.020	−0.008	0.017	−0.020	0.028	−0.005	0.028	−0.032**	0.015	−0.035**	0.016	−0.031	0.026	−0.032	0.026
1944 & Northeast	0.003	0.015	0.025*	0.013	0.015	0.022	0.026	0.021	−0.032***	0.012	−0.033***	0.012	−0.034**	0.020	−0.034*	0.020
1945 & Northeast	0.011	0.015	0.031**	0.015	0.03	0.025	0.037	0.026	0.028**	0.013	0.031**	0.013	0.011	0.030	0.0154	0.029
age	0.003***	0.001	0.002***	0.001	0.002**	0.001	0.002	0.001	0.002***	0.001	0.002***	0.000	0.001	0.001	0.001	0.001
age2	0.000	0.000	0.000*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Groningen	−0.086**	0.038	−0.099***	0.026	−0.11***	0.011	−0.125*	0.017	−0.162***	0.040	−0.274***	0.039	−0.275***	0.026	−0.360***	0.033
Friesland	−0.132***	0.038	−0.114***	0.021	−0.080***	0.011	−0.090***	0.012	−0.180***	0.038	−0.227***	0.037	−0.308***	0.026	−0.343***	0.026
Drenthe	−0.106***	0.039	−0.099***	0.024	−0.090***	0.012	−0.105***	0.018	−0.086**	0.035	−0.185***	0.035	0.012	0.026	−0.077**	0.034
Overijssel	−0.126***	0.035	−0.140***	0.022	−0.138***	0.032	−0.143***	0.032	−0.122***	0.027	−0.107***	0.028	−0.153***	0.045	−0.141***	0.046
Gelderland	−0.113***	0.032	−0.117***	0.021	−0.129***	0.027	−0.130***	0.027	−0.168***	0.023	−0.135***	0.023	−0.232***	0.026	−0.206***	0.027
Utrecht	0.012	0.055	−0.015	0.025	0.014	0.033	0.0122	0.031	−0.217***	0.032	−0.150***	0.031	−0.180***	0.027	−0.127***	0.028
Noord-Holland	0.081	0.063	0.029	0.031	0.078**	0.033	0.073**	0.032	−0.212***	0.022	−0.190***	0.023	−0.221***	0.026	−0.204***	0.025
Zuid-Holland	−0.140***	0.043	−0.198***	0.028	−0.170***	0.037	−0.174***	0.037	−0.367***	0.022	−0.330***	0.022	−0.362***	0.025	−0.337***	0.025
Noord-Brabant	−0.130***	0.027	−0.125***	0.019	−0.157***	0.011	−0.153***	0.013	−0.132***	0.028	−0.078***	0.029	−0.244***	0.029	−0.201***	0.032
Constant	−1.212***	0.025	−1.275***	0.019	−1.12***	0.014	−1.137***	0.016	−0.802	0.022	−0.801***	0.024	−0.771***	0.030	−0.771***	0.032
Add. controls	*No*		*Yes*		*No*		*Yes*		*No*		*Yes*		*No*		*Yes*	
Urban Areas	*No*		*No*		*Yes*		*Yes*		*No*		*No*		*Yes*		*Yes*	
No. individuals	444778		444778		196.449		196.449		451782		451782		200998		200998	

The 1944 (1943) cohort has been exposed to the famine in the second (first) year of life. The 1945 has been prenatally exposed and the omitted 1946/1947 birth cohort is born post-famine. The West (Northeast) faced the most severe (modest) famine. The omitted South was saved from serious food shortages. Robust s.e.'s clustered at the municipality level; *** p<0.01, ** p<0.05, * p<0.1; estimated by a probit model.

