The Mortality Effects of Local Boards of Health in England, 1848-70

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Abstract

World health has improved immeasurably among developed countries since the middle of the nineteenth century. However, because there is no clear consensus about the precise role played by public health interventions in this improvement, there is also no clear policy prescription for developing countries for which health remains relatively poor. In this paper, I explore the Public Health Act of 1848—England's first attempt at systematic sanitation improvement—and in so doing I provide clear quantitative evidence of the relationship between public health and mortality in the context of a country in the midst of the transition from rural to urban and from agricultural to industrial. Between 1848 and 1870, the Public Health Act oversaw the adoption of more than 600 local boards of health (comprising roughly one-quarter of the English population), each of which it endowed with the power to tax, to borrow, to regulate, to provide sanitation services, and to build, re-build, seize, or otherwise alter local infrastructure such as sewers or waterworks. Since the jurisdictions of local boards of health were not coterminous with the jurisdictions of the geographical unit within which mortality statistics were recorded and reported (i.e. Poor Law unions), the mortality effects of the Public Health Act have been largely unexplored. In order to overcome this geographical mismatch, I introduce a new panel dataset, culled from a variety of primary sources, that maps the jurisdictions of local boards of health into the jurisdictions of poor law unions. I then leverage variation in both the timing and extent of board adoption across unions in order to estimate the cumulative effect of the adoption of a local board of health on mortality 1, 2, 3, and 4 years after adoption. My estimates suggest that the adoption of a union-wide local board of health reduced mortality by 14.2 percent after four years, that approximately 225,000 lives were saved by local boards of health between 1848 and 1870, and that the aggregate English mortality rate was 3.7 percent lower in 1870 than it would have been had the Public Health Act not been passed. I also calculate that the benefits of board adoption (i.e. the total statistical value of lives saved) exceeded the costs (i.e. total board expenditure) under all but the unlikeliest of assumptions about the relationship between board borrowing (which I do observe) and board expenditure (which I do not).

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1. Introduction

The health improvement that the developed world has achieved since the middle of the nineteenth century has been well-documented.[1] Infants are more likely to reach adolescence, adolescents are more likely to reach adulthood, adults are more likely to reach old-age, and many of the key killers of the nineteenth century (e.g. tuberculosis, typhoid, typhus, cholera) have been all but eliminated. Figures 1 and 2 quantify this achievement. Life expectancy at birth increased by at least 60 percent between 1800 and 1950 in France, Germany, Japan, the Netherlands, Sweden, and the United Kingdom. Average height, for which both nutrition and exposure to disease are in part responsible, also increased in each of these countries between 1850 and 1900 and again between 1900 and 1950.

What is less well-documented is the extent to which public health interventions, especially *early* public health interventions, contributed to this health improvement. Rising incomes and the emergence of modern medicine have confounded attempts to quantify the importance of, for instance, the introduction of sewage systems, water pumping plants, water treatment plants, and industrial regulations. McKeown & Record (1962) and McKeown (1976), using mortality records from England and Wales, demonstrate that a decline in communicable disease was largely responsible for the decline in mortality during the second half of the nineteenth century, and that this decline in communicable disease pre-dated, by decades, the discoveries of any medical solutions thereto (e.g. vaccinations).[2] Instead, they attribute the bulk of the decline in mortality to increased nutritional intake made possible by rising incomes. Szreter (1988, 1997), on the other hand, argues that public health interventions played a leading role in the mortality decline between 1870 and 1900. Cutler & Miller (2005), Watson (2006), Ferrie & Troesken (2008), and Alsan & Goldin (2015) corroborate the significance of public health interventions in the late nineteenth and early twentieth centuries, but only for selected cities in the United States.

Evidence suggests that it is in the midst of a country's transition from rural to urban and from agricultural to industrial that it is most susceptible to negative health shocks, and

[1] See Fogel (2004), Deaton (2013), and studies of Australia, Britain, France, Germany, Japan, the Netherlands, Sweden, and the United States in Steckel & Floud, eds. (1997).

