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3

Prior Exposure to Disease and Later Health and Mortality
Evidence from Civil War Medical Records

Chulhee Lee

3.1 Introduction

Researchers in various disciples have long tried to understand the interrelationship of socioeconomic status, environment, and health. This subject is related to a number of important issues, such as the changing relationship among host, agent, and environmental factors, the socioeconomic differences in health, and the long-term decline in mortality. The medical and epidemiological literature provides many examples of the possible links between early-life conditions and chronic disease at older ages. A series of studies by D. J. P. Barker and his colleagues (Barker 1992, 1994) links many of the degenerative conditions of old age to exposure to infectious disease, malnutrition, and other types of biomedical and socioeconomic stress in utero and in the first year of life. Studies have found that infectious diseases affect the chances of suffering chronic conditions such as heart, respiratory, and musculoskeletal disorders (Elo and Preston 1992; Costa 2000). These findings provide evidence for the "insult accumulation model," which states that each insult from illness or injury leaves the individual more susceptible to disease in the future (Alter and Riley 1989). However, the relationship between the early-life conditions of a cohort and its later health is not entirely

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straightforward. Individuals who survive infectious disease may acquire partial or complete immunity and therefore may have lower mortality rates (Lee 1997).

It is well documented that there are considerable variations in health across populations of different socioeconomic backgrounds (United Nations [UN] 1973). Inequality in health is an important social problem even in highly wealthy and egalitarian nations today (Kitagawa and Hauser 1973; Notkota et al. 1985; Lehmann, Mamboury, and Minder 1990; Diderichen 1990; Lawson and Black 1993; Deaton and Paxson 1999). Some evidence suggests that the social health gradient has not diminished in spite of rising income during the second half of the twentieth century (Preston, Haines, and Pamuk 1981; Marmot et al. 1991; Marmot 1999). It is widely accepted that such health differentials by socioeconomic status cannot be fully explained by differences in health behaviors or in access to medical care. Numerous hypotheses have been suggested to explain how social and economic environments alter human biological functioning. Some frequently cited mediating factors between wealth and health include work-related stress, family background, and other social support networks. A growing number of studies demonstrate that health at middle and older ages reflects earlier health and may be correlated across and within generations (Barker et al. 1989; Barker 1997; Ravelli et al. 1998; Wadsworth and Kuh 1997). Some studies see the principal impacts of socioeconomic status on health as stemming not from brief episodes but instead from the accumulation of repeated stress over the lifespan (Seeman et al. 1997). Another line of research focuses on the role of income inequality, maintaining that inequality in relative socioeconomic status raises the level of psychosocial stress that negatively affects endocrine and immunological processes (Sapolsky 1993; Wilkinson 1996). In spite of the tremendous amount of previous research, there is still heated debate going on over the magnitude of the socioeconomic differences in health and the causes of the recent rise in the inequality in health (Fogel and Lee 2002).

The patterns of socioeconomic differences in mortality and morbidity provide important clues to the causes of long-term changes in health. Studies have attributed the long-term improvement in health to a number of factors, including the elimination of chronic malnutrition; advances in public health; improvements in housing, sanitation, and food hygiene; and advances in medical technology (Higgs 1973, 1979; Appleby 1975; McKeown 1976, 1983; Condran and Cheney 1982; Livi-Bacci 1982; Kunitz 1983; Fogel 1986, 1991). Recent historical studies have found that health as measured by life expectancy and mean adult height deteriorated through the early nineteenth century in the United States and some European nations in spite of the growth in per capita income (Pope 1992; Floud and Steckel 1997). This finding indicates that economic growth and epidemiological conditions are not independent forces, and (more importantly) that, under certain circumstances, the effects of economic development on the disease environment can be strongly adverse.[1] Despite the extensive research on such issues, the relative importance of the potential factors of health remains unclear. Achieving a proper understanding of these matters is important not only from a historical point of view, but also, perhaps more significantly, for predicting the impact on health of ongoing technological and social changes in developing countries.

The purpose of this article is to deepen our understanding of these issues by exploring the effects of socioeconomic status and local disease environment on the later health and mortality of Union Army recruits. The Union Army sample and supplemental data set containing information on local death rates are ideal for addressing the issues introduced above, since they possess the following major advantages over data analyzed in previous research. First, the semicontrolled conditions of the army camps during the war provide a unique chance to determine the relationship between socioeconomic background and health. The Civil War brought together a large number of men from heterogeneous socioeconomic and ecological backgrounds into an extremely unhealthy environment that caused unusually high rates of disease contraction and consequent mortality.[2] Upon being mustered into the service, rural dwellers were suddenly plunged into close contact with impoverished men from cities where disease and mortality rates were high, but who were nevertheless in good enough health to pass a physical examination. Another unique feature of the army is that recruits were confined to relatively homogeneous living conditions in terms of the quality of diet, housing, and disease environment compared to normal society. Owing to these features of army life, we are able to identify more clearly the effects of socioeconomic and ecological factors—in particular, the extent of previous exposure to disease—on the degree of susceptibility or resistance to disease. Furthermore, detailed descriptions of disease diagnoses, and cause and date of death while in service, which are contained in the Union Army medical records, make it possible to examine the patterns of cause-specific mortality and timing of wartime deaths.

In an earlier paper, I analyzed the wartime disease experiences of Union

1. The possible causes of the downward swings in the trend of health, according to these studies, are rapid urbanization, a decline in the proportion of the population employed in agriculture, increased geographical mobility, more rapid increases in population than in food supply, a rise in the relative food price, an increase in inequality in income distribution, short-term adverse movement in real wages, and the turbulence of the Civil War (Rosenberg 1962; Steckel 1983, 1995; Fogel 1986, 1991; Komlos 1987; Floud, Wachter, and Gregory 1990; Cuff 1992; Costa 1993; Gallman 1995, 1996; Margo 2000, ch. 7).

2. About 12 percent of all recruits who served in the Union Army died while in service (Vinovskis 1990). Death from disease was more than twice as frequent as death from injury (Steiner 1968, 8). Civil War armies actually suffered comparatively less disease mortality than any previous army. The ratio of the number of deaths from disease to the number of soldiers killed in combat was 7 for the American army in the Mexican War, and 8 for British soldiers in the Napoleonic Wars (McPherson 1988, 487).

Army recruits based on a relatively small sample of persons from the state of Ohio (Lee 1997). This study showed that the relationship between personal characteristics and health among army recruits was nearly the opposite of the common patterns of socioeconomic differences in health found in the civilian populations in the nineteenth century. Former farmers, rural residents, and natives, who were healthier on average prior to enlistment, were more likely to contract and die from disease than were nonfarmers, urban dwellers, and non natives, respectively. I suggested that socioeconomic differences in early childhood exposure to disease were responsible for the unusual patterns of mortality differentials while in service.[3]

This article extends and improves my previous study in three major respects. First, I use a much larger sample of Union Army recruits from eighteen different states in the Northeast, Midwest, and upper South. This larger and geographically more balanced sample will provide a more general picture of wartime medical experiences during the Civil War. This also enables me to analyze how the effects of socioeconomic and ecological factors on health varied across different regions. Second, I employ an improved measure of economic status, namely, household wealth per adult male equivalent. This new index will more accurately represent the economic well-being of a person than does household wealth because it considers not only the extent of economic resources but also the need for spending. Finally, and most significantly, I use a more explicit measure of the local disease environment, namely, county-level child death rates, which will enrich our understanding of the link between the extent of exposure to disease and later health.

3.2 Data

This study is based on a sample of the several primary data sources that were collected and linked as part of the project titled "Early Indicators of Later Work Levels, Disease, and Death" jointly sponsored by the National Institutes of Health, the Center for Population Economics at the University of Chicago, and Brigham Young University. The sample used in this paper is composed of 28,546 recruits who enlisted in the states of Connecticut, Delaware, Illinois, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New York, Ohio, Pennsylvania, Vermont, West Virginia, and the District of Columbia.

3. Despite the negative consequences for net nutritional status, survivors of unhealthy environments developed better immunity to some of the infectious diseases that were rampant in army life. Lee (1997) provides suggestive evidence in support of this hypothesis, based on the patterns of disease-specific mortality differentials and of the timing of death. Some diseases are known to have greater potential for the development of immunity. By classifying diseases by this criterion, I found that the "paradoxical" differentials were greater for diseases with greater immunity potential. The difference in the hazard of dying from immunity-sensitive disease was much greater in the earlier stages of military service when enlistees were not seasoned to the unhealthy environment of the army camps.

The service records contain very detailed descriptions of the diseases or wounds that recruits suffered during military service. As soon as a recruit was too ill to report for duty, his condition was noted in morning reports. If his condition required medical attention, it was recorded in the regimental surgeon's report; if he was hospitalized, the diagnosis of the disease was described in the case history together with the ultimate outcome, such as return to service, discharge for disabilities, or death (U.S. Surgeon General's Office 1870, vol. 1). Information on disease and on date and cause of death in service were gathered from these sources. Military service records provide information on demographic and socioeconomic characteristics of recruits, such as age, occupation at enlistment, place of birth, and height, among other variables, as well as on their military careers, including rank, military duty, company, regiment, change in military status, dates of enlistment and discharge, and so on. Additional information on socioeconomic status and on household structure prior to enlistment can be drawn from manuscript schedules of the 1860 census: These contain information on age, occupation, place of birth, household wealth, place of residence, and literacy, not only for recruits but also for their family members.

In order to construct county-level child death rates, an indicator of local epidemiological environment in the areas in which recruits lived prior to enlistment, I utilize a sample of mortality data from the 1860 federal population census.[4] This sample is not a complete compilation of the mortality schedules for 1850 and 1860. The collection contains information on roughly 400,000 decedents in twenty states, with good coverage of Midwestern and Southern states, but has less information for the Northeast (e.g., the collection contains no records for New York, Massachusetts, or Pennsylvania). Each record reports the state and county in which the death occurred, the date and cause of death, the decedent's age at death, and his or her occupation and place of birth.

One obstacle in using these county-level variables on mortality is a potential bias problem. The number of deaths may have been understated in these sources for several reasons. The two most important of these are, first, the retrospective nature of the question (if the interviewee either forgot

4. The mortality data used in this study are available at the Web page of the Center for Population Economics, http://www.cpe.uchicago.edu. This sample of mortality data was created by genealogist Ronald V. Jackson during the 1980s. Although Jackson's principal interest was in obtaining nominal information to provide to individuals exploring their family history, he collected the full range of data available in the mortality schedules. These records were generated by census marshals in their house-to-house canvass in the 1850 and 1860 censuses of the United States. The marshals concluded their interviews with each household by inquiring whether anyone from the household had died in the twelve months preceding the day of the interview. If the answer was affirmative, information on decedents was recorded on a separate mortality schedule. Most of these schedules were returned to state archives earlier in this century, and many have since been microfilmed. Some of these were acquired by Jackson and computerized at his facility in Salt Lake City. See the chapter by Ferrie in this volume for detailed features of these data.

about a death or was unaware of one, such death would not be reported on these schedules), and second, should an entire household have died, none of their deaths would be reported. If the magnitude of such potential undercounts differed across counties, there will be a bias problem arising from measurement errors, as described in Condran and Crimmins (1979). I have not made any attempt to correct such potential errors in this study.

