Life Expectancy during the Great Depression in Twelve Western Economies

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ABSTRACT

The global economic recession has renewed interest in the relation between declining economies and population health. Understanding the extreme case of the Great Depression may inform the current debate as well as theory regarding biological and behavioral adaptations to unwanted economic change. We test the procyclical hypothesis that period life expectancy improved during the Great Depression. We applied time-series methods to life table data from the following societies: Denmark, England and Wales, Finland, France, Iceland, Italy, the Netherlands, New Zealand, Norway, Scotland, Sweden, and Switzerland. Findings do not support the hypothesis in that period life expectancy at birth during the Great Depression remains within the interval expected from history. Additional analyses support the robustness of the results. Findings diverge from an earlier report based on U.S. data and indicate that population health in many countries did not improve during the sharpest economic decline in the 20th century.

INTRODUCTION

The global recession has reinvigorated the longstanding yet unresolved debate over the association between macro-economic change and population health.[1-5] One element of this debate focuses on the consequences of economic crises such as the Great Depression.[6] The Great Depression refers to the period after a calamitous crash on October 29, 1929 of the United States stock market. This unprecedented downturn, which reverberated across the Atlantic to Europe, led to record high unemployment rates, a fall in real income and assets, and declines in economic productivity.[7] Measurement of the health effects, if any, of the extreme case of the Great Depression may inform both contemporary population health as well as theory regarding biological and behavioral adaptations to unwanted economic change.

In a recent analysis of mortality during the Great Depression, Tapia Granados and Diez Roux examine the relation between Gross Domestic Product and period life expectancy in the United States from 1920 to 1940.[8] The authors report that life expectancy appeared to improve during the Great Depression (1930-33) but stagnated when the economy expanded (1934-36). Descriptive reports during the 1930s in the US also noted declines in population mortality during the Great Depression.[9,10]

The argument that the U.S. mortality response during the Great Depression holds implications for other places and times assumes that gains in life expectancy would also occur in similarly affected countries. Many European countries (e.g., Great Britain) had strong ties to the U.S. economy and responded to the 1929 Crash with a sharp rise in unemployment, falls in Gross Domestic Product, and decline in real wages.[11] Countries relatively less integrated with the U.S. economy (e.g., France, Scandinavian countries) experienced economic downturns of similar magnitude which began around 1931 slightly after the start of the Great Depression in the U.S.[12-14] The ripple effect on Western economies seemed inevitable, as the U.S. economy represented 42.5% of global manufacturing output from 1925-1929.[11] The shared experience of the Great Depression implies that researchers could assess the external validity of the U.S. case by examining life expectancy during that period in other Western societies.

We test whether period life expectancy in other Western economies rose above expected values during the initial and most economically perturbing phase of Great Depression (1930-1933). Our test populations include residents of twelve countries that kept high-quality life table data from at least 1878 and experienced stark economic downturns. We analyze males and females separately because the genders exhibit different temporal variation in life expectancy and also may respond differently to economic downturns.

Our analysis builds upon previous reports in two ways. First, we use mortality data that have been developed consistent with explicit, well-understood demographic conventions intended to insure comparability over time and across societies. Second, we employ analytic methods that remove temporal patterns in period life expectancy before examining the effect of the Great Depression.

METHODS

Variables and Data

Demographers define period life expectancy as the mean age of death of a hypothetical cohort born in the reference period and subject, throughout their lives, to the mortality of that period.[15] Period life expectancy serves as a cross-sectional summary index of the mortality experience at all ages. We, therefore, used as the dependent variable annual period life expectancy, separately for males and females. We acquired these data from the Human Mortality Database (HMD) website (www.mortality.org). The HMD includes countries only if their census and vital registration systems meet basic quality standards for accurate reporting. We refer the reader to the Human Mortality Database Methods Protocol which describes the methodology for calculating period life expectancy.[16]

Interrupted time-series methods, described below, require 50 consecutive observations prior to the interruption. Researchers typically characterize the onset of the Great Depression as occurring in late 1929 or 1930. We, therefore, selected countries for analysis only if the HMD includes period life expectancy at birth for at least 50 years before the Great Depression (i.e., from 1878 or earlier). This selection criterion yielded the following 12 societies for analysis: Denmark, England and Wales, Finland, France, Iceland, Italy, the Netherlands, New Zealand, Norway, Scotland, Sweden, and Switzerland. All of these countries experienced stark economic decline during the Great Depression.[12-14,17,18]