[2] Vaccinations for the most important communicable diseases did not appear until the late 1870s: cholera (1879), typhoid (1896), diphtheria (1896), tuberculosis (1921), whooping cough (1926), typhus (1937). Furthermore, it was not until 1900 that the germ theory of disease began to displace "misguided miasma theories." See Preston (1996). that vaccinations for cholera, typhoid, diphtheria, tuberculosis, whooping cough, and typhus were discovered.

hence is most in need of intervention. Table 1 demonstrates that rapid health improvement tended to lag the rapid economic improvement generated by industrialization by between 25 and 50 years. Table 2 demonstrates that industrialization and its concomitants (e.g. slum formation, overcrowded cities, insufficient infrastructure) adversely affected health, as proxied by height, in the short run. Today's transitioning economies are hardly immune to these concomitants, however ameliorated they are by higher incomes and the knowledge of, if not access to, modern medicine.[3] As such, an understanding of the capacity of early public health interventions serves a dual role as both historical description and contemporary prescription.

In this paper, I evaluate the mortality effects of the Public Health Act of 1848—England's first attempt at systematic sanitation improvement—and in so doing I provide clear quantitative evidence of the relationship between public health and mortality in the context of a transitioning economy. The state of English sanitation on the eve of the Act was grim. Englanders in the 1840s died at roughly three times the rate at which Englanders die today and, proportionally speaking, about as many Englanders died from cholera, diarrhea, diphtheria, dysentery, respiratory organs, tuberculosis, typhus, and whooping cough (8.5 per 1,000 persons) as die from *any* cause today (9.3 per 1,000 persons).[4] Neither the quantity nor the quality of infrastructure was sufficient to meet the drainage and water supply requirements of a rapidly growing urban population in a rapidly industrializing economy. In the half-century before the Act, England's population had doubled (from 7.75 to 15.25 million) and had become increasingly concentrated in urban centers (from 33.8 to 54.0 percent). The number of cities of more than 3,000, 10,000, and 20,000 people roughly doubled, tripled, and quadrupled, respectively. In 1801, London was the only English city of more than 100,000 people. By 1851, it was one of nine.[5]

[3] In India, Indonesia, and the Philippines, for instance, the incidence of tuberculosis is between 70 and 130 times higher, the percent of deaths by communicable disease is between 2 and 4 times higher, and the rate of infant mortality is between 3 and 6 times higher than it is in the United States. Consequently, the life expectancy at birth in these countries is between 10 and 11 years shorter than it is in the United States (as of 2015). See World Bank Database: data.worldbank.org.

[4] The death rate was significantly worse for English infants, who died at a rate of no less than 125 per 1,000 born until the 1910s, roughly 30 times the rate at which they die today. I use 1859 cause-of-death data from *24th Annual Report of the Registrar-General* (1861), the first of these reports to disaggregate mortality by cause at the registration district level.

[5] Law (1967).

It was against this backdrop, and as a result of the efforts of a great many sanitary reformers, that the Public Health Act was passed. The Act oversaw the adoption of more than 600 local boards of health between 1848 and 1870, and by 1870 the jurisdictions of these local boards of health accounted for approximately one-quarter of the English population. Each local board of health was endowed with a variety of powers by which to effect sanitation improvement, including the power to tax, to borrow, to provide certain services (e.g. street sweeping, the removal of refuse and rubbish), to regulate certain activities (e.g. new construction, the disposal of industrial waste), and to build, re-build, seize, or alter local infrastructure such as sewers or other waterworks. Local boards were adopted, for all intents and purposes, voluntarily, upon the petition of at least ten percent of the taxpayers within a given "area." Since "area" was undefined by the Act, the jurisdictions of local boards did not match—except by accident—the jurisdictions of any other administrative subdivision of England, including the administrative subdivision within which mortality statistics were recorded and reported (i.e. the Poor Law union). This geographical mismatch has heretofore made it impossible to estimate the effect of the adoption of a local board of health on mortality.