Since the data have been constructed from a number of different sources with uneven rates of successful linkage, the use of several different samples depending on the variables used in the analysis is unavoidable. Among the socioeconomic variables needed for this study, household wealth and county of residence as of 1860 are found only in the census data. Of the 28,546 recruits, 11,056 men (about 39 percent) were successfully linked to the 1860 census. Therefore, I limit the sample to these 11,056 recruits whenever household wealth is concerned. In addition to these individuals, we have information on county of enlistment for 8,264 recruits among those who were not linked to the 1860 census. Assuming that these recruits enlisted in the army in the same counties where they lived in 1860, I use the sample of 19,320 men who were linked to the 1860 census or whose counties of enlistment were known, whenever the information on the county of residence prior to enlistment is needed. Finally, of the 11,056 men who were linked to the 1860 census, 3,864 lived in counties for which the county death rates are available. I use this sample where the effects of local epidemiological environment indicated by child death rate are analyzed.

Table 3.1 compares the medical experiences while in service and other personal characteristics of the three major samples that are used in this study. The three samples are generally similar in terms of the number of cases per person and the number of deaths per 1,000 cases for all diseases combined and for each of six major diseases.[5] Among the personal characteristics, only the percentages of farmers and of immigrants are notably different between the full and census-linked samples.[6] Despite the uneven geographical coverage of the Jackson collection of mortality data, the sample linked to the mortality census is comparable to the full sample in terms of regional composition. Although we cannot preclude the possibil-

5. The number of cases is slightly greater for the recruits who were successfully linked to the 1860 census than for the entire sample, which is to be expected due to the nature of the data collections. The rate of linkage to census records is higher for those who are connected to pension records because pension files provide useful information, especially on place of residence, that helps to locate and identify persons in manuscript schedules of censuses. And army veterans with health problems originating from military service were more likely to apply for and receive pensions because early pension laws required such conditions. Therefore, it is not surprising that recruits who were connected to census records present more severe medical experiences while in service.

6. These differences can also be explained by the disparate linkage rates to pension records: Immigrants were less likely to be found in pension records because many of the foreigners who died during the early postwar years had no eligible dependents or were used behind the front and so were less likely to incur war-related disabilities (Fogel 1993).

Table 3.1 Medical Experiences in Service and Personal Characteristics: A Comparison of Three Samples

	Full Sample	Population Census–Linked Sample	Mortality Census–Linked Sample
Number of cases per person			
All diseases	2.066	2.338	2.086
Diarrhea	0.431	0.506	0.440
Typhoid	0.061	0.074	0.064
Malaria	0.218	0.228	0.234
Pneumonia	0.034	0.036	0.029
Measles	0.036	0.044	0.042
Smallpox	0.013	0.016	0.013
Number of deaths per 1,000 cases			
All diseases	37.6	40.8	37.8
Diarrhea	60.2	60.5	57.7
Typhoid	308.7	324.4	290.3
Malaria	13.5	15.0	14.4
Pneumonia	170.1	186.9	207.2
Measles	81.5	83.5	73.6
Smallpox	229.0	288.9	326.5
Personal characteristics			
Mean age	25.6	26.1	25.9
Mean height	67.5	67.9	68.0
Percentage of farmers	47.6	57.6	57.5
Percentage of the U.S.-born	69.3	82.1	86.2
Region of enlistment (%)			
New England	9.2	10.3	10.4
Mid-Atlantic	37.3	31.2	37.4
East North Central	35.8	39.1	34.1
West North Central	11.1	12.5	8.0
South	6.6	6.9	10.1
Military position			
Percentage of privates	91.8	89.8	88.9
Percentage of infantrymen	67.5	65.1	67.8
N	28,536	11,073	3,864

ity of sample selection bias based solely on this comparison, the result suggests that such a bias problem is not likely to be serious.

3.3 Socioeconomic Background, Disease, and Mortality

In this section, I basically replicate my previous study (Lee 1997) using a much larger and more representative sample. Let us begin with a description of the overall features of medical experiences of the recruits in the sample. Nearly 12 percent of recruits in the sample died while in service, two-thirds from illness and the rest from wounds. The total casualties and the fraction of deaths caused by disease are well matched with the statistics for the entire Union Army. I identified the six most common diseases in army camps, namely, typhoid, smallpox, measles, diarrhea (including dysentery), pneumonia, and malaria.[7] These diseases are responsible for nearly four-fifths of all deaths caused by illness and two-fifths of all disease cases. Of these diseases, diarrhea is the single most important killer, accounting for 32 percent of all deaths caused by disease, followed by typhoid, which explains 23 percent of disease-caused deaths.

Table 3.2 reports the wartime mortality from disease in general (D), the mean number of cases per person-year (C), and the case fatality rates (F) of all diseases for recruits according to age, occupation, population size of county, household wealth, and nativity.[8] The mean number of cases of disease per person-year reflects how susceptible recruits of a particular socioeconomic background were to disease, while the case fatality rates indicate how robust they were in resisting the diseases they contracted.

Among the variables pertaining to socioeconomic status used in the analysis, household wealth per adult male equivalent may require an explanation regarding the method of construction. Household wealth is one of the most widely used indicators of economic well-being of individuals. In studying the determinants of health in the nineteenth century, household wealth is often interpreted as a measure of nutritional status because the quality of diet was one of the most important links between economic status and health at a time when medical interventions were limited. In order to construct a more accurate measure of a person's economic well-being (or quality of diet), it is necessary to consider the size of the household's needs as well as its material resources. Use of simple per capita household wealth, taking household size into account, only partially satisfies this requirement because the demand for consumption goods differs by age, sex, and labor force status. A common method of measuring the needs of a household is to convert the number of household members into a scale of adult male equivalents based on the demographic structure of the household, such as the number of householders of a particular age and sex. In order to apply this method it is necessary to determine the scale of a particular type of person based on the relative size of his or her consumption. Here, I consider only food consumption as the basis for determining the scale. I utilize the average caloric consumption of a typical male and a female at given ages as a proportion of that consumed by a male aged twenty to thirty-nine, reported in Fogel (1993, 9). For instance, the average caloric consumption of

7. Malaria includes intermittent and remittent fevers; typhoid includes typho-malaria and continuous fevers.

8. The definitions of these figures are as follows: The mean number of cases per person-year of disease k for group j is $(\sum_p \mathrm{CASE}_{pjk} / \sum_p \mathrm{SERVICE}_{pj})$, and the case fatality rate of disease k for group j is $(\mathrm{DEATH}_{jk} / \sum_p \mathrm{CASE}_{pjk})$, where CASE_{pjk} is the number of cases of disease k that a recruit p in group j suffered, $\mathrm{SERVICE}_{pj}$ is the length of service in year (measured in days) for a recruit p in group j, and DEATH_{jk} is the number of the recruits who died from disease k.

Table 3.2 **Socioeconomic Background and Wartime Mortality from All Types of Disease**

	All Ages				Ages 19 and Younger				Ages 20–24				Ages 25–29				Ages 30 and Older			
Category	*N*	D	C	F	*N*	D	C	F	*N*	D	C	F	*N*	D	C	F	*N*	D	C	F
Farmer	13,595	103.5	1.27	42.4	4,402	93.6	1.27	37.3	4,209	106.2	1.17	43.1	2,030	111.8	1.24	46.2	2,954	108.7	1.47	47.0
Nonfarmer	14,951	54.3	0.90	31.4	3,514	45.0	0.92	23.5	4,408	45.6	0.81	28.4	2,740	46.7	0.83	29.1	4,289	75.8	1.06	42.2
Rural county	15,521	91.5	1.22	38.1	4,472	85.2	1.21	34.2	4,618	88.8	1.12	37.2	2,485	85.7	1.18	36.6	3,946	105.4	1.40	45.8
Urban county	3,799	45.3	0.72	30.7	847	29.5	0.79	16.7	1,073	36.3	0.59	28.5	682	48.4	0.63	36.8	1,197	62.7	0.84	40.8
Rural farmer	9,153	109.8	1.31	42.5	2,891	102.4	1.31	38.4	2,840	109.2	1.20	41.8	1,362	114.5	1.29	44.3	2,060	118.0	1.53	48.1
Rural																				
nonfarmer	6,368	65.2	1.09	30.9	1,581	53.8	1.05	24.6	1,778	56.2	0.99	27.6	1,123	50.8	1.05	24.8	1,886	91.7	1.26	42.9
U.S.-born	19,709	80.8	1.18	35.9	6,533	72.9	1.17	31.4	6,100	76.4	1.08	34.1	3,096	82.0	1.17	36.5	4,272	98.1	1.39	44.9
Farmer	11,215	100.9	1.32	40.2	3,812	91.3	1.32	35.8	3,533	99.3	1.21	39.2	1,655	110.6	1.32	43.7	2,215	112.9	1.58	47.2
Nonfarmer	8,575	54.6	1.00	28.4	2,510	45.0	0.97	22.9	2,567	44.8	0.89	24.5	1,441	49.3	1.01	25.5	2,057	82.2	1.19	41.9
Foreign-born	8,756	70.7	0.85	42.9	1,594	68.4	0.87	35.4	2,517	72.3	0.76	47.9	1,674	60.3	0.70	43.0	2,971	76.4	1.01	43.7
Farmer	2,380	115.5	1.02	55.2	590	108.5	1.02	48.8	676	142.0	0.93	67.8	375	117.3	0.90	60.8	739	96.1	1.18	46.3
Nonfarmer	6,376	54.0	0.78	36.4	1,004	44.8	0.79	25.5	1,841	46.7	0.68	36.1	1,299	43.9	0.64	35.0	2,232	69.9	0.95	42.5
Wealth, farmer																				
$0–14	903	106.3	1.39	38.9	261	107.3	1.34	38.2	226	119.5	1.25	45.7	158	94.9	1.44	31.7	258	100.7	1.55	38.6
$15–143	1,117	123.5	1.37	47.1	303	108.9	1.37	41.7	276	126.8	1.18	48.5	182	164.8	1.36	60.0	356	112.4	1.58	43.7
$144–325	1,305	123.4	1.37	47.1	428	144.9	1.35	54.2	395	106.3	1.27	38.0	174	97.7	1.44	37.4	308	129.9	1.56	55.5
$326–809	1,514	111.6	1.32	45.0	506	122.5	1.35	45.5	475	105.3	1.19	43.5	187	117.6	1.12	51.4	346	101.2	1.65	43.6
$810–	1,512	108.5	1.32	44.1	489	81.8	1.31	31.8	576	102.4	1.32	39.4	201	129.4	1.21	62.2	246	158.5	1.47	72.2
Wealth,																				
nonfarmer																				
$0–14	1,235	76.1	1.04	36.4	279	60.9	115	25.0	262	61.1	0.90	29.4	198	30.3	0.93	15.8	496	110.9	1.11	56.3
$15–143	1,120	54.5	1.07	27.2	248	40.3	0.92	19.3	223	26.9	1.10	13.2	210	61.9	1.04	28.9	439	72.9	1.25	38.7
$144–325	937	79.0	1.03	40.4	234	68.4	0.94	35.2	242	70.2	1.06	32.9	154	32.5	0.95	18.4	307	117.3	1.14	61.1
$326–809	723	66.4	1.06	33.4	207	72.5	1.10	33.7	213	51.6	0.88	28.3	108	55.6	0.98	30.2	195	82.1	1.30	39.8
$810–	655	64.1	1.02	33.4	195	46.2	1.12	21.1	225	93.3	0.87	55.0	102	58.8	0.95	32.8	133	45.1	1.18	22.6

Notes: N = number of recruits; D = number of deaths per 1,000 men; C = number of cases per person-year; F = number of deaths per 1,000 cases.

a female aged five to nine is 66.67 percent of an adult male's average consumption. Accordingly, a female aged five to nine is regarded as equivalent to 0.6667 of an adult male.