Table 5: Outcome III: married or widowed

	Women								**Men**							
	I		II		III		IV		I		II		III		IV	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
1943 & West	0.059***	0.021	0.046***	0.017	0.065***	0.024	0.064**	0.025	0.048**	0.020	0.037**	0.017	0.065***	0.025	0.059**	0.027
1944 & West	0.039**	0.015	0.024*	0.013	0.040**	0.019	0.038*	0.020	0.043***	0.014	0.032***	0.011	0.041**	0.018	0.038**	0.018
1945 & West	0.008	0.015	−0.013	0.013	−0.023	0.016	−0.024	0.017	0.026***	0.010	0.013	0.009	0.009	0.014	0.009	0.014
1943 & Northeast	0.064*	0.034	0.045**	0.019	0.059*	0.034	0.058	0.036	0.049	0.030	0.030	0.021	0.09 * *	0.041	0.083*	0.043
1944 & Northeast	0.031	0.027	0.010	0.015	0.044*	0.026	0.042	0.027	0.039	0.024	0.024	0.017	0.053	0.035	0.049	0.037
1945 & Northeast	0.023	0.022	0.000	0.015	0.028	0.034	0.026	0.034	0.027	0.020	0.011	0.015	0.038	0.031	0.034	0.032
age	0.003***	0.001	0.003***	0.001	0.003**	0.001	0.004**	0.001	0.003***	0.001	0.003***	0.001	0.005***	0.001	0.005***	0.002
age2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Groningen	−0.062	0.082	−0.057*	0.032	−0.141***	0.029	−0.107***	0.036	−0.037	0.052	0.032	0.027	−0.092***	0.021	−0.017	0.034
Friesland	−0.005	0.048	−0.041	0.028	−0.036	0.029	−0.022	0.031	0.036	0.031	0.040***	0.021	0.012	0.021	0.045**	0.024
Drenthe	0.089**	0.045	0.063	0.059	0.237***	0.030	0.271***	0.036	0.072***	0.028	0.114***	0.032	0.109***	0.022	0.189***	0.036
Overijssel	0.059	0.049	0.073***	0.029	0.038	0.033	0.033	0.034	0.085***	0.030	0.086***	0.021	0.074***	0.025	0.065**	0.027
Gelderland	−0.006	0.053	−0.001	0.028	−0.025	0.049	−0.037	0.050	0.044	0.040	0.028	0.023	0.023	0.048	0.002	0.049
Utrecht	−0.176***	0.053	−0.141***	0.029	−0.150***	0.029	−0.171***	0.032	−0.036	0.041	−0.052**	0.023	−0.034	0.022	−0.079***	0.030
Noord-Holland	−0.283***	0.065	−0.218***	0.028	−0.256***	0.036	−0.263***	0.039	−0.1516***	0.044	−0.120***	0.020	−0.143***	0.023	−0.155***	0.027
Zuid-Holland	−0.195***	0.056	−0.119***	0.032	−0.165***	0.044	−0.175***	0.043	−0.089**	0.039	−0.049**	0.022	−0.068**	0.028	−0.089***	0.030
Noord-Brabant	0.045	0.048	0.045*	0.024	−0.008	0.030	−0.026	0.031	0.048*	0.028	0.014	0.015	0.022	0.015	−0.015	0.021
Constant	1.025***	0.038	1.102***	0.023	0.907***	0.032	0.889***	0.033	0.918	0.024	0.955***	0.016	0.828***	0.022	0.810***	0.021
Add. controls	*No*		*Yes*		*No*		*Yes*		*No*		*Yes*		*No*		*Yes*	
Urban Areas	*No*		*No*		*Yes*		*Yes*		*No*		*No*		*Yes*		*Yes*	
No. individuals	444778		444778		196.449		196.449		451782		451782		200998		200998	

The 1944 (1943) cohort has been exposed to the famine in the second (first) year of life. The 1945 has been prenatally exposed and the omitted 1946/1947 birth cohort is born post-famine. The West (Northeast) faced the most severe (modest) famine. The omitted South was saved from serious food shortages. Robust s.e.'s clustered at the municipality level; *** p<0.01, ** p<0.05, * p<0.1; estimated by a probit model.

