

## **Predicting Older Age Mortality Trends**

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### **Abstract**

Improving early prenatal and postnatal conditions account for at least 16 to 17 percent of the decline in ten year mortality rates of 60-79 year olds between 1900 and 1960-80. Historical trends in early prenatal and postnatal conditions imply that while the baby-boom cohort may be particularly long-lived compared to past cohorts, mortality rates may not fall as steeply for the cohorts born after 1955 as for earlier cohorts.

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## 1. Introduction

Life expectancy at older ages has increased sharply in the OECD countries during the twentieth century. In 1900 a 60 year old Italian, Frenchman, or Englishman could expect to live another 13 years and a Swede another 16 years. By 1950 life expectancies at age 60 had risen to 17 and 18 years, respectively. By the end of the century a 60 year old Italian, Frenchman, or Swede could expect to live another 23 years and an Englishman another 21 years.<sup>1</sup> This unexpected increase in life expectancy, while one of the major accomplishments of the last century, has strained social security systems and remains poorly understood, making forecasts of future mortality trends problematic. One particularly intriguing line of research has argued, not without controversy, that aging begins at or even before birth. Not only can maternal health and nutrition affect in-utero development, but poor nutrition and infectious disease in early infancy can have a permanent scarring effect, leading to the onset of chronic disease at older ages (Barker 1992; Barker 1994).

This paper investigates the contribution of early life environmental factors to the twentieth century mortality decline and investigates whether aging is less likely to begin at birth as humans have gained more and more control over their environment. As a proxy for the early life environment we use season of birth. Doblhammer and Vaupel (2001) present convincing evidence that in recent populations those 50 years old and over born in the northern hemisphere live longer if they were born in the fourth quarter instead of the second quarter whereas in the southern hemisphere the pattern is exactly reversed. They argue that those

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<sup>1</sup>See *Human Mortality Database*, University of California, Berkeley and Max Planck Institute for Demographic Research. Available at [www.mortality.org](http://www.mortality.org) or [www.humanmortality.de](http://www.humanmortality.de).

born in the second quarter, after the long winter months, experienced reduced intrauterine growth. The populations they examined were for the most part born in the twentieth century when the mortality transition was already well under way. But, to understand the twentieth century decline in older age mortality, we need to examine a population that reached old age at the beginning of the twentieth century. A unique longitudinal data set allows us to examine the effect of quarter of birth on older age mortality in an American population that was at least age 60 in 1900. We compare quarter of birth effects in this population with those observed in the American population of the same age in 1960-80. This allows us to quantify the importance of the changing relationship between season of birth and older age mortality to the twentieth century mortality decline and to provide suggestive evidence on future mortality trends.

## **2. Empirical Framework and Data**

The past population that we examine is one of white men who fought for the Union in the American Civil War of 1861-65 and who were alive in 1900.<sup>2</sup> The sample is based upon the military service records of more than 35,000 men linked to their pension records and to the 1850, 1860, 1900, and 1910 censuses. In 1900 we have detailed data on the individual characteristics of close to 5000 men, whom we can follow until death. The population that we study is representative of white, northern-born men or pre-1861 immigrants in terms of wealth and older age mortality (Fogel 2001).

Our recent population is one of men and women of all races in the 1960-80

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<sup>2</sup>The Union Army data were collected by a team of researchers led by Robert Fogel and are available at <http://www.cpe.uchicago.edu>.

micro-census samples. Because we cannot follow these individuals until death, we create age, sex, cohort, and quarter of birth cells and calculate 10 year mortality rates for each cell across the census years. We limit the sample to the native-born age 60-79 because we are calculating mortality rates from cell sizes and because age misreporting increases with age. To ensure comparability across samples we also restrict the Union Army sample to the native-born age 60-79 and examine 10 year mortality rates.

We estimate season of birth effects in the Union Army data by running a probit regression of the form

$$\text{Prob}(\text{death}=1) = \Phi(\alpha + \gamma_1 Q_1 + \gamma_2 Q_2 + \gamma_3 Q_3 + \delta X) \quad (1)$$

where death is death within 10 years,  $Q_1$ ,  $Q_2$ , and  $Q_3$  are the first (January-March), second (April-June), and third (July-September) quarters, with the fourth quarter (October-December) omitted, and the  $X$  is a vector of control variables including age, occupation at enlistment and in 1900, size of city of residence at enlistment and in 1900, household personal property wealth in 1860, marital status in 1900, wartime wound and infectious disease experience, and POW status. We present derivatives for quarter of birth,  $i$ , effects,  $\beta_i = \partial P / \partial Q_i$ .