The results presented in table 3.2 confirm the previous finding that the pattern of mortality differentials in the army was nearly the opposite of the relationship between the socioeconomic status and health of civilians. On average, former farmers had about a 35 percent higher case fatality rate, and about 40 percent more cases of disease per year of service than nonfarmers. As a consequence of a higher susceptibility and case fatality rate combined, farmers were twice as likely to be killed by disease while in service as nonfarmers.[9] This result remains unchanged if country of birth and household wealth are controlled for. For instance, farmers had markedly higher case fatality and wartime mortality rates in all five categories of household wealth.

To examine the effect of population size of place of residence, I divided the sample into rural and urban residents. I include in urban areas all counties that are classified as metropolitan areas by the Integrated Public Use Microdata Series (IPUMS) of the 1860 census.[10] The result reported in table 3.2 indicates that rural residents were twice as likely to die from disease while in service as were city dwellers. In particular, recruits from rural areas were much more susceptible to diseases than urban residents, as indicated by the difference in the mean number of cases per person-year.

Since most of the farmers lived in rural areas, the effects of occupation and urban residence can be distinguished by comparing rural farmers, rural nonfarmers, and urban residents. Farmers who lived in rural counties were two and half times as likely to die from disease in service as urban residents. These differences reflect the combined effects of occupation and place of residence. The difference in the number of cases is accounted for almost equally by the effects of urban residence and of occupation, while the difference in the case fatality rate is largely explained by the effect of occupation.

Native recruits were similar to the foreign-born in the risk of dying while in service. Natives suffered more disease per year of service, but had a lower case fatality rate than nonnatives. These two different factors of mortality cancel each other out. This result contrasts with the pattern found in Ohio where native recruits were at considerably higher risk of dying from disease while in service than nonnatives. A regional comparison of the association

9. Nonnatives were overrepresented among nonfarmers, and farmers were wealthier than nonfarmers on average. Hence, it is necessary to control for these factors in order to identify the pure effect of occupation.

10. The following counties were classified as metropolitan areas in 1860: Albany, Erie, Kings, New York, Richmond, Rensseaer (N.Y.); Baltimore (Md.); Middlesex, Norfolk, Suffolk (Mass.); Cook (Ill.); Hamilton, Kenton (Ohio); Jefferson (Ky.); Clark, Floyd (Ind.); Orleans (La.); San Francisco (Calif.); Essex, Hudson, Camden (N.J.); Montgomery, Philadelphia, Allegheny (Pa.); Kent, Providence (R.I.); and St. Louis (Mo.).

between socioeconomic factors and mortality while in service indicates that natives recorded a higher mortality rate than nonnatives only in the East North Central region (see section 3.5). Although the pattern of mortality differentials varies considerably across age categories, the above result is generally true for each age group. As in the case of Ohio, the household wealth of recruits prior to enlistment appears to have had no clear effect on the likelihood of contracting diseases or the risk of dying from those diseases.

I conduct logistic regressions to examine the effect of each of the socioeconomic factors, controlling for all other factors at the same time. Three different models are employed. The first and second regressions estimate the effect of each independent variable on the separate probabilities of contracting a disease and dying from a disease (respectively) while in service, based on the sample of all recruits linked to the 1860 census. For the third regression, the sample is limited to the recruits who had at least one illness while in service. The second regression examines the determinants of the degree of susceptibility to disease while the third is concerned with fatality in case of contraction. The result of the first regression on mortality shows the combined consequence of the differences in susceptibility and lethality.

The recruits in the sample are classified into three groups according to occupation and place of residence: rural farmers (control group), rural nonfarmers, and residents in urban counties. Variables on personal characteristics such as age, age squared, nativity, and log of household wealth per adult equivalent are included. Variables on height are also added as an index of nutritional status of recruits. The year of enlistment represents variations in the severity of military missions, epidemiological conditions, and the length of service. In a previous study I found that military rank and duty had very strong effects on the chances of dying while in service (Lee 1999). This study also shows that military positions were selectively assigned to the newly enlisted according to their socioeconomic backgrounds. To control for this potential indirect effect of socioeconomic characteristics on the probability of dying through the assignments of military positions, I include dummy variables on duty (which equals 1 if infantryman and zero otherwise) and rank (equals 1 if private and zero otherwise).

The results of the regressions are presented in table 3.3. The estimated parameters for occupation and urban county confirm the patterns of mortality differentials described above (see table 3.2). Farmers from rural areas were much more likely to contract diseases and be killed by them than were nonfarmers from rural counties and city dwellers. As suggested by Lee (1997), the most plausible interpretation of these results is that the effect of earlier exposure to disease was particularly important. A number of studies have noted the fragility of isolated populations once they come in contact with different disease pools (McNeill 1976; Curtin 1989; Pritchett and Tunali 1995; Fetter and Kessler 1996; Sköld 1997). Despite the negative con-

Table 3.3 **Results of Logistic Regressions: Correlates of Probability of Dying from Disease**

	All Recruits Linked to the 1860 Census					Recruits Who Contracted Disease		
		Dying from Disease (mean = 0.098) (1)		Contracting Disease (mean = 0.700) (2)			Dying from Disease (mean = 0.139) (3)	
Independent Variable	Mean	Parameter	$\partial P/\partial X_i$	Parameter	$\partial P/\partial X_i$	Mean	Parameter	$\partial P/\partial X_i$
Intercept		3.104		–5.549		6.410		
Age	26.039	–0.011	–0.050	–0.100***	–0.451	25.932	0.006	0.028
Age squared × 10^{-1}	74.480	0.004	0.107	0.017***	0.470	74.117	0.001	0.026
Height	67.923	–0.179	–0.267	0.246	0.366	67.957	–0.277	–0.411
Height squared × 10^{-1}	461.923	0.014	0.275	–0.018	–0.362	462.543	0.021	0.418
Farmers, rural county	0.573	N.I.	N.I.	N.I.	N.I.	0.609	N.I.	N.I.
Nonfarmers, rural county	0.349	–0.497***	–0.131	–0.432***	–0.113	0.327	–0.380***	–0.098
Urban county	0.078	–0.932***	–0.138	–0.959***	–0.142	0.064	–0.599***	–0.081
Born in United States	0.820	–0.251***	–0.053	0.187***	0.040	0.831	–0.310***	–0.064
Log of adjusted wealth	4.674	0.009	0.012	–0.030***	–0.041	4.675	0.014	0.019
Duty-infantryman	0.649	1.093***	0.288	–0.308***	–0.081	0.621	1.215***	0.325
Rank-private	0.899	0.420***	0.070	0.192**	0.032	0.901	0.385***	0.063
Year of enlistment								
1861	0.247	N.I.	N.I.	N.I.	N.I.	0.273	N.I.	N.I.
1862	0.392	0.053	0.014	–0.125	–0.034	0.422	0.075	0.020
1863	0.045	0.144	0.016	–0.033	–0.004	0.049	0.161	0.019
1864	0.231	–0.968***	–0.225	–1.033***	–0.240	0.184	–0.656***	0.140
1865	0.084	–1.131***	–0.173	–0.874***	–0.134	0.072	–0.890***	–0.127

Notes: The number of observations is 10,124 for regressions (1) and (2), and 7,152 for (3). Dependent variables are dummy variables that equal 1 if a person died from a disease for regressions (1) and (3), if a person contracted a disease for regression (2), and zero otherwise. N.I. = not included.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

sequences for net nutritional status, survivors of unhealthy environments developed better immunity to some of the infectious diseases that were rampant in army life.

The results regarding the effects of country of birth reveal two countervailing effects on wartime mortality as observed in table 3.2. First, U.S.-born recruits were more likely to suffer illness (column [2]) but were less likely than immigrants to die when they became sick (column [3]). The advantage of natives over foreigners in terms of fatality outweighs the disadvantage in the odds of contracting diseases. As a consequence, native recruits were about 5 percent less likely to die from disease while in service than were immigrants (column [3]). The lower contraction rate of immigrants may be explained by the circumstance that they were more likely to be confined to unhealthy environments. For instance, many immigrants suffered from the overcrowding, bad ventilation, and spoiled foods of ship cabins on the voyage from Europe to America. Moreover, most of the immigrants came to and first stayed in large cities in the Northeast where communicable diseases were more prevalent than in the countryside. On the other hand, the higher fatality among foreign-born recruits could be attributable to the generally poor health conditions of immigrants compared to natives as indicated by their higher mortality and smaller stature in nineteenth-century America (Haines 1977; Higgs 1979).[11]

Finally, a close relationship between the adjusted household wealth and the odds of contracting disease stands out in the regression result (column [2]). An increase in the log of adjusted household wealth by 1 standard deviation (2.45) around the sample mean is associated with a decline by 7.4 percent in the probability of having at least one case of illness while in service. In contrast, the adjusted household wealth is positively associated with the odds of dying from disease for those who suffered illness, although the relationship is statistically insignificant. The effect of the adjusted household wealth on the probability of dying from illness, a combined outcome of the above two countervailing effects, is relatively small in magnitude and statistically insignificant.[12]

I perform similar regression analyses separately for the six most common

11. Height, an indicator of nutritional status, had no significant effect on the probabilities of contracting and dying from disease while in service. A possible explanation for this result is that the link between nutritional status and health was dominated by the strong influence of infectious diseases in the army. The result of the chapter by Joseph Ferrie in this volume is suggestive with regard to this point. In the mid-nineteenth-century United States, household wealth, another proxy of nutritional status, was negatively related with mortality caused by consumption, but not with the chances of dying from cholera, a more fatal infectious disease.

12. I also used the sum of personal property wealth per adult equivalent as a measure of economic status. The results obtained using this alternative index of wealth were similar to those reported in table 3.3. For the odds of contracting disease while in service, the estimated coefficient for personal property wealth was –0.056 and statistically significant. But its effect on the probability of dying from disease was insignificant. The results for other variables were little changed.

diseases, namely, typhoid, smallpox, measles, diarrhea, pneumonia, and malaria. According to epidemiological studies, the significance of immunity influence of prior contraction differs from one disease to another. For some diseases, such as measles, smallpox, and typhoid, an attack would confer immunity and thus reduce the odds of contracting or dying from those diseases in the future (such diseases will be called *immunity diseases* below). For other diseases, such as malaria, diarrhea, dysentery, and pneumonia, a prior contraction has little influence on susceptibility to or resistance against a later contraction (this type will be called *nonimmunity diseases*).[13] If the immunity hypothesis suggested above is true, the difference in mortality between recruits who had come from different environments should be larger for immunity diseases than for nonimmunity diseases.

Table 3.4 presents the results for the probability of contracting each specific disease. The results are largely consistent with the immunity hypothesis suggested above. The advantages of nonfarmers and urban dwellers over farmers and rural dwellers are generally greater for immunity diseases than for nonimmunity diseases. The greater odds of contraction among U.S.-born recruits is statistically significant for two of three immunity diseases (typhoid and smallpox), compared to only one nonimmunity disease (diarrhea). Meanwhile, the effect of adjusted household wealth is statistically significant for one immunity disease (measles) and one nonimmunity disease (diarrhea).

Table 3.5 reports the regression results for the probability of dying from each specific disease conditional on contracting it. The relationship between socioeconomic factors and fatality is less clearly seen for individual diseases than for all diseases. The effect of occupation and urban residence is statistically significant only for typhoid. Natives had a significantly lower fatality than immigrants for an immunity disease (measles) and two nonimmunity diseases (diarrhea and malaria). The wealthier had disadvantages only in the case of pneumonia.