Consistent with the operational definition in the literature that confines the most severe component of economic stagnation to 1930-1933, we defined the Great Depression in our tests as 1930-1933, inclusive.[8] We focus on this time period as many countries reported economic gains after 1933 despite the overarching persistence of the Great Depression into the late 1930s. Restriction of the test to this 4 year period avoids interpretational ambiguity of period life expectancy gains or losses during modest economic expansion (e.g., 1933 onward) in the context of overall stagnation.

The Great Depression affected Western economies at varying time points but predominantly from 1930 to 1933, with the nadir typically occurring in 1931 or 1932.[12] To ensure that we captured any lagged associations between the Great Depression and unexpected changes in period life expectancy in Western countries, we examined up to 3 years after the start of the Great Depression (i.e., period life expectancy from 1930 to 1933). We, therefore, specified the Great Depression variable as a binary indicator with the value "1" for 1930 and "0" otherwise, and test 0, 1, 2 and 3 year lags of that variable (i.e., 1930, 1931, 1932, and 1933).

Analyses

Our test turns on whether the observed values of period life expectancy differ from the values expected under the null hypothesis of no perturbation in life expectancy during the Great Depression. Life expectancy in the late 19th and early 20th centuries trends upward and exhibits the tendency to remain elevated or depressed or to oscillate after high or low values. These patterns, typically referred to as autocorrelation, complicate observational tests because the expected value of autocorrelated series is often not their mean.

Researchers have devised methods to address this problem by identifying temporal patterns in the dependent variable and expressing them as an effect of earlier values in the dependent variable itself.[19] This data-driven time-series approach, referred to as ARIMA modeling, identifies and removes autocorrelation from the dependent variable series such that (1) the expected value of the residuals is 0, and (2) the residual annual observations are statistically independent of one another.

We believe that much of the divergence in research into the association between contracting economies and mortality arises from differences in method. The field has not adopted a convention for measuring the association between economic and mortality time series although candidates for such a convention have been developed in the last decade.[20-23] This circumstance raises the question of whether researchers choose methods that yield results they favor. We tried to address this problem by using two analytic routines. First, we, as all authors have in this field, used our judgment in identifying and modeling autocorrelation in the mortality time series.[5] Second, we applied a more automated, rule-based approach that uses relatively little researcher discretion and can be repeated exactly by any researcher with access to the data and to state-of-the-art software.

The approach that uses relatively more researcher discretion implements strategies devised by Dickey and Fuller[24] as well as Box and Jenkins[19] to identify and model patterns in annual period life expectancy for the 50 years prior to 1929. The Dickey-Fuller routines detect non-stationarity. Box and Jenkins methods model trends by differencing a series (i.e., subtracting the values of each year from those of the next year). The Box and Jenkins approach also uses autoregressive (AR) and moving average (MA) parameters to model other forms of autocorrelation. AR parameters best describe patterns that persist for relatively long periods, whereas MA parameters parsimoniously describe less persistent patterns.

For each country and separately for each gender, we identified and estimated models of period life expectancy for the 50 years prior to 1929, including controls for autocorrelation. Next, we added to this model the Great Depression variable at no lag (i.e., 1930) as well as lags of 1 through 3 years to ensure capturing any associations through 1933. We then repeated our time-series estimations for the time span that includes the Great Depression (i.e., through 1937).

Outliers in period life expectancy other than any associated with the Great Depression may inflate standard errors and induce a type II error. In the 50 years prior to 1929, several events in Europe (e.g., the 1918 influenza pandemic, World War I) may have perturbed period life expectancy sufficiently to create outlying values. To control for potential outliers, we added a binary variable for the 1918

Influenza pandemic to the final equations and applied iterative outlier detection and adjustment routines[25] to the residuals.