Using the census micro-samples we construct ten year mortality rates across the 1960-80 micro census samples for a group which is defined by age, sex, cohort, and quarter of birth.<sup>3</sup> We then estimate weighted OLS regressions of

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<sup>3</sup>The census samples are available at <http://www.ipums.umn.edu>.

the form

$$m = \alpha + \beta_1 Q_1 + \beta_2 Q_2 + \beta_3 Q_3 + \delta X + u \quad (2)$$

where  $m$  is the mortality rate,  $Q_1$ ,  $Q_2$ , and  $Q_3$  are the first, second, and third quarters of birth (the fourth is omitted),  $X$  is a vector of age, sex, and cohort controls, and  $u$  is an error term. The weights are equal to cell sizes. (We also experimented with a logarithmic specification, but the linear specification gave us a better fit.)

We attribute the difference in ten year mortality rates due to a change in the coefficients on season of birth as

$$Q_{1,UA}(\beta_{1,UA} - \beta_{1,R}) + Q_{2,UA}(\beta_{2,UA} - \beta_{2,R}) + Q_{3,UA}(\beta_{3,UA} - \beta_{3,R}) \quad (3)$$

using the recent function and as

$$Q_{1,R}(\beta_{1,UA} - \beta_{1,R}) + Q_{2,R}(\beta_{2,UA} - \beta_{2,R}) + Q_{3,R}(\beta_{3,UA} - \beta_{3,R}) \quad (4)$$

using the Union Army function, where the  $\beta$ s are the estimated coefficients from the Equation 2 or the derivatives of the coefficients in Equation 1 and where the subscripts  $UA$  and  $R$  indicate the Union Army sample and the recent sample respectively. Note that we are assuming that ten year mortality rates both in the Union Army sample and in the more recent census sample can be written as linear functions of quarter of birth using the estimated coefficients or their derivatives. Also note that season of birth effects represent a lower bound estimate of the

effect of early life conditions. As we show in Costa and Lahey (2003), men who grew up in large cities, where infectious disease was endemic, were permanently scarred even controlling for later residence and season of birth.

### **3. Results and Interpretation**

Table 1 shows that quarter of birth predicts older age mortality in both the Union Army sample and in the more recent population, but that the effect of quarter of birth has lessened. Union Army veterans born in either the second or the third quarter had higher mortality rates by 0.04 than those born in the fourth quarter, a 9 percent increase in the mean 10 year mortality rate of 0.45. In contrast, in 1960-80 those born in the second rather than the fourth quarter experienced an 0.03 increase in mortality rates, an increase of 8 percent relative to the mean 10 year mortality rate of 0.36. Those born in the third rather than the fourth quarter had mortality rates higher by 0.01, a 4 percent increase in the mean 10 year mortality rate. When we expanded our age category to include 50 year olds as well, we found no quarter of birth effects.

Why were spring and summer such bad seasons to be born in? We can rule out social differences in the distribution of births. In the Union Army data, household wealth in 1860 (either own or parents') is a good indicator of household wealth during the growing years. But, there was no difference in either mean total household personal property wealth or real estate wealth in 1860 between those born in the spring and summer and those born in other quarters. (T-tests yielded  $P > |t| = 0.621$  and  $P > |t| = 0.909$ , respectively.) We also looked at measures of the father's occupational status by quarter of birth for all children age

10 or less in the micro-sample of the 1900 census, the only early census which identifies month of birth. But, there was no difference in the father's mean occupational score or his Duncan socioeconomic index between those children born in the spring and summer and those born in other quarters or those children born in the spring and those born in other quarters. (The differences were significant at only the 20% level.) We can also rule out any selection effects during the war. Quarter of birth was neither a statistically significant nor a qualitatively important predictor of war survivorship. Lastly, we can also rule out any mortality selection effects in early life as potential explanations for our season of birth effects. As we discuss below, infant mortality peaked in the summer months, implying that babies born in the spring and summer who survived should be the longest-lived if only the fittest survive a high mortality regime.

Past patterns in mortality and birth weights suggest that seasons affected both the adequacy of maternal diets and infectious disease incidence in early infancy and in pregnancy. The mortality of infants and of children below age two peaked in the summer because of diarrhea and its sequelae throughout the nineteenth century, starting to dampen in the late nineteenth and early twentieth century but persisting until 1920 (Condran and Lentzer 2003).

Poor nutritional intake and maternal infection from respiratory disease during the winter months may have led to low birth weights and high prematurity rates among babies born in the spring.<sup>4</sup> A study of a rural North Carolina mill town begun in 1939 found that in the spring vitamin levels were at their lowest point (Beardsley 1989: 204). Data on birth weight and prematurity rates from Johns

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<sup>4</sup>The winter mortality peak from respiratory disease did not dampen until 1920 (Michael Haines, personal communication).

Hopkins in the first third of the twentieth century show that babies born during the second quarter (April-June) were more likely to be premature and that babies born during the spring (March-May) had lower birth weights, even if they were full-term (Costa 2004).