For another test of the immunity hypothesis, I examine the time pattern of wartime mortality. It is documented in the medical histories of the Civil War that the earlier *seasoning period* in the army was most critical for the survival of recruits. During this period enlistees with limited prior development of immunity were exposed to a pool of various infectious diseases in the army (Steiner 1968). If the differences in wartime mortality between farmers and nonfarmers were mainly caused by the difference in immunity status, most of the difference should have occurred in the early stages of military service when the recruits were not seasoned to the severe disease environment of the army camps.

13. For the epidemiological characteristics of these and other diseases see May (1958), Steiner (1968, 12–26), and Kunitz (1983, 351–53). For more recent documentation of the history of specific diseases, see Fetter and Kessler (1996) for measles, Zurbrigg (1997) for malaria, and Sköld (1997) for smallpox.

Table 3.4 **Result of Logistic Regressions: Personal Characteristics and Probability of Contracting Particular Disease ($\partial P / \partial X_i$)**

	Typhoid (mean = 0.065) (1)	Smallpox (mean = 0.013) (2)	Measles (mean = 0.038) (3)	Diarrhea (mean = 0.277) (4)	Pneumonia (mean = 0.031) (5)	Malaria (mean = 0.151) (6)
Age	0.091	–0.268	–0.549*	–0.040	–0.076	–0.116
Age squared × 10^{-1}	–0.160	0.211	0.030	0.035	0.083	0.048
Height	–0.070	–0.128	1.552	0.516	0.565	–0.224
Height squared × 10^{-1}	0.049	0.117	–1.539	–0.509	–0.448	0.236
Farmers, rural county	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
Nonfarmers, rural county	–0.068***	–0.254***	–0.216***	–0.061***	–0.159***	–0.053***
Urban county	–0.175***	–2.127	–0.254***	–0.109***	–0.238***	–0.086***
Born in United States	0.043*	0.057	0.066*	0.072***	–0.001	0.022
Log of adjusted wealth	0.022	–0.058	–0.053*	–0.028**	–0.049	–0.003
Duty-infantryman	0.102	–0.049	0.006	–0.041***	0.039	–0.110***
Rank-private	0.031***	0.036	0.023	0.023*	–0.007	0.032**
Year of enlistment						
1861	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
1862	0.019	–0.002	–0.037	0.036**	0.027	0.017
1863	–0.021	–0.073	0.046*	0.025**	–0.039	0.005
1864	–0.141***	–0.127**	0.002	–0.112***	–0.146***	–0.096
1865	–0.175***	–0.165**	0.029	–0.055***	–0.048	0.019

Notes: The number of observations is 10,124 for all regressions. Dependent variables are dummy variables that equal 1 if a person contracted a particular disease, and zero otherwise. N.I. = not included.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 3.5 **Result of Logistic Regressions: Personal Characteristics and Probability of Dying from Particular Diseases in Case of Contraction ($\partial P/\partial X_i$)**

	Typhoid (mean = 0.321, N = 654) (1)	Smallpox (mean = 0.319, N = 135) (2)	Measles (mean = 0.083, N = 387) (3)	Diarrhea (mean = 0.100, N = 2,808) (4)	Pneumonia (mean = 0.171, N = 315) (5)	Malaria (mean = 0.016, N = 1,528) (6)
Age	–0.395	0.057	0.806	0.206	–0.064	–0.580
Age squared × 10^{-1}	0.430	0.392	–0.973	–0.078	0.392	0.703
Height	–1.370	–1.789	3.267	–1.545+	4.119	–0.661
Height squared × 10^{-1}	1.361	1.864	–3.049	1.544+	–4.071	0.929
Farmers, rural county	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
Nonfarmers, rural county	–0.144***	–0.038	–0.231	–0.045	0.014	0.137
Urban county	–0.157**	N.I.	0.009	–0.005	–0.074	0.144+
Born in United States	–0.051	0.077	–0.349***	–0.072**	–0.058	–0.213**
Log of adjusted wealth	0.037	0.014	–0.127	0.037	0.194*	0.089
Duty-infantryman	0.400***	0.134	0.319**	0.243***	0.499***	0.352**
Rank-private	0.062	0.204	0.043	0.024	0.138	0.008
Year of enlistment						
1861	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
1862	–0.059	–0.112	0.335**	0.022	–0.188	0.063
1863	0.009	0.012	–1.686	0.057*	0.067	–1.461
1864	–0.153***	–0.244*	0.173	–0.114**	–0.055	–0.080
1865	–0.080	–0.125	0.173	–0.178***	–0.009	–0.113

Notes: Dependent variables are dummy variables that equal 1 if a person died from a particular disease, and zero otherwise. N.I. = not included.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 3.6 **Hazard Rates of Dying from Disease: Number of Deaths per 1,000 Men within Four-Month Intervals**

	Any Illness (1)		Immunity (2)		Non-immunity (3)	
Months in Military Service	Farm	Nonfarm	Farm	Nonfarm	Farm	Nonfarm
0–4	23.8	12.8	13.2	4.5	5.7	3.2
4–8	48.5	22.2	20.6	13.4	18.0	8.0
8–12	29.2	21.3	9.3	5.0	12.9	10.5
12–16	24.9	18.6	6.6	3.3	13.5	9.7
16–20	20.3	13.1	6.3	3.2	9.6	6.5
20–24	21.4	10.7	4.4	2.0	12.5	7.2
24–28	18.5	18.1	2.5	1.0	10.8	12.2
28–32	11.0	11.6	2.4	1.5	7.3	8.4
32–36	10.1	7.4	1.3	0.8	6.5	4.7

Notes: The number of recruits who died from a particular type of disease within each four-month interval was divided by the number of recruits who remained alive in service at the beginning of the time interval and then was multiplied by 1,000. If a recruit died from any cause while in service or was discharged alive, he was removed from the pool of population at risk. For the classification of disease see text.

To see whether this was the case, I calculate the hazard rate of dying from a particular type of disease for each of the four-month intervals from enlistment. The hazard rate for the fifth to eighth month, for example, shows what proportion of the recruits remaining alive in service at the beginning of the fifth month died from any illness or some specific type of disease within the following four months. If a recruit died from any cause or was discharged alive between the fifth and eighth months, he is removed from the population at risk when the hazard rate of the next time interval (the ninth to twelfth month) is calculated.

The time patterns of wartime mortality reported in table 3.6 are consistent with the immunity hypothesis. In general, hazard rates of dying from any disease or immunity disease were higher during the first year in service, particularly from the fifth to the eighth months, than in subsequent periods, confirming the remarks on the seasoning period given in medical histories of the Civil War (see fig. 3.1). Moreover, a disproportionately large fraction of the difference between farmers and nonfarmers in mortality caused by immunity diseases was made in the first eight months. For nonimmunity diseases, in contrast, the incidence of wartime deaths is relatively evenly distributed over time in military service (see fig. 3.2). There is no clear time pattern of the difference between farmers and nonfarmers in the hazard rate of dying from nonimmunity-type diseases except that the difference was especially large between the fifth and eighth months in service.

The results presented in this section largely confirm the previous findings based on the sample of Ohio regiments (Lee 1997), building a strong circumstantial case for the importance of earlier disease exposure. However,

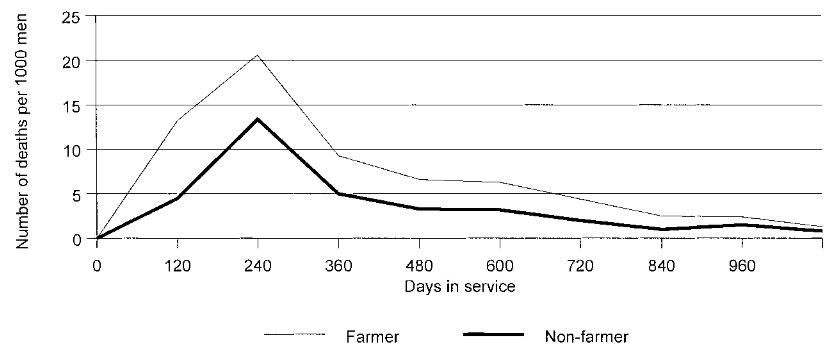

Fig. 3.1 Hazard functions of dying from immunity disease

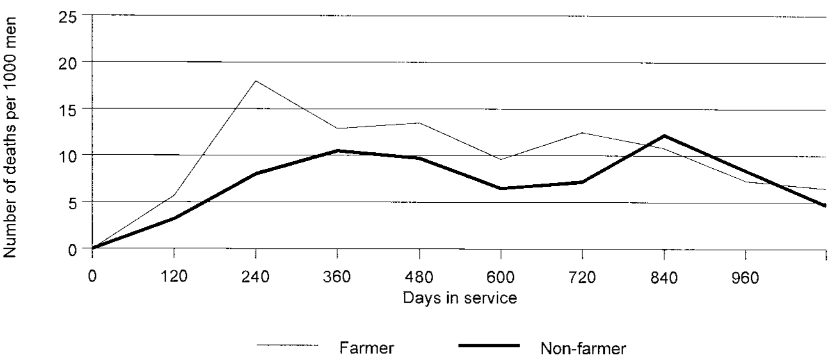

Fig. 3.2 Hazard functions of dying from nonimmunity disease

occupation or urban residence are only indirect indicators of local disease environments. Therefore, the interpretations of the results suggested above are subject to reservations. We now turn to a more direct test using an explicit measure of disease environments that will help to establish the above argument more strongly.

3.4 Local Disease Environment, and Later Health and Mortality

In this section, I analyze the influences of prior exposure to disease using a more explicit measure of local epidemiological environment, namely, the child death rate of each county where recruits resided prior to enlistment. Child or infant mortality is a widely used indicator of the prevalence of infectious diseases. Previous studies have found that infectious diseases increased the chances of suffering chronic conditions such as heart, respiratory, and musculoskeletal disorders at middle and older ages (Barker 1992, 1994; Elo and Preston 1992; Costa 2000). The link between earlier contraction of infectious diseases and later health conditions could be explained in part by the nutritional losses caused by the infections. For example, Haines (1998) found that the crude death rate of the localities where Union Army recruits were reared had a strong negative effect on their heights at the time of enlistment. The analysis of this article is distinct from the existing literature in that it is concerned with the relatively short-term influences of infectious diseases when individuals were exposed to highly severe disease conditions in the army.

As explained above, I calculated the number of deaths in each county for children under age ten and for the population at large from the sample of the 1860 mortality census. By dividing the number of deaths by the county population, I computed the child and crude death rates for each county. Finally, this county-level data set on death rates was linked to the sample of recruits based on the names of the state and county where the recruits lived in 1860. It turned out that 3,864 recruits lived in the counties for which death rates are estimated. For 3,550 of them there is nonmissing information for each variable used in the analysis. The balance of this section is based on the sample of these 3,550 recruits. The sample means of the crude death rate (number of deaths per thousand) and child death rate (number of child deaths per thousand children) are 2.6 and 4.8, respectively. These death rates fall short of the estimate of the crude death rate for the United States circa 1860, 21 deaths per thousand (Poulson 1981, table 10.2). Even if we consider the fact that the Northern death rate was lower than the national average, the estimated county death rates are still much too low, indicating that the number of deaths should be severely undercounted in our mortality data. I use these underestimated county death rates without making any corrections. It should be noted that by doing so I implicitly assume that the extent of undercounting is similar across counties.