The steps described above required that we estimate, separately for each country and each gender (i.e., 12 countries X 2 genders = 24 tests), the following equation:

$$\nabla_d Y_t = c + \left(\omega_0 + \omega_1 B + \omega_2 B^2 + \omega_3 B^3\right)\nabla_d I_t + \omega_4 \nabla_d F_t + \frac{\left(1-\theta B^q\right)}{\left(1-\phi B^p\right)} a_t \qquad [1]$$

∇_d is the difference operator that indicates the variable has been differenced at order d (i.e., value at time t subtracted from value at time t+d).

Y_t is period life expectancy of infants born during year t.

c is a constant

I_t is the binary "Great Depression" variable scored 1 for 1930 and 0 otherwise.

B^n is the value of the variable at year t+n.

ω_0 to ω_3 are the estimated parameters for the Great Depression variable (from 1930 to 1933).

F_t is the binary Flu pandemic variable scored 1 for 1918 and 0 otherwise.

ω_4 is the estimated parameter for the 1918 Flu pandemic variable.

θ is the MA parameter.

φ is the AR parameter.

B^p and B^q are the values of *a* at year t-p for autoregressive and t-q for moving average patterns respectively.

a_t is the error term at month t.

Rule-based approach

As noted above, we conducted a second test that requires no researcher discretion in the application of ARIMA modeling rules. More specifically, we applied widely disseminated software that uses decision rules agreed among time-series analysts to detect and model autocorrelation. We used Scientific Computing Associates time-series analysis software because of its wide availability and automated implementation of expert-system univariate identification and modeling as well as of outlier detection routines.[26,27] The scholarly literature includes several interrupted time-series tests that use this software.[28,29]

The automated approach identifies the best fitting ARIMA model for period life expectancy of men and women for each of our populations for the years 1878 through 1928. The software also uses Chang's, Tiao's, and Chen's outlier detection routines[25] to discover any years from 1878 through 1933 in which the observed values fell outside the 95% confidence interval (2-tailed test) of the expected values. If the Great Depression induced salutary behavior and improved period life expectancy, we would find outliers above the 95% confidence level some time between 1930 and 1933. We refer the reader to the Appendix for a detailed description of the procedure.

RESULTS

Table 1 shows the mean, standard deviation, and range of period life expectancy over the test years. In all countries, mean life expectancy for females exceeds that of males. From 1878 to 1928, period life expectancy exhibits an upward trend for most countries.

Table 2 displays the outlier-adjusted results in which we used our judgment in implementing the Box and Jenkins rules. The general rise in period life expectancy over time required that we difference most (i.e., 20 of the 24) of the series to render them stationary in their mean. For 16 of the 24 series, period life expectancy also exhibits autocorrelation best modeled by autoregressive and/or moving average parameters. We observe a mean reduction of 8.8 years (males) and 7.45 years (females) of period life expectancy statistically attributable to the 1918 Spanish flu.

In 1930, period life expectancy for females in Italy and France and for males in England and Wales rises above expected levels. The greatest gain occurs in 1930 among males in England and Wales (coef. = 2.09 years; standard error [SE] = .7334, p<.01). The three unexpected gains appear in 1930 and do not persist into subsequent years. In the other 21 tests, period life expectancy from 1930 to 1933 remains within intervals expected from history.

The expert system software finds lower than expected period life expectancy for men and women in each of our test societies except Iceland and Denmark for either or both 1918 or 1919. The procedure also detects lower than expected values during several war years for many of the combatant countries in World War I. The routines, however, find no outliers for either men or women in any country for the years 1929 through 1933. The first author can provide tabulated ARIMA models and identified outliers to interested readers.

DISCUSSION

We examined life expectancy in twelve countries to determine the external validity of reports from the U.S. that period life expectancy improved procycically during the Great Depression. Among females, we find that only 2 of the 12 test countries (Italy and France) exhibit unexpected gains in period life expectancy in 1930, a year in which France's economy showed relative prosperity but Italy's economy experienced a precipitous decline.[11,30] Among males, 1 of the 12 countries (England and Wales) yields an increase in period life expectancy in 1930, the first calendar year of Britain's Great Depression. The remaining 21 tests show no perturbation in period life expectancy. Taken together, results do not generally support the procyclical hypothesis that life expectancy improved during the Great Depression.