Union Army veterans born in the spring and summer were more likely to die of heart disease and stroke than those born at other times of the year, an association consistent with the correlation between low birth weight and low weight gain in infancy and hypertension, coronary heart disease, and cerebral hemorrhage later at older ages (Barker 1992, 1994). Veterans born in the third compared to the fourth quarter were 1.3 times more likely to die of heart disease. Men born in the second quarter were 1.7 times as likely to die of stroke as those born in the fourth quarter and those born in either the first or third quarter were 1.6 times as likely to die of stroke as those born in the fourth quarter.<sup>5</sup>

The impact of season of birth effects fell between 1900 and 1960-80, coincident with declining infectious diseases rates, particularly from summer waterborne diseases, and an improving food supply. The declining impact of season of birth accounts for roughly 16 to 17 percent of the 0.087 difference in the 10 year mortality rates of Union Army veterans and of Americans in 1960-1980. (Equations 3 and 4 yield 0.014 and 0.015, respectively, which represents 16 and 17 percent of the difference in 10 year mortality rates.) Because differences in the seasonality of births in the two samples are negligible, the difference in ten year mortality rates due to changes in season of birth is virtually zero.<sup>6</sup>

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<sup>5</sup>Results on cause of death are from independent competing risk hazard models that control for demographic and socioeconomic characteristics. The respective hazard ratios were 1.251, 1.701, 1.583, and 1.596 with respective standard errors of 0.156, 0.362, 0.336, and 0.347.

<sup>6</sup>The fractions born in the first, second, third, and fourth quarters were 0.261, 0.252, 0.241, and 0.245, respectively, in the Union Army sample. The respective fractions for Americans in



#### 4. Predicting Future Mortality Trends

Trends in birth weight seasonality suggest that improving prenatal and early postnatal conditions will lead to a continuing decline in older age mortality. The baby-boom generation (born 1945-1964) grew up at time when infectious disease was rare and when the food supply was not as limited by agricultural seasonality and this generation may not even experience an adverse effect of being born in either the spring or summer. Although there is still a seasonality pattern in birthweights, this seasonality pattern is not very pronounced, differs from that observed at the beginning of the century, and has been dampening steadily since the 1960s (calculated from various issues of *Vital Statistics*). If there are no long-term season of birth effects on older age mortality for the baby-boom generation, then our regression results suggest that in 2025 (when the peak of the baby-boom generation reaches age 70) 10 year mortality rates at ages 60-79 will be at least 3 percent lower than those of the elderly in 1960-80.<sup>7</sup> Although a 3 percent decline over 55 years is modest, recall that between 1900 and 1960-80, a 70 year time span, the diminishing impact of season of birth on mortality rates led to a 3 percent decline in mortality rates.

Our findings provide both good and bad news for social security systems. The cohort which will reach age 70 in 2025 was born in 1955 after sharp improvements in prenatal and postnatal conditions and this cohort may be particularly long-lived compared to past cohorts. Because of long-run fertility trends, the baby-boom cohort will also be a very large cohort relative to later cohorts, strain-

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1960-1980 were 0.266, 0.232, 0.257, and 0.245.

<sup>7</sup>We assume that the coefficients on season of birth in a mortality regression would be 0 for the baby-boom generation and calculate the difference in 10 year mortality rates due to changes in the coefficients using the 1960-80 function.

ing pay-as-you-go systems. However, the difference in early life conditions for cohorts born in 1955 instead of 1995 was not as stark as that for cohorts born in 1915 instead of 1955. The rate of mortality declines may therefore diminish after 2025 because any further changes could not come from improving early life factors – they would need to come from improvements in medical care or in health habits.

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Table 1: Comparison of the Effects of Quarter of Birth on Ten Year Mortality Rates of 60-79 Year Olds, Native-Born Union Army Veterans, 1900, and Native-Born Americans, 1960-1980

	UA Veterans		1960-1980	
	$\frac{\partial P}{\partial x}$	Std Err	Coef-icient	Std Err
Dummy=1 if born in				
First quarter	0.020	0.022	0.003	0.005
Second quarter	0.042*	0.023	0.030‡	0.006
Third quarter	0.041*	0.023	0.013†	0.006
Fourth quarter				
Observations	4927		128	
Pseudo R <sup>2</sup> /R <sup>2</sup>	0.036		0.984	

The Union Army regression results are from a probit equation on individual level data in which the dependent variable is whether the veteran died within 10 years of being observed alive in 1900 (see Equation 1). The 1960-1980 results are from a weighted ordinary least squares equation using group-level data (see Equation 2). See the text for the control variables. Ten year mortality rates in the Union Army sample are 0.445 and in 1960-1980 are 0.358. The symbols ‡ and † indicate that the coefficient is statistically significantly different from zero at the 1 and 5 percent level, respectively.