Table 3.7 presents the results of logistic regressions that show the effect of local disease environment indicated by county child-death rate on the probabilities of dying from disease (column [1]), of contracting disease (column [2]), and of dying from disease in case of contraction (column [3]). As predicted by the immunity hypothesis, the child death rate is negatively associated with the odds of contracting any disease. The magnitude of the effect is considerably large. An increase in the child death rate by 1 standard deviation (3.6) around the sample mean is associated with a 45 percent decrease in the chances of contracting a disease while in service.[14] However, the child death rate has no significant effect on the fatality rate of those who had one or more disease cases. Largely due to the influence on the odds of contraction, the child death rate has a strong effect on the chances of dying

14. The child death rate variable is subject to a measurement error problem because the undercount of deaths may not be constant across counties. If this is the case, the effect of child death rate in the regression would be biased toward zero.

Table 3.7 Result of Logistic Regressions: County Child Death Rate and Probabilities of Contracting and Dying from Diseases

	All Recruits Linked to the 1860 Census					Recruits Who Contracted Diseases		
		Dying from Disease (mean = 0.098) (1)		Contracting Disease (mean = 0.663) (2)			Dying from Disease (mean = 0.120) (3)	
Independent Variables	Mean	Parameter	$\partial P/\partial X_i$	Parameter	$\partial P/\partial X_i$	Mean	Parameter	$\partial P/\partial X_i$
Intercept		–31.445		–12.586			–24.320	
Child death rate	4.771	–0.041**	–0.083	–0.062***	–0.125	4.574	–0.019	–0.035
Age	25.842	–0.0035	–0.148	–0.107***	–0.461	25.636	–0.005	–0.022
Age squared × 10^{-1}	72.881	0.006	0.166	0.017***	0.433	71.910	–0.002	0.050
Height	68.022	0.824	1.154	0.454	0.635	68.109	0.610	0.853
Height squared × 10^{-1}	463.34	–0.057	–1.093	–0.032	–0.607	464.520	–0.042	–0.800
Farmers, rural county	0.572	N.I.	N.I.	N.I.	N.I.	0.611	N.I.	N.I.
Nonfarmers, rural county	0.358	–0.496***	–1.131	–0.353***	–0.093	0.328	–0.392***	–0.101
Urban county	0.070	–1.464***	–0.206	–0.850***	–0.120	0.061	–1.227***	–0.162
Born in United States	0.863	–0.184	–0.035	–0.056	–0.011	0.860	–0.193	–0.037
Log of adjusted wealth	4.871	–0.046	–0.054	–0.056***	–0.066	4.831	–0.032	–0.038
Rank-private	0.888	0.137	0.024	0.076	0.013	0.886	0.115	0.020
Duty-infantryman	0.678	1.066***	0.275	–0.271***	–0.070	0.648	1.179***	0.310
Year of enlistment								
1861	0.250	N.I.	N.I.	N.I.	N.I.	0.283	N.I.	N.I.
1862	0.374	–0.177	–0.047	–0.067	–0.018	0.407	–0.196	–0.053
1863	0.043	–0.070	–0.008	0.036	0.004	0.051	–0.109	–0.013
1864	0.241	–0.939***	–0.221	–1.119***	–0.264	0.180	–0.506**	–0.107
1865	0.091	–1.070***	–0.170	–0.826***	–0.131	0.079	–0.866***	–0.128

Notes: The number of observations is 3,550 for regressions (1) and (2), and 2,355 for (3). Dependent variables are dummy variables that equal 1 if a person died from a disease for regressions (1) and (3) and if a person contracted a disease for regression (2), and zero otherwise. N.I. = not included.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

from disease. I tried several different specifications, by including instead of the child death rate the crude death rate, the infant death rate (death rate of children under age one), the log of the child death rate, and dummy variables for five categories of counties according to the size of the child death rate. The results for these specifications, not reported here, provide practically the same implications.[15]

The results for other independent variables are generally similar to the results from the previous regressions in which the child death rate is not included (table 3.3). The only major difference is that the effect of country of birth loses statistical significance. Using the 3,550-man sample, I also conducted similar regressions after excluding the child death rate. A comparison of the results of these regressions, not presented here, with the original regressions presented in table 3.6 shows that the disappearance of the effect of nativity is due mainly to the restriction of the sample, not the inclusion of the child death rate in the regressions. The results also indicate that despite the additional control of the child death rate in the regressions, the magnitudes of the coefficients for occupation and urban county remain little changed. This implies that the two different measures of exposure to disease—population size of place of residence and child death rate—independently affected the chances of dying while in service.

Tables 3.8 and 3.9 offer the results of similar regressions conducted separately for six specific diseases. The effect of the child death rate significantly affects the chances of infection only for two nonimmunity diseases, diarrhea and malaria (table 3.8). On the other hand, measles is the only disease whose fatality was significantly influenced by the child death rate (table 3.9).[16] These results suggest that immunity may not be the only link between local disease environment and health. This point is also relevant for the question of why farmers were disadvantaged even for nonimmunity-type diseases for which their superior nutritional status should have provided an advantage. A possible explanation is that people who lived in unhealthy environments were more aware of how to avoid contracting disease than those with little experience of disease. According to a qualitative record, for example, Germans ate fewer sweets, cooked their food more carefully, and more actively pursued cleanliness (Hess 1981, 66–67). A number of contemporary accounts suggest that rural residents and farmers were particularly unhygienic and ignorant of child health (Preston and Haines 1991, 38–39). Alternatively, it could be explained by a population selection caused by

15. The estimated coefficient for infant death rate for the odds of contracting disease is much smaller in magnitude, –0.011, compared to –0.062 obtained using child death rate. However, since the standard deviation of infant death rate (16.9) is nearly five times larger than that of child death rate (3.6), an increase in either measure of mortality would produce a similar decline in the probability of contracting disease while in service.

16. Using alternative measures of local mortality rate such as crude death rate and infant death rate does not change the result.

Table 3.8 Result of Logistic Regressions: County Child Death Rates and Probability of Contracting Particular Disease ($\partial P / \partial X_i$)

	Typhoid (mean = 0.054) (1)	Smallpox (mean = 0.011) (2)	Measles (mean = 0.036) (3)	Diarrhea (mean = 0.245) (4)	Pneumonia (mean = 0.025) (5)	Malaria (mean = 0.146) (6)
Child death rate	0.002	–0.046	0.018	–0.116***	0.068	–0.113***
Age	0.159	–0.511	0.169	–0.120	–0.079	–0.281
Age squared $\times 10^{-1}$	–0.205	0.460	–0.590	0.115	0.069	0.240
Height	2.041	–0.371	7.276***	0.425	1.311	0.515
Height squared $\times 10^{-1}$	–1.999	0.298	–7.310***	–0.396	–1.181	–0.514
Farmers, rural county	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
Nonfarmers, rural county	0.010	–0.379***	–0.206***	–0.083***	0.193***	0.064**
Urban county	–0.063	–1.892	–0.345**	–0.084***	–2.020	–0.124***
Born in United States	0.082*	0.108	0.040	0.018	–0.011	–0.032
Log of adjusted wealth	0.003	–0.110	–0.082	–0.067***	–0.054	–0.050*
Rank-private	0.055	–0.016	0.074	0.032	–0.039	0.009
Duty-infantryman	0.078*	–0.138	–0.018	–0.036	0.046	–0.103***
Year of enlistment						
1861	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
1862	0.004	–0.064	0.001	0.081***	0.089	0.060*
1863	–0.029	0.010	0.040	0.015	0.041	0.007
1864	–0.224***	–0.195	–0.070	–0.106***	–0.147	–0.134***
1865	–0.133**	–0.257	0.001	–0.011	–0.014	–0.030

Notes: The number of observations is 3,550 for all regressions. Dependent variables are dummy variables that equal 1 if a person contracted a particular disease, and zero otherwise. N.I. = not included.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 3.9 **Result of Logistic Regressions: County Death Rates and Probability of Dying from Particular Disease in Case of Contraction ($\partial P/\partial X_i$)**

	All Diseases (mean = 0.120, N = 2,355) (1)	Typhoid (mean = 0.333, N = 201) (2)	Smallpox (mean = 0.040, N = 40) (3)	Measles (mean = 0.084, N = 131) (4)	Diarrhea (mean = 0.101, N = 878) (5)	Pneumonia (mean = 0.237, N = 93) (6)	Malaria (mean = 0.023, N = 522) (7)
Child death rate	–0.035	–0.092	–0.488	–0.693*	–0.080	–0.242	0.160
Age	–0.022	–0.461	5.763	8.939*	0.185	0.582	–1.660
Age squared × 10^{-1}	0.050	0.552	–5.213	–9.414*	–0.101	–0.430	1.853*
Height	0.853	–2.137	36.202	90.255**	–1.349	8.398	–9.882*
Height squared × 10^{-1}	–0.800	2.259	–35.468	–90.959**	1.371	–8.451	10.047*
Farmers, rural county	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
Nonfarmers, rural county	–0.101***	–0.055	2.044*	–0.117	–0.066	–0.195	–0.206
Urban county	–0.162***	–1.592	N.I.	0.467	–0.068	N.I.	–1.337
Born in United States	–0.037	–0.042	0.956	–0.274	0.017	0.120	–0.359***
Log of adjusted wealth	–0.038	0.127	–1.818*	–0.276	0.006	–0.076	0.069
Rank-private	0.020	–0.142	0.565	2.289	–0.027	0.272	0.157
Duty-infantryman	0.310***	0.554***	1.757	0.878**	0.223***	0.162	–0.008
Year of enlistment							
1861	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
1862	–0.053	–0.102	1.321	0.239	–0.108	0.008	–0.053
1863	–0.013	0.034	1.056*	–1.195	0.010	0.216	–1.380
1864	–0.107***	–0.045	0.321	0.267	–0.030	0.143	–0.114
1865	–0.128***	–0.040	–1.204	–0.068	–0.148*	–0.072	0.052

Notes: Dependent variables are dummy variables that equal 1 if a person died from a particular disease, and zero otherwise. N.I. = not included.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

differential mortality; that is, individuals who survived an unhealthy environment were on average more robust. Further studies are called for to determine how prior exposure to unfavorable epidemiological environments, if survived, strengthen human resistance to disease.

3.5 Regional Differences

This section documents how the relationship between socioeconomic factors and wartime mortality differed across regions. Let us begin with a regional comparison of the general features of wartime mortality. Table 3.10 reports the cause-specific death rates for five regions. The result indi-

Table 3.10 Number of Cases and Deaths from Specific Causes, by Region

	All	New England	Mid-Atlantic	East North Central	West North Central	South
Number	28,546	2,623	10,643	10,227	3,167	1,886
Cases per person-year						
Wounds	0.29	0.35	0.38	0.25	0.20	0.20
Illnesses	1.07	0.86	0.91	1.28	1.30	0.91
Deaths per 1,000 men						
Wounds	38.5	72.4	39.3	30.3	37.3	33.9
Illnesses	77.7	100.6	50.0	85.0	127.6	79.5
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Immunity diseases	24.5	34.3	15.5	27.3	36.6	25.4
	(30.5)	(34.1)	(31.0)	(32.1)	(28.4)	
Typhoid	18.7	29.7	14.1	18.9	23.7	20.1
	(23.2)	(28.9)	(26.7)	(21.3)	(18.2)	(25.0)
Smallpox	2.9	1.1	0.9	4.1	6.9	2.7
	(3.6)	(1.1)	(1.8)	(4.6)	(5.3)	(3.3)
Measles	2.9	3.4	0.5	4.4	6.0	2.7
	(3.6)	(3.3)	(0.9)	(5.0)	(4.6)	(3.3)
Nonimmunity diseases	37.1	44.6	23.5	41.2	64.7	35.5
	(47.7)	(44.3)	(47.0)	(48.5)	(50.7)	
Diarrhea	26.0	31.3	18.0	28.3	44.8	19.1
	(32.2)	(30.4)	(34.2)	(31.9)	(34.4)	(23.7)
Pneumonia	5.8	4.2	2.1	7.8	11.1	9.0
	(7.2)	(4.1)	(3.9)	(8.8)	(8.5)	(11.2)
Malaria	2.9	5.3	2.3	2.2	4.7	4.2
	(3.7)	(5.2)	(4.3)	(2.5)	(3.6)	(5.3)
Tuberculosis	2.5	3.8	1.1	2.8	4.1	3.2
	(3.0)	(3.7)	(2.1)	(3.2)	(3.1)	(3.9)
Scurvy	1.5	0.4	1.5	2.0	0.9	1.6
	(1.9)	(0.4)	(2.9)	(2.2)	(0.7)	(2.0)
All other diseases	17.5	23.6	12.2	18.0	28.1	18.0
	(21.7)	(23.0)	(23.2)	(20.3)	(21.5)	(22.4)

cates that recruits who were enlisted into the New England regiments were particularly more vulnerable to wounds, compared to other regions. They were nearly twice as likely to die from wounds as were recruits who enlisted in other regions, largely due to a higher case fatality rate. This indicates that New England regiments were presumably sent on more dangerous missions. On the other hand, mortality from disease was the highest for the West North Central (12.8 percent), followed by New England (10.1 percent) and the East North Central (8.5 percent). The Mid-Atlantic regiments had the lowest mortality from disease (5 percent). It is notable that, if New England is excluded, there is a clear negative association between disease-influenced mortality and the extent of urbanization. New England regiments may deviate from such a regularity because they went through more severe military missions, as indicated by the greater casualties caused by wounds. The distribution of the specific causes of death from illness, reported in parentheses in table 3.10, does not differ much between regions.