An intuitive response to our findings may be to assume that the twelve Western economies we studied suffered much milder depressions than did the U.S., thereby rendering comparisons across countries inappropriate. We caution against this inference. All the countries we studied experienced a sharp rise in unemployment as well as a decline in productivity at some point from 1930 to 1933 that rivaled the magnitude of the Great Depression in the U.S. For example, economists have described Norway as a country that underwent a "mild" Great Depression relative to the U.S.[13] Norway, however, shows an 8.4 percent decline in GDP per capita from 1930-1931 and an unemployment rate of 22 percent in 1931, which rivals the U.S. case in its magnitude (e.g., 9.0% GDP reduction from 1929-1930; maximum unemployment rate of 22.9% in 1932).

Strengths and Limitations

Strengths of our analysis include that we used life table data constructed by demographic conventions that insure comparability of life expectancy over time and across societies. Second, time-series methods remove autocorrelation in the dependent variable — which could bias correlational tests towards a type I error — before examining the effect of the Great Depression. Third, we test the robustness of the results by using a rule-based methodology that researchers can replicate with available software. In all 24 tests, the rule-based approach discovered no perturbation in period life expectancy from 1930 to 1933, which indicates that life expectancy in our twelve test countries did not improve during the Great Depression.

Limitations of our study involve the lack of data on cause-specific mortality or on specific welfare support provided by each country. This information would permit a more detailed comparative analysis of the population mortality response to the Great Depression in the U.S. relative to the twelve Western countries we analyzed. It remains possible, for instance, that a larger welfare support structure in Western countries allowed these populations to withstand the Great Depression with less social unrest than in the U.S. case. For example, maintenance of relative social stability or federal support programs in Europe during the Great Depression may have resulted in fewer changes in health behaviors that Tapia Granados and Diez Roux propose as causes of mortality decline in the U.S.[8] We encourage closer inspection of country differences in social and political structure to explain these divergent findings.

The United States does not have national mortality data available prior to 1900. Absent these life expectancy data, we could not apply our time-series routines to the United States. Based on our results, however, the improvement of population health in the United States during the Great Depression did not occur in other Western societies.

Examination of life expectancy for both sexes in twelve populations required estimation of coefficients for 24 tests. A limitation of our analysis, therefore, involves the increased likelihood of a type I error (i.e., falsely rejecting the null) due to multiple tests. In all but three tests, however, we do not reject the null (i.e., no perturbation in period life expectancy). The rule-based methodology, moreover, indicates a null result for all 24 tests. Therefore, results for the Great Depression preclude this potential error introduced by multiple testing.

Conclusion

Although much research tests the relation between macroeconomic conditions and mortality, less work has examined the population consequences of extreme economic downturns. Investigation of the Great Depression indicates that period life expectancy in twelve societies did not rise above expected levels. Our findings suggest that contemporary procyclical explanations that connect economic downturns to improvements in life expectancy do not generalize to Western societies forced to adapt to the most extreme economic crisis in the 20th century.

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Table 1. Mean, standard deviation, and minimum as well as maximum values for period life expectancy, 1878-1937, for the twelve societies analyzed.

	Mean	Std. Dev.	Minimum	Maximum
Period Life Expectancy				
Females				
Denmark	56.35	.75	45.72	65.18
England and Wales	53.77	.82	44.58	64.55
Finland	49.34	.70	38.94	59.94
France	51.12	.72	42.98	62.16
Iceland	54.06	1.12	18.83	66.38
Italy	45.01	.97	28.33	58.17
Netherlands	54.33	1.03	41.81	67.72
New Zealand	62.12	.52	55.32	69.17
Norway	58.04	.69	48.48	67.70
Scotland	52.02	.66	44.82	61.20
Sweden	57.45	.68	47.98	66.08
Switzerland	53.61	.89	41.77	65.42
Males				
Denmark	53.98	.76	43.82	63.04
England and Wales	40.74	.79	41.05	60.45
Finland	45.54	.67	26.32	54.77
France	46.83	.66	33.84	56.15