Table 6: Outcome IV: hospitalization

	Women								Men							
	I		II		III		IV		I		II		III		IV	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
1943 & West	0.009	0.029	0.015	0.028	−0.011	0.041	−0.009	0.042	0.006	0.028	0.017	0.030	−0.036	0.036	−0.035	0.039
1944 & West	0.055*	0.028	0.059**	0.028	0.073**	0.042	0.073*	0.042	0.003	0.023	0.012	0.024	−0.031	0.026	−0.029	0.028
45 & West	0.046**	0.020	0.054***	0.020	0.029	0.023	0.028	0.023	0.054***	0.018	0.061***	0.018	0.068***	0.020	0.069***	0.021
1943 & North-East	−0.066*	0.035	−0.057*	0.032	−0.077	0.048	−0.075	0.050	−0.003	0.033	0.009	0.034	−0.041	0.047	−0.041	0.051
1944 & North-East	−0.031	0.029	−0.023	0.025	−0.009	0.040	−0.009	0.040	0.017	0.028	0.027	0.028	0.026	0.040	0.027	0.041
1945 & North-East	0.034	0.025	0.042*	0.022	0.080***	0.029	0.079***	0.029	0.039	0.024	0.047**	0.023	0.050	0.033	0.050	0.034
age	0.002	0.001	0.002	0.001	0.003	0.002	0.003	0.002	0.006***	0.001	0.006***	0.001	0.007***	0.001	0.006***	0.001
age2	0.000	0.000	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Groningen	0.019	0.051	0.011	0.064	−0.100**	0.046	−0.072	0.050	−0.043	0.046	−0.044	0.052	−0.035	0.069	−0.007	0.071
Friesland	−0.009	0.033	−0.001	0.035	−0.012	0.046	−0.001	0.047	−0.098**	0.043	−0.094**	0.046	−0.090	0.069	−0.076	0.070
Drenthe	0.053	0.039	0.054	0.044	0.008	0.047	0.038	0.051	0.014	0.043	0.018	0.047	0.061	0.069	0.096	0.071
Overijssel	−0.023	0.035	−0.027	0.036	−0.026	0.046	−0.032	0.046	0.005	0.045	−0.001	0.047	0.050	0.070	0.045	0.070
Gelderland	0.065	0.040	0.064*	0.036	0.132**	0.054	0.121**	0.054	0.060	0.045	0.056	0.045	0.131	0.082	0.121	0.082
Utrecht	0.071*	0.041	0.062*	0.035	0.104**	0.053	0.083	0.052	0.038	0.044	0.026	0.045	0.13 **	0.067	0.109	0.067
Noord-Holland	−0.006	0.049	−0.03	0.040	0.032	0.054	0.025	0.054	−0.004	0.050	−0.021	0.047	0.099	0.070	0.093	0.070
Zuid-Holland	0.004	0.032	−0.021	0.033	0.009	0.049	−0.001	0.049	−0.017	0.041	−0.035	0.043	0.055	0.069	0.046	0.070
Noord-Brabant	0.079**	0.033	0.083***	0.032	0.121**	0.054	0.104*	0.053	0.084**	0.038	0.082**	0.039	0.137*	0.074	0.0123*	0.074
Constant	0.009	0.032	−0.023	0.040	0.016	0.055	0.008	0.065	−0.096**	0.041	−0.129***	0.044	−0.159**	0.063	−0.196***	0.065
Additional controls	*No*		*Yes*		*No*		*Yes*		*No*		*Yes*		*No*		*Yes*	
Urban Areas	*No*		*No*		*Yes*		*Yes*		*No*		*No*		*Yes*		*Yes*	
No. individuals	444778		444778		196.449		196.449		451782		451782		200998		200998	

The 1944 (1943) cohort has been exposed to the famine in the second (first) year of life. The 1945 has been prenatally exposed and the omitted 1946/1947 birth cohort is born post-famine. The West (Northeast) faced the most severe (modest) famine. The omitted South was saved from serious food shortages. Robust s.e.'s clustered at the municipality level; *** p<0.01, ** p<0.05, * p<0.1; estimated by a negative binomial count model.