Table 3.11 presents the mortality from all types of diseases, immunity diseases, and nonimmunity diseases for a number of different socioeconomic categories. Though different from one another in the absolute mortality, the Mid-Atlantic, East North Central, and West North Central are generally similar in terms of the mortality differentials according to socioeconomic backgrounds. Meanwhile, New England and the South demonstrate remarkably different patterns. I first describe the patterns of mortality differentials for the Mid-Atlantic, East North Central, and West North Central. In these three regions, farmers were about 1.7 times as likely to be killed by disease as were nonfarmers. The mortality differential between farmers and nonfarmers is much greater (2.5 times greater for farmers than for nonfarmers) for immunity diseases. A comparison between farmers and nonfarmers who lived in rural counties shows similar patterns. Recruits from rural counties were at much greater risk of dying from disease, especially from immunity diseases, compared to recruits from urban areas. These mortality differentials according to occupation and urban residence remain true if country of birth and household wealth are controlled for. The association between country of birth and mortality from disease differs between farmers and nonfarmers. For nonfarmers, there is no significant difference in mortality between natives and nonnatives. For farmers, on the other hand, the foreign-born were considerably less likely to die than natives.[17] As in the case of the full sample, household wealth had no systematic effect on the likelihood of dying from disease. But mortality from nonimmunity disease is clearly lower for the top wealth category in all regions but the South.

The advantages that farmers and rural residents had over nonfarmers

17. This result indicates that the advantages of nonnatives over natives found in the Ohio regiments (Lee 1997), although not observed for the entire sample, are true not only for the state of Ohio but also for the entire Midwest and Mid-Atlantic regions.

Table 3.11 **Socioeconomic Background and Wartime Mortality, by Region (number of deaths per 1,000)**

	New England				Mid-Atlantic				East North Central				West North Central				South			
Category	*N*	ILL	IMM	NIM	*N*	ILL	IMM	NIM	*N*	ILL	IMM	NIM	*N*	ILL	IMM	NIM	*N*	ILL	IMM	NIM
Farmer	897	121.5	55.7	43.5	3,094	70.5	26.5	31.4	6,212	100.8	36.4	46.2	2,375	143.1	42.9	74.5	1,017	112.1	40.3	47.2
Nonfarmer	1,726	89.8	23.2	45.2	7,549	41.6	11.0	20.3	4,015	60.5	13.4	33.4	792	80.8	17.7	35.4	869	41.4	8.1	21.9
Rural county	1,306	117.2	39.8	49.0	4,893	62.9	23.1	28.0	6,526	91.9	31.1	44.0	1,833	138.6	42.0	69.8	963	109.0	40.5	44.7
Urban county	228	100.9	30.7	61.4	2,732	41.4	5.5	24.5	646	44.9	7.7	27.9	1	0.0	0.0	0.0	192	36.4	0.0	36.5
Rural farmer	569	123.0	52.7	43.9	2,137	81.0	30.9	34.6	4,307	105.4	38.1	48.1	1,441	152.6	47.2	80.5	699	125.9	50.1	47.2
Rural nonfarmer	737	112.6	29.9	52.9	2,756	49.0	17.1	22.9	2,219	65.8	17.6	36.1	392	86.7	23.0	30.6	264	64.4	15.2	37.9
U.S.-born	1,394	89.0	30.1	38.0	6,618	56.1	20.1	25.4	8,172	90.8	30.8	43.3	2,269	116.8	41.4	54.2	1,337	73.3	26.2	35.9
Farmer	541	83.2	33.3	31.4	2,548	76.5	30.2	34.1	5,477	106.1	39.1	48.6	1,814	128.4	46.3	60.6	835	93.4	37.1	41.9
Nonfarmer	853	92.6	28.1	42.2	4,070	43.2	13.8	19.9	2,695	59.7	14.1	32.7	455	70.3	22.0	28.6	502	39.8	8.0	25.9
Foreign-born	1,229	113.9	39.1	52.1	4,025	40.0	8.0	20.4	2,055	61.8	13.6	32.6	898	154.8	24.5	91.3	549	94.7	23.7	34.6
Farmer	356	179.8	89.9	61.8	546	42.1	9.2	18.3	735	61.2	16.3	28.6	561	190.7	32.1	119.4	182	197.8	54.9	71.4
Nonfarmer	878	87.1	18.3	48.1	3,479	39.7	7.8	20.7	1,320	62.1	12.1	34.8	337	95.0	11.9	44.5	367	43.6	8.2	16.3
Wealth, farmer																				
$0–100	82	134.1	85.4	0.0	273	102.6	44.0	40.3	555	99.1	41.4	45.0	131	122.1	38.2	68.7	138	159.4	50.7	72.5
$101–500	53	56.6	18.9	75.5	200	105.0	50.0	45.0	439	97.9	25.1	47.8	182	148.4	65.9	65.9	98	132.7	30.6	61.2
$501–1,500	128	156.3	39.1	78.1	281	81.9	32.0	28.5	517	127.7	46.4	63.8	320	162.5	43.8	96.9	136	117.6	51.5	44.1
$1,501–5,000	180	127.8	61.1	33.3	411	85.2	29.2	36.5	808	99.0	43.3	43.3	376	175.5	63.8	87.8	129	108.5	62.0	31.0
$5,001	62	129.0	64.5	48.4	222	90.1	40.5	40.5	506	98.8	33.6	25.7	102	147.1	49.0	98.0	41	24.4	0.0	24.4
Wealth, nonfarmer																				
$0–100	194	128.9	30.9	56.7	827	68.9	14.5	33.9	480	66.7	18.8	29.2	54	148.1	74.1	37.0	91	33.0	0.0	33.0
$101–500	123	97.6	8.1	56.9	447	42.5	6.7	26.8	256	54.7	11.7	39.1	61	82.0	16.4	32.8	42	47.6	23.8	23.8
$501–1,500	137	116.8	43.8	51.1	338	44.4	11.8	32.5	314	54.1	19.1	22.3	68	73.5	29.4	29.4	44	90.9	22.7	68.2
$1,501–5,000	127	110.2	15.7	86.6	299	63.5	16.7	23.4	273	69.6	22.0	44.0	60	116.7	0.0	50.0	26	153.8	38.5	115.4
$5,001–	56	107.1	71.4	17.8	152	32.9	6.8	19.7	168	29.8	11.9	6.0	26	76.9	38.5	0.0	23	173.9	0.0	87.0

Notes: N = number of recruits; ILL = all types of disease; IMM = immunity disease; NIM = nonimmunity disease.

and city dwellers, respectively, are much less visible for New England. For immunity diseases, the difference in mortality between farmers and nonfarmers is comparable to the difference found for the above three regions. But farmers and nonfarmers in New England were no different in their likelihood of dying from nonimmunity diseases. The mortality gap between rural and urban residents is even smaller, only 16 percent, because the former had a higher, not lower, mortality from nonimmunity diseases than did the latter. In contrast, the mortality differentials by occupation and county of residence were much more pronounced for recruits from the South. Such greater mortality differentials are largely due to the differences in mortality from immunity disease. For example, Southern farmers were five times more likely to die from immunity disease than were nonfarmers. Among 192 recruits who lived in urban areas in the South prior to enlistment, not a single person was killed by immunity disease, while 4.1 percent of rural residents died from this type of disease.

The farm-nonfarm gap in mortality differs considerably between natives and the foreign-born for these two regions: The advantages of nonfarmers over farmers are much greater for the foreign-born than for natives. In New England, foreign-born farmers were twice as likely to die from illness as were foreign-born nonfarmers, largely due to their lower mortality from immunity disease. In the South, on the other hand, mortality from illness is more than three times greater for foreign-born farmers than for nonfarm immigrants. If household wealth is controlled for, farmers in New England were slightly more likely to die from disease than were nonfarmers, as observed above, for all but one category of wealth. In the South, on the other hand, the farm-nonfarm difference in mortality depends upon the magnitude of household wealth. That is, among the wealthy, farmers were less likely to die from disease than were nonfarmers, mainly due to their lower mortality from nonimmunity disease. Among the poor, in contrast, mortality from disease is greater for farmers than for nonfarmers.

I conduct logit regressions to see how the effects of socioeconomic factors on the probability of dying from disease differed across regions. Table 3.12 presents the results. The regression results for the Mid-Atlantic, East North Central, and West North Central are generally similar to the results for the entire sample. The major difference is that natives are not significantly different from nonnatives in terms of the likelihood of dying from disease while in service. The advantages that recruits from urban areas or nonfarmers had over rural farmers are greater in the Midwest than in the Northeast. This result could be explained by the fact that, in a more urbanized region such as the Northeast, the difference in the extent of exposure to disease between rural and urban population was presumably small relative to that in a more rural region.