I make two principal contributions. First, I construct a new, comprehensive dataset of local boards of health adopted in England between 1848 and 1870 from a variety of overlooked or otherwise unused primary sources. I overcome the geographical mismatch between local boards of health and Poor Law unions by mapping each local board of health into the Poor Law union or unions within which it was adopted. I then characterize each Poor Law union, of which there were approximately 600, by the proportion of its population that fell under the jurisdiction of a local board of health in each year. Figure 3 illustrates the variation that I observe in the extent of local board adoption across unions and over time. This variation enables me to adopt a difference-in-differences framework that accounts for fixed differences across unions and, thereby, to improve upon existing time-series analyses of the role played by public health interventions in England's nineteenth century mortality decline. Without geographical variation, these analyses have been compelled to compare the timing of the decline of *aggregate* English mortality, often

disaggregated by age or cause-of-death, with the timing of other England-wide changes.[6] Since aggregate English mortality, presented in Figure 4, did not begin to decline precipitously until the 1870s, the implicit consensus of this literature is that English public health efforts prior to 1870 were non-existent, ineffectual, or obstructed by municipal inactivism. This consensus takes for granted that mortality between 1848 and 1870 would not have been higher had the Public Health Act of 1848 not been passed.

Second, I conduct the first (to my knowledge) econometric study of the effect of a national public health intervention on pre-1870 mortality rates. I use an event study model that leverages variation in both the timing and the extent of local board adoption across unions. My estimates reveal a clear and statistically significant break in relative mortality trends in the year of board adoption. Following Finkelstein (2007), I interpret the difference between pre- and post-adoption trends as an estimate of the impact of the adoption of a local board of health. I calculate that the adoption of a union-wide local board of health would have reduced mortality by 14.2 percent after four years. Accounting for the proportion of the English population that fell under the jurisdiction of a local board of health, this amounts to a 3.7 percent reduction in aggregate English mortality by 1870, or approximately 225,000 lives saved. I also calculate that the benefits of the adoption of a local board of health, as measured by the total statistical value of the lives that they saved, exceeded the costs of the adoption of a local board of health, as measured by total board expenditure, under all but the unlikeliest of assumptions about the relationship between board borrowing (which I do observe) and board spending (which I do not).

The remainder of this paper is organized as follows. In Section 2, I provide a brief sketch of relevant English local government areas, enumerate the sources from which my

[6] This literature dates to the nineteenth century. See Longstaff (1884), Phillips (1908), Gale (1943), Logan (1950), McKeown & Record (1962), McKeown (1976), Szreter (1988), Guha (1994), Szreter (1994), and Szreter (1997). One of the advantages of my approach is that I need not rely on notoriously unreliable cause-of-death data. It was not until 1845 that the General Register Office (GRO) began to issue medical practitioners printed forms for the purpose of certification, not until 1860 that more than 80% of registered deaths were certified, not until the Registration Act of 1874 that the procedure for certification was standardized, and not until the 1880s that GRO statisticians were empowered to submit confidential inquiries to double check ambiguous death certificates. Moreover, misdiagnoses were commonplace. The quality of medical science and of medical practitioners was not what it is today, and socially sensitive causes of death such as alcoholism, syphilis, or suicide were very often intentionally misdiagnosed for the sake of the reputations of the families of the deceased. See Eyler (1976), Eyler (1979), Luckin (1980), Hardy (1994), and Bell & Millward (1998) for a more comprehensive discussion of the shortcomings of mid-nineteenth century cause-of-death statistics.

dataset is drawn, illustrate the procedure by which local boards were adopted, created, and composed, summarize the powers endowed to local boards, and assess the extent to which these powers were exercised. In Section 3, I introduce my empirical model, discuss identification and a number of potential threats thereto, interpret my results, and conduct a back-of-the-envelope cost-benefit analysis of local board adoption. In Section 4, I conclude.