	Mean	Std. Dev	Minimum	Maximum
Iceland	48.91	1.14	16.76	61.89
Italy	43.37	.95	23.50	55.57
Netherlands	52.10	1.10	38.95	66.22
New Zealand	59.19	.55	50.61	66.44
Norway	55.08	.70	46.24	64.70
Scotland	48.96	.60	42.22	57.48
Sweden	54.91	.71	45.36	63.84
Switzerland	50.52	.85	39.17	61.50

Table 1 (continued)

	Denmark		England and Wales		Finland	
	Males	Females	Males	Females	Males	Females
Differencing	First Differences	First Differences	First Differences	First Differences	--	First Differences
Constant	.201 (.064)**	--	.352 (.048)**	.411 (.062)**	46.725 (1.708)**	--
1918 Influenza	-.889 (.562)	-.840 (.813)	-8.792 (.703)**	-7.650 (.580)**	-18.551 (.925) **	-2.447 (1.183)*
Great Depression:						
1930	-.178 (.621)	-.004 (1.028)	2.093 (.734)**	1.209 (.644)	2.199 (1.168)	1.456 (1.745)
1931	-.855 (.643)	-.838 (1.259)	.401 (.755)	.581 (.653)	1.825 (1.426)	2.049 (2.263)
1932	-.157 (.643)	-.762 (1.259)	.457 (.756)	.145 (.653)	1.762 (1.425)	1.410 (2.275)
1933	.668 (.620)	-.216 (1.028)	-.145 (.735)	-.301 (.642)	.275 (1.167)	-.071 (1.719)
MA Parameters	--	--	B^1= .573 (.125)**	--	--	B^3 = .413 (.142)**
AR Parameters	B^1= -.463 (.124)**	--	--	B^1 = -.565 (.124)**	B^1 = .879 (.060)**	--

*p<0.05; two-tailed test
**p<0.01; two-tailed test

Table 2. Outlier-adjusted equations for male and female period life expectancy in twelve societies as a function of the Great Depression, the 1918 Influenza pandemic, and autocorrelation (n=60 years beginning 1878). Standard errors in parentheses.

	France		Iceland		Italy	
	Males	Females	Males	Females	Males	Females
Differencing	First differences	First differences	--	--	First differences	First differences
Constant	--	.409 (.101)**	51.045 (.895)	57.974 (1.404)	--	.3700 (.057)**
1918 Influenza	-7.713 (.731)**	-9.636 (.640)**	-6.355 (2.158)*	-7.984 (2.836)**	-12.445 (.877)**	-18.097 (.725)**
Great Depression at:						
1930	1.694 (.924)	1.71 (.800)*	-1.949 (2.515)	1.836 (3.376)	2.024 (1.128)	1.733 (.779)*
1931	1.167 (1.132)	.766 (.910)	-.433 (2.900)	1.200 (3.953)	.779 (1.380)	.610 (.806)
1932	.656 (1.132)	.367 (.899)	-.177 (2.899)	2.727 (3951)	-.2 96 (.381)	.087 (.803)
1933	.353 (.924)	-.022 (.763)	-.586 (2.514)	3.125 (3.372)	.388 (1.117)	.913 (.769)
MA Parameters	--	B^1 = .114 (.050)*	--	--	--	B^1= .501 (.134)**
AR Parameters	B^1= -.463 (.124)**	--	--	B^1 = -.565 (.120)**	B^1 = .879 (.060)**	--

*p<0.05; two-tailed test
**p<0.01; two-tailed test

[Table 2 continued]

	The Netherlands		New Zealand		Norway	
	Males	Females	Males	Females	Males	Females
Differencing	First differences	First differences	First differences	First differences	First differences	First differences
Constant	.438 (.135)**	.362 (.129)**	--	.210 (.051)**	.2857 (.117)*	.349 (.122)**
1918 Influenza	- 7.775 (.709)**	-7.61 (.674)**	-11.983 (.607)**	-7.105 (.444)**	-7.235 (.613)**	-6.645 (.641)**
Great Depression at:						
1930	1.624 (.897)	1.630 (.852)	.0670 (.838)	-.0226 (.493)	. 8380 (.776)	.948 (.811)
1931	.438 (1.100)	.320 (1.044)	.0490 (1.084)	.1356 (.511)	.2360 (.951)	.086 (.993)
1932	.642 (1.100)	.490 (1.044)	1.359 (1.082)	.3258 (.511)	.0540 (.951)	-.276 (.993)
1933	.416 (.897)	.240 (.853)	1.183 (.837)	.6961 (.493)	.0720 (.776)	-.028 (.811)
MA Parameters	--	--	--	--	--	--
AR Parameters	--	--	B2 = -.425 (.124)**	B^1 = -.455 (.117)**	--	--