The regression results for New England and the South do not support the hypothesis that recruits from healthier environments were more robust in

Table 3.12 Result of Logistic Regressions: Correlates of Probability of Dying from Any Disease, by Region

	New England[a]		Mid-Atlantic[b]		East North Central[c]		West North Central[d]		South[e]	
Independent Variable	Mean	Parameter	Mean	Parameter	Mean	Parameter	Mean	Parameter	Mean	Parameter
Intercept		–0.059		26.228		–15.141		3.797		8.803
Age										
under 20	0.254	N.I.	0.224	N.I.	0.284	N.I.	0.269	N.I.	0.276	N.I.
20–24	0.309	–0.227	0.301	–0.182	0.291	–0.254	0.273	–0.146	0.287	–0.082
25–29	0.160	–0.015	0.160	–0.462*	0.160	–0.045	0.139	–0.089	0.161	0.140
30 and older	0.277	0.309	0.315	0.359**	0.266	0.109	0.318	–0.278	0.276	0.158
Height	67.7	–0.089	67.3	–0.863	68.1	0.341	68.5	–0.199	68.3	–0.366
Height squared $\times 10^{-1}$	459.7	0.007	454.2	0.062	465.1	–0.024	470.2	0.016	467.1	0.030
Born in United States	0.616	–0.657***	0.806	0.165	0.884	0.278	0.813	–0.317	0.850	–0.472
Farmers, rural county	0.438	N.I.	0.397	N.I.	0.651	N.I.	0.805	N.I.	0.710	N.I.
Nonfarmers, rural county	0.474	–0.028	0.440	–0.375**	0.309	–0.493***	0.195	–0.453*	0.252	–0.253
Urban county	0.088	–0.197	0.163	–0.630***	0.040	–1.044**	0.000	N.I.	0.038	–0.183
Wealth										
\$0–100	0.242	–0.204	0.315	0.364*	0.234	–0.217	0.127	–0.204	0.297	–0.205
\$101–500	0.158	–0.759	0.187	0.106	0.163	–0.201	0.175	–0.017	0.192	–0.220
\$501–1,500	0.225	N.I.	0.183	N.I.	0.192	N.I.	0.279	N.I.	0.240	N.I.
\$1,501–5,000	0.271	–0.081	0.209	0.132	0.254	–0.169	0.325	0.024	0.188	–0.021
\$5,000–	0.104	–0.018	0.107	0.028	0.157	–0.284	0.095	–0.187	0.082	–0.407

Year of enlistment										
1861	0.281	N.I.	0.231	N.I.	0.221	N.I.	0.248	N.I.	0.403	N.I.
1862	0.544	–0.303	0.359	0.329*	0.385	0.130	0.470	0.212	0.209	–0.649*
1863	0.077	0.487	0.050	0.366	0.024	0.390	0.052	–1.361**	0.076	–0.282
1864	0.091	–0.674*	0.303	–0.690***	0.224	–1.302***	0.204	–0.804***	0.216	–0.796**
1865	0.006	–14.30	0.057	–2.874***	0.144	–0.702***	0.026	–1.515***	0.095	–13.895
Duty-infantryman	0.659	1.371***	0.673	0.912***	0.667	1.262***	0.534	1.154***	0.631	1.363***
Rank-private	0.883	0.513	0.925	0.727**	0.885	0.266	0.892	0.511*	0.898	0.181

Notes: Dependent variable is dummy variable that equals 1 if a person died from a disease, and zero otherwise. N.I. = not included.

[a]Dependent variable mean = 0.125; N = 1,091.

[b]Dependent variable mean = 0.073; N = 3,139.

[c]Dependent variable mean = 0.090; N = 3,927.

[d]Dependent variable mean = 0.155; N = 1,269.

[e]Dependent variable mean = 0.155; N = 707.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

resisting disease because of their superior immunity status. If other socioeconomic factors and military positions are controlled for, occupation and county of residence do not have any significant effects on the probability of dying from disease while in service. In New England, natives were much less likely to be killed by disease than were foreign-born recruits. In the South, the mortality differentials according to occupation and place of residence, clearly seen in table 3.11, are no longer present once other variables are controlled for.

These peculiar patterns of New England and the South remain a puzzle to be examined in further studies. A possible explanation for the case of New England is that the effects of socioeconomic backgrounds were relatively weak because New England regiments went through more difficult and dangerous military missions, as indicated by greater casualties caused by wounds. Under circumstances where people are exposed to strong common risk factors that are not associated with their socioeconomic backgrounds, it would be more difficult to identify the effects on mortality of socioeconomic factors. In the South, the weak relationship between socioeconomic background and wartime mortality may be explained as follows: First, since urban development was relatively retarded in the South, urban and rural disease environments were probably not much different in this region compared to those in the North.[18] Second, even the rural population may have been exposed to relatively unhealthy environments in the South due to a climate that is more favorable to the development of various infectious diseases.

3.6 Summary and Implications

The most important result of this study is that prior exposure to unfavorable epidemiological environments reduced the chances of contracting and dying from disease while in service. Farmers and rural residents, who were healthier on average prior to enlistment owing to a greater extent of isolation from other people, were more likely to succumb to illness and to be killed by disease than nonfarmers and urban dwellers, respectively. Native recruits were subject to a greater risk of illness than were foreigners, who had more chances of exposure to infectious diseases in the course of immigration. More direct evidence for the relationship between local disease environment prior to enlistment and health while in service comes from the result that recruits from a county with a higher child death rate were less likely to contract disease than those from a low-mortality county.

The different degree of immunity against pathogens is probably the most

18. In 1860, slightly more than 8 percent of the population in the South lived in cities with a population of 2,500 or more, as compared to 36 percent in the Northeast and 14 percent in the North Central (U.S. Bureau of the Census 1975, A178–179).

important link between the extent of prior exposure to disease and later health. That is, despite the negative consequences for net nutritional status, survivors of unhealthy environments developed better immunity to some of the infectious diseases that were rampant in army life. This hypothesis is supported by the result that the mortality differentials by occupation and place of residence are particularly large for diseases such as typhoid, smallpox, and measles that are known to have greater potential for the development of immunity. Consistent with the immunity hypothesis, moreover, a disproportionately large fraction of the difference between farmers and nonfarmers in mortality caused by immunity diseases was made in the early stage of military service when recruits were not seasoned to the new disease environment in the army camp.[19]

However, immunity may not be the only link between local disease environments and health. The effect of the county death rate on the odds of contracting disease is strong for nonimmunity diseases such as diarrhea and malaria. Also, farmers were disadvantaged even for nonimmunity-type diseases for which their superior nutritional status should have provided an advantage. A possible explanation is that people who lived in an unhealthy environment were better aware of how to avoid contracting disease than those with little experience of disease. An alternative account is population selection caused by differential mortality: Individuals who survived an unhealthy environment were on average more robust.

The results of this study provide a counterexample of the "insult accumulation model" stating that each insult from illness or injury leaves the individual more susceptible to disease in the future (Alter and Riley 1989). The medical experiences of recruits suggests that it is possible that a prior insult provides a resistance to disease, especially when a person is suddenly exposed to a severe disease environment such as Civil War army camps. More generally, this study suggests that we need to reconsider the interrelationship between epidemiological environments and the development of human resistance to disease in order to better understand the links between early-life conditions and later health.

This study provides new evidence pertaining to the link between economic status and health in the nineteenth century. A weak association between wealth and mortality has been a puzzling phenomenon in U.S. economic and demographic history. Steckel (1988) has found that wealth conveyed no systematic advantage for the survival of women or children in households matched in the 1850 and 1860 censuses. As late as 1900, economic status appears to have been a much less important correlate of child mortality than

19. These conclusions are confirmed by the chapter in this volume by Daniel Smith, based on published military service records of New York regiments. Regiments whose recruits came from counties that were more rural and that had lower crude death rates experienced higher mortality during the war. Moreover, the background factors associated with prior exposure to disease were much stronger during the first year in service than thereafter.

place of residence (Preston and Haines, 1991, 150–58). This has led to discussions of egalitarian patterns of death and of relatively small differences in health by social class, perhaps because the poor were better fed in the United States than in Europe.[20] I reported in previous research that there existed a positive effect of wealth on health at least for some diseases on which nutritional influence is great (Lee 1997). I also claimed that the association between wealth and mortality from all causes was weak because the influence of infectious diseases was so strong that it dominated the effect of economic status. The present study has found that economic status measured by household wealth per adult equivalent reduced the chances of contracting diseases while in service. However, wealth had no favorable effect on mortality. This result suggests that in spite of a weak wealth-mortality link, economic status may have been an important determinant of health in the nineteenth century, particularly if morbidity rather than mortality is considered.

This article also strengthens my previous hypothesis that changing human resistance to disease is a potentially important factor in the changes in health in nineteenth-century America. Life expectancy and mean adult height, major indicators of health, declined through the early nineteenth century (Fogel 1986; Komlos 1987, 1992, 1996; Floud, Wachter, and Gregory 1990; Pope 1992; Steckel 1995; Gallman 1995, 1996). A highly plausible explanation for the cycle in health is the epidemiological impact of increased geographical mobility. Higher rates of interregional trade and migration increased morbidity and mortality by spreading communicable diseases and by exposing newcomers to different disease environments. The rise of public schools and changes in labor organization exerted a similar effect by increasing the risk of exposure to infectious diseases (Steckel 1995, 1929–30). The results of this study provide additional evidence for this hypothesis, highlighting the adverse effect of contact with new disease environments caused by geographical migrations.

There was a turnaround in the deterioration in health in the late nineteenth century. Mortality rates started to decline again after the Civil War, and adult height began to increase in the late nineteenth century. Even though a consensus has been reached that the elimination of chronic malnutrition; advances in public health; improvements in housing, sanitation, and food hygiene; and advances in medical technology were important factors which contributed to the decline in mortality, the relative importance of those factors is still under debate (Higgs 1973, 1979; Appleby 1975; McKeown 1976, 1983; Condran and Cheney 1982; Livi-Bacci 1982; Kunitz 1983; Fogel 1986, 1991). The evidence provided in this article suggests that an increase in the degree of resistance, either immunological or social, against infectious diseases could be another potential factor.

Considering the roles of human resistance to disease helps to explain sev-

20. In contrast to these studies, the chapter in this volume authored by Joseph Ferrie found that wealth, especially personal wealth, had a strong impact on mortality in rural America.

eral puzzles in the patterns of the improvements in health since the late nineteenth century, particularly regarding the exact timing of the change. According to pioneering regional studies, the upturn of the trend in the mean height did not occur until the 1880s or 1890s, twenty to thirty years later than the beginning of mortality improvements (Steckel and Haurin 1994; Wu 1994; Coclanis and Komlos 1995). The nutrition hypothesis does not explain why mortality began to decline long before any signs of nutritional improvements appeared. On the other hand, the hypothesis regarding human resistance to disease is at least consistent with the timing of the mortality decline. The proportion of the population living in urban areas substantially increased and, owing to the developments of canals and railroads, the degree of geographical mobility rose between 1830 and 1860.[21] These changes presumably increased the fraction of the population who were exposed to but survived various infectious diseases. The results of this study suggest that such shifts in the epidemiological experiences of the population would have lowered the mortality from infectious diseases. This explanation is also consistent with the urban-rural difference in the mortality decline. The decline in mortality rates was faster in urban areas than in rural areas between 1870 and 1900. Previous studies have explained this phenomenon largely by the advances in the urban public health system (Haines 1977; Condran and Crimmins 1980; Preston, Haines, and Pamuk 1981). However, the effectiveness of the advances in public health measures such as the provision of central water supplies, sewage systems, and inspection of food and milk was at best limited even until the last decade of the nineteenth century (Condran and Crimmins-Gardner 1978; Condran and Cheney 1982). On the other hand, the proportion of the population with prior experiences with communicable diseases may have increased more rapidly in cities than in the countryside. If this was the case, we would expect a faster mortality decline in urban areas than in rural areas.

References

Alter, G., and J. Riley. 1989. Frailty, sickness, and death: Models of morbidity and mortality in historical populations. *Population Studies* 43:25–45.

Appleby, A. B. 1975. Nutrition and disease: The case of London, 1550–1750. *Journal of Interdisciplinary History* 6:1–22.

21. In 1830, 4.5 percent of the population were living in large cities with 50,000 residents or more; this percentage rose to 11.0 percent by 1860 and reached 18.7 percent by 1890 (U.S. Bureau of the Census 1965, 14). The proportion of the population residing in small cities with 2,500 to 50,000 inhabitants rose from 5.5 percent in 1830 to 9.9 percent in 1860 (U.S. Bureau of the Census, 14). The decline in the proportion of the population employed in agriculture could have also contributed to the decline in the urban mortality rate, since new migrants to large cities would have been more likely to be nonagricultural workers as the agricultural sector shrank.