2. Institutional Background

2.1 English Local Government Areas & Data

English local government areas in the nineteenth century were, in a word, a "chaos."[7] Inhabitants of municipal boroughs, for example, "lived in a fourfold area for local government purposes—the borough, the parish, the union, and the county," and this is to say nothing of the hundred, the riding, the ward, the cinque port, the police district, or the parliamentary constituency. In this section I illustrate the geography of and the relationships between each of the three administrative subdivisions of England upon which the rest of this paper relies: (i) the parish, (ii) the union, and (iii) the local board of health. I also introduce the data that I employ within each subdivision and the sources from which these data are drawn and transcribed. A more detailed description of the way in which my dataset is constructed can be found in the Data Appendix.

The Parish. A descendent of the Saxon "vill" or township, the parish was, in its infancy, the ecclesiastical counterpart to the feudal manor.[8] By the beginning of the nineteenth century it had acquired a hodgepodge of administrative functions, including, but not limited to, the keeping of the peace, the repression of vagrancy, and the relief of destitution.[9] For the purposes of this paper, the parish is significant because it was the smallest subdivision in the hierarchy of English local government, and therefore the subdivision in relation to which both the union and the local board of health were defined.[10] There were approximately 13,000 parishes in England by the middle of the nineteenth century. Panel

[7] Of English local government, George Goschen said in 1871 that "we have a chaos as regards authorities, a chaos as regards rates, and a worse chaos than all as regards areas." See Lipman (1949), p. 79.
[8] Lipman (1949), p. 24.
[9] Webb & Webb (1906), p. 4.
[10] Redlich & Hirst (1903), pp. 22-23.

A of Figure 5, for example, plots the boundaries of each of the 242 parishes within the county of Berkshire.

The Union. The union was conceived as an intermediary between the parish and the county by the Poor Law Amendment Act of 1834, which required an administrative subdivision that would be, on the one hand, large enough that its tax base could conceivably finance the construction and operation of a workhouse, and, on the other hand, small enough that the average commute for welfare recipients and welfare administrators would not be prohibitively lengthy. Parishes failed the first test. Counties failed the second. The solution was to agglomerate parishes into approximately 600 unions of parishes that, when brought into existence, would become "by far the most complete governmental organization in the country."[11] Panel B of Figure 5, for example, plots the boundaries of each of the 12 unions in the county of Berkshire, as well as the boundaries of the parishes of which these unions were made up. This organization was subsequently used to superintend a new, secular system for the registration of births, deaths, and marriages. Registration data were compiled and reported annually by the General Register Office, and it is from the tenth through the thirty-third of these *Reports* (1849-72) that I obtain the number of deaths in each union in each year between 1847 and 1870. I obtain the population, the percent of adults working in agriculture, the area in acres, and the names of the constituent parishes of each union in 1841, 1851, 1861, and 1871 from *Decennial Census Reports* (1841-71). I obtain the political affiliation, the proportion of acreage that consisted of water (i.e. harbors, creeks, rivers, etc.), the proportion of population that fell under the jurisdiction of a municipal government, and indicators for whether coal or cotton-textiles were "special occupations" of each union from the *Census Report* of 1851.[12] Political affiliation is defined as the proportion of the members of parliament representing each union that were considered conservative in 1852 by the *Guide to the House of Commons* (1857). I obtain the per capita welfare expenditure of each union from the *Fourth Annual Report of the Poor Law Board* (1851). Welfare expenditure is defined as the amount "expended for in-maintenance, for

[11] Cannan (1898), pp. 62-63.
[12] Neither the boundaries of parliamentary constituencies nor the boundaries of municipal boroughs matched the boundaries of poor law unions. See the data appendix for the method by which I match these areas to one another.