*p<0.05; two-tailed test
**p<0.01; two-tailed test

[Table 2 continued]

	Scotland		Sweden		Switzerland	
	Males	Females	Males	Females	Males	Females
Differencing	First Differences	First Differences	First Differences	First Differences	First Differences	First Differences
Constant	.316 (.059)**	.358 (.059)**	.266 (.058)**	.303 (.027)**	.311 (.108)**	.303 (.083)**
1918 Influenza	-4.383 (.604)**	-4.776 (.609)**	-9.219 (.571)**	-8.906 (.584)**	-10.175 (.565)**	-7.779 (.589)**
Great Depression:						
1930	.0063 (.670)	.197 (.698)	.299 (.635)	.157 (.613)	.584 (.715)	.787 (.683)
1931	1.002 (.697)	.952 (.697)	-.527 (.678)	-.779 (.617)	.158 (.876)	-.143 (.754)
1932	-.3015 (.697)	-.803 (.698)	.276 (.676)	.191 (.615)	-.398 (.876)	-.653 (.754)
1933	.4051 (.695)	.405 (.697)	.560 (.629)	.901 (.607)	.246 (.715)	.145 (.679)
MA Parameters	--	--	B^1= .381 (.137)**	B^1 = .688 (.108)**	--	--
AR Parameters	B^1= -.827 (.081)**	B^1 = -.834 (.078)**	--	--	--	B^1 = -.241 (.135)*

*p<0.05; 1 tailed test
**p<0.01; 1 tailed test

[Table 2 continued]

APPENDIX

The rule-based approach applies widely disseminated decision rules developed by time-series analysts to implement the logic described above. This analysis can be repeated exactly by any researcher with access to the Human Mortality Database and to state-of-the-art software that implements these decision rules. The software uses rules devised by Box and Jenkins[19] and others[20-24] to identify best fitting ARIMA models and those offered by Chang, Tiao, and Chen[25] to discover outliers. None of the authors of this paper contributed to the development of this software or benefit in any way from its dissemination.

We used the software to first identify the best fitting ARIMA model for period life expectancy of men and women for each of our societies for the years 1858 through 1928. We then allowed the software to use these models to estimate expected values for the years 1858 through 1933 and to use Chang's, Tiao's, and Chen's[25] outlier detection routines to discover any years in which the observed values fell outside the 95% confidence interval (2-tailed test) of the expected values. We anticipated, for example, that the "Spanish Flu" may have yielded outliers in 1918 and or 1919 below the 95% confidence interval, and that those countries most involved in World War I may exhibit lower than expected period life expectancy during one of more of the war years. If the theory that the Great Depression induced salutary behavior were correct, we would also find outliers below the 95% confidence level sometime between 1929 and 1933. Readers can obtain the commands for our analyses from the first author.

Essentially our method searched for two patterns of outliers. We refer to these changes as spikes and decay. Spikes are outliers in which the observed value for a single year falls above or below the 95% confidence interval of the expected value. Decay alludes to outliers in which the initial spike decays geometrically such that at least one subsequent value remains outside the 95% confidence interval.

A spike would be specified in equation 1 as follows.

$$\nabla^d Z_t = \theta_0 + \omega I_t + \frac{\left(1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta q B^q\right)}{\left(1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p\right)} a_t \quad [1]$$

I_t is a binary variable scored 0 for all years before the outlier, 1 for the year of the outlier, and 0 afterward.

Decay would be specified as follows.

$$\nabla^d Z_t = \theta_0 + \frac{\omega I_t}{(1 - \delta B)} + \frac{\left(1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta q B^q\right)}{\left(1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p\right)} a_t \quad [2]$$

δ is the proportion of I_t carried into the next year.