Barker, D. J. P. 1992. *Fetal and infant origins of adult disease.* London: British Medical Journal of Publishing Group.

———. 1994. *Mothers, babies, and disease in later life.* London: British Medical Journal of Publishing Group.

———. 1997. Maternal nutrition, fetal nutrition, and disease in later life. *Nutrition* 13 (9): 807–13.

Barker, D. J. P., C. Osmond, J. Golding, D. Kuh, and M. E. J. Wadsworth. 1989. Growth in utero, blood pressure in childhood and adult life, and mortality from cardiovascular disease. *British Medical Journal* 298:564–67.

Coclanis, P. A., J. Komlos. 1995. Nutrition and economic development in post-Reconstruction South Carolina. *Social Science History* 19:91–115.

Condran, G. A., and R. A. Cheney. 1982. Mortality trends in Philadelphia: Age- and cause-specific death rates 1870–1930. *Demography* 19:97–123.

Condran, G. A., and E. Crimmins. 1979. Descriptions and evaluation of mortality data in the Federal Census, 1850–1900. *Historical Methods* 12:1–23.

———. 1980. Mortality differentials between rural and urban areas of states in the northeastern United States, 1890–1900. *Journal of Historical Geography* 6:179–202.

Condran, G. A., and E. Crimmins-Gardner. 1978. Public health measures and mortality in U.S. cities in the late nineteenth century. *Human Ecology* 6:27–54.

Costa, D. L. 1993. Height, wealth, and disease among the native-born in the rural, antebellum North. *Social Science History* 17:355–83.

———. 2000. Understanding the twentieth-century decline in chronic conditions among older men. *Demography* 37:53–72.

Cuff, T. 1992. A weighty issue revisited: New evidence on commercial swine weights and pork production in mid–nineteenth century America. *Agricultural History* 66:55–74.

Curtin, P. D. 1989. *Death by migration.* Cambridge: Cambridge University Press.

Deaton, A., and C. Paxson. 1999. Mortality, education, income, and inequality among American cohorts. NBER Working Paper no. W7140. Cambridge, Mass.: National Bureau of Economic Research.

Diderichen, F. 1990. Health and social inequality in Sweden. *Social Science and Medicine* 31:359–67.

Elo, I. T., and S. H. Preston. 1992. Effects of early-life conditions on adult mortality: A review. *Population Index* 58:186–212.

Fetter, B., and S. Kessler. 1996. Scars from a childhood disease: Measles in the concentration camps during the Boer War. *Social Science History* 20:593–611.

Floud, R., and R. Steckel. 1997. *Health and welfare during industrialization.* Chicago: University of Chicago Press.

Floud, R., K. Wachter, and A. Gregory. 1990. *Height, health, and history.* Cambridge: Cambridge University Press.

Fogel, R. W. 1986. Nutrition and the decline in mortality since 1700: Some preliminary findings. In *Long-term factors in American economic growth,* ed. S. L. Engerman and R. E. Gallman, 439–555. Chicago: University of Chicago Press.

———. 1993. The conquest of high mortality and hunger in Europe and America: Timing and mechanisms. In *Favorites of fortune: Technology, growth, and economic development since the Industrial Revolution,* ed. P. Higonnet, D. Landes, and H. Rosovsky, 33–71. Cambridge: Harvard University Press.

Fogel, R. W., and C. Lee. 1993. New sources and new techniques for the study of secular trends in nutritional status, health, mortality, and process of aging. *Historical Methods* 26:5–43.

———. 2002. Who gets health care. *Daedalus* 131 (1): 107–17.

Gallman, R. E. 1995. Pork production and nutrition during the late nineteenth century: A weighty issue visited yet again. *Agricultural History* 69:592–606.
———. 1996. Dietary change in antebellum America. *Journal of Economic History* 56:193–201.
Gould, B. A. 1869. *Investigations in the military and anthropological statistics of American soldiers.* Cambridge: Harvard University Press.
Haines, M. R. 1977. Mortality in nineteenth century America: Estimates from New York and Pennsylvania census data, 1865 and 1900. *Demography* 14:311–31.
———. 1998. Health, height, nutrition, and mortality: Evidence on the antebellum puzzle from the Union Army recruits for New York State and the United States. In *The biological standard of living in comparative perspective,* ed. J. Komlos and J. Baten, 155–80. Stuttgart: Franz-Steiner-Verlag.
Haines, M. R., and B. A. Anderson. 1988. New demographic history of the late nineteenth-century United States. *Explorations in Economic History* 25:341–65.
Hess, E. J. 1981. The 12th Missouri Infantry: A socio-military profile of a Union regiment. *Missouri Historical Review* 76:53–77.
Higgs, R. 1973. Mortality in rural America, 1870–1920: Estimates and conjectures. *Explorations in Economic History* 10:177–95.
———. 1979. Cycles and trends of mortality in 18 large American cities, 1871–1900. *Explorations in Economic History* 16:381–408.
Kitagawa, E. V., and P. M. Hauser. 1973. *Differential mortality in the United States: A study in socioeconomic epidemiology.* Cambridge: Harvard University Press.
Komlos, J. 1987. Height and weight of West Point cadets: Dietary change in antebellum America. *Journal of Economic History* 47:897–927.
———. 1992. Toward an anthropometric history of African-Americans: The case of the free Blacks in antebellum Maryland. In *Strategic factors in nineteenth-century American economic history,* ed. C. Goldin and H. Rockoff, 297–330. Chicago: University of Chicago Press.
———. 1996. Anomalies in economic history: Toward a resolution of the antebellum puzzle. *Journal of Economic History* 56:202–14.
Kunitz, S. J. 1983. Speculations on the European mortality decline. *Economic History Review* 36:349–64.
Lawson, J. S., and D. Black. 1993. Socioeconomic status: The prime indicator of premature death in Australia. *Journal of Biosocial Science* 25:539–52.
Lee, C. 1997. Socioeconomic background, disease, and mortality among Union Army recruits: Implications for economic and demographic history. *Explorations in Economic History* 34:27–55.
———. 1999. Selective assignment of military positions in the Union Army: Implications for the impact of the Civil War. *Social Science History* 23:67–97.
Lehmann, P., C. Mamboury, and C. Minder. 1990. Health and social inequalities in Switzerland. *Social Science and Medicine* 31:369–86.
Livi-Bacci, M. 1982. The nutrition-mortality link in past times: A comment. *Journal of Interdisciplinary History* 14:293–98.
Margo, R. 2000. *Wages and labor markets in the United States, 1820–1860.* Chicago: University of Chicago Press.
Marmot, M. 1999. Multi-level approaches to understanding social determinants. In *Social epidemiology,* ed. L. Berkman and I. Kawachi, 349–367. Oxford: Oxford University Press.
Marmot, M., G. D. Smith, S. Stansfield, C. Patel, F. North, J. Head, I. White, E. Brunner, and A. Feeny. 1991. Health inequalities among British civil servants: The Whitehall II study. *Lancet* 337 (8 June): 1387–93.
May, J. M. 1958. *The ecology of human disease.* New York: MD Publications.

McKeown, T. 1976. *The modern rise of population.* New York: Academic Press.
———. 1983. Food, infection, and population. *Journal of Interdisciplinary History* 14:227–47.
McNeill, W. H. 1976. *Plaugues and peoples.* Garden City, N.Y.: Doubleday.
McPherson, J. M. 1988. *Battle cry of freedom.* New York: Oxford University Press.
Notkota, V., S. Punsar, M. J. Karvonen, and J. Haapakoski. 1985. Socio-economic conditions in childhood and mortality and morbidity caused by coronary heart disease in adulthood in rural Finland. *Social Science and Medicine* 21:517–23.
Pope, C. L. 1992. Adult mortality in America before 1900: A view from family histories. In *Strategic factors in nineteenth century American economic history,* ed. C. Goldin and H. Rockoff, 267–96. Chicago: University of Chicago Press.
Poulson, B. W. 1981. *Economic history of the United States.* New York: Macmillan.
Preston, S. H., and M. R. Haines. 1991. *Fatal years: Child mortality in late nineteenth century America.* Princeton, N.J.: Princeton University Press.
Preston, S. H., M. R. Haines, and E. Pamuk. 1981. Effects of industrialization and urbanization on mortality in developed countries. In *International Population Conference, Manila, 1981: Solicited papers.* Vol. 2, 233–54. Liege: International Union for the Scientific Study of Population.
Pritchett, J. B., and İ. Tunali. 1995. Strangers' disease: Determinants of yellow fever mortality during the New Orleans epidemic of 1853. *Explorations in Economic History* 32:517–39.
Ravelli, A. C. J., J. H. P. Vander Meulen, R. P. J. Michels, C. Osmond, D. J. P. Barker, C. N. Hales, and O. P. Bleker. 1998. Glucose tolerance in adult after prenatal exposure to famine. *Lancet* 351 (17 January): 173–76.
Rosenberg, C. E. 1962. *The cholera years.* Chicago: University of Chicago Press.
Sapolsky, R. 1993. Endocrinology alfresco: Psychoendocrine studies of wild baboons. *Recent Progress in Hormone Research* 48:437–68.
Seeman, T., B. Singer, J. Row, R. Horwitz, and B. McEwen. 1997. Price of adaptation: Allostatic load and its health consequences. *Archives of Internal Medicine* 157:2259–68.
Sköld, P. 1997. Escape from catastrophe. *Social Science History* 21:1–25.
Soltow, L. 1992. Inequalities in the standard of living in the United States, 1798–1875. In *American economic growth and standard of living before the Civil War,* ed. R. Gallman and J. Wallis, 121–72. Chicago: University of Chicago Press.
———. 1983. Height and per capita income. *Historical Method* 16:1–7.
———. 1988. The health and mortality of women and children, 1850–1860. *Journal of Economic History* 48:333–45.
———. 1995. Stature and the standard of living. *Journal of Economic Literature* 33:1903–40.
Steckel, R. H., and D. R. Haurin. 1994. Health and nutrition in the American Midwest: Evidence from the height of Ohio National Guardsmen, 1850–1910. In *The standard of living and economic development: Essays in anthropometric history,* ed. J. Komlos, 93–116. Chicago: University of Chicago Press.
Steiner, P. E. 1968. *Disease in the Civil War: Natural biological warfare in 1861–1865.* Springfield, Ill.: Charles C. Thomas.
United Nations. 1973. *The determinants and consequences of population trends: New summary of findings of interaction of demographic, economic, and social factors.* New York: United Nations.
U.S. Bureau of the Census. 1965. *Statistical history of the United States from Colonial times to the present.* Washington, D.C.: GPO.
———. 1975. *Historical statistics of the United States, Colonial times to 1970.* Washington, D.C.: GPO.

U.S. Surgeon General's Office. 1870. *Medical and surgical history of the War of the Rebellion.* Washington, D.C.: GPO.

Vinovskis, M. A. 1990. Have social historians lost the Civil War? Some preliminary demographic speculations. In *Toward a social history of the American Civil War,* ed. M. A. Vinovskis, 1–30. New York: Cambridge University Press.

Wadsworth, M. E. J., and D. J. L. Kuh. 1997. Childhood influences on adult health. *Pediatric and Perinatal Epidemiology* 11:2–20.

Wilkinson, R. G. 1996. *Unhealthy societies: The afflictions of inequalities.* London: Routledge.

Wu, J. 1994. How severe was the Great Depression? Evidence from the Pittsburgh region. In *The standard of living and economic development: Essays in anthropometric history,* ed. J. Komlos, 93–116. Chicago: University of Chicago Press.

Zurbrigg, S. 1997. Did starvation protect from malaria? *Social Science History* 21:27–58.