out-relief, and for other expenses of or immediately connected with [the English Poor Law].” I obtain the rateable value (i.e. property wealth) of each union in the years 1856 and 1868 from the *Return of the Gross Estimated Rental Property* (1861) and the *Return of Rateable Value* (1869), respectively.[13] Lastly, I obtain measures of the religiosity and the religious affiliation of the inhabitants of each union from the *Religious Supplement to the Census* of 1851. Religiosity is defined as the percent of population that attended any church service on March 30th, 1851. Religious affiliation is defined as the percent of church sittings that were non-conformist (i.e. non-Anglican Protestant) in 1851.

The Local Board of Health. The Public Health Act of 1848 introduced an additional administrative subdivision—the local board of health—atop of this existing network of parishes and unions. Local board districts were defined as the parishes or parts of parishes of which they were made up, and were neither constrained nor informed by the boundaries of unions. There was, therefore, only coincidental geographical agreement between the administrative subdivision within which mortality statistics were reported (i.e. the union) and the administrative subdivision for which mortality reduction was the raison d'être (i.e. the local board of health). I match the two administrative subdivisions in the following way. First, I obtain the population, the adoption date, and the names of the parishes partly or wholly within the districts of each local board of health adopted between 1848 and 1866 from the *Return of Local Boards* (1868).[14] Second, I match the parishes partly or wholly within the districts of each local board of health to the union or unions to which they belonged. Third, I determine the fraction of each union’s population that fell within the jurisdiction of a local board in every year between 1848 and 1866. I then characterize each union by (i) the extent to which it was “treated” by the adoption of a local board of health and (ii) the year in which this “treatment” occurred. The Wallingford Poor Law Union, for example, consisted of 29 parishes, five of which combined to form the Wallingford Local Board of Health in 1863. These five parishes—Allhallows, St. Leonard, St. Mary-the-More, St. Peter, and Wallingford Castle—accounted for 31.5 percent of the Wallingford Union’s population. I therefore consider the Wallingford Poor Law Union to have been 31.5 percent treated, beginning in 1863, by the Public Health Act. Panel C of Figure 5 plots

[13] Parl. Papers, 54 (1861), pp. 1-276; Parl. Papers, 53 (1868-69), pp. 33-58.
[14] Parl. Papers, 58 (1867-68), pp. 789-823. This *Return* also enumerates the area in acres and the rateable value of each of these local boards.

the boundaries of each of the three local boards of health adopted between 1848 and 1866 in the country of Berkshire.

Throughout the remainder of the paper I use the union-year as my unit of observation. It is therefore necessary to (i) merge boards adopted in the same union in the same year and (ii) divide boards that crossed union boundaries.[15] These modifications yield 444 board adoptions in 272 distinct unions between 1848 and 1866. Of these 272 adoption unions, about two-thirds (176 unions) experienced only one board adoption and about one-third (96 unions) experienced more than one board adoption during this period. The remaining 304 unions did not adopt a local board of health. Figure 6 plots the distribution of board adoptions per union. Figure 7 demonstrates that the diffusion of local boards of health across England was gradual and, even by 1866, far from comprehensive—in that year, only 26.6 percent of England's population and 19.7 percent of England's rateable value fell under the jurisdiction of a local board of health.

I exclude two types of unions from my dataset. First, I exclude all 27 metropolitan London unions since metropolitan London was excluded from the Public Health Act.[16] This leaves 549 total unions and 272 adoption unions. Second, I exclude all 20 unions within which at least one local board was adopted between 1867 and 1870. Although I observe where these boards were adopted, I do not observe their exact adoption date, and therefore cannot characterize the post-adoption period of their corresponding unions with any precision.[17] This leaves 529 total unions and 252 adoption unions, each of which has a well-defined post-period through 1870.

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[15] Here I give two examples. The first example demonstrates board-merging. Two boards were adopted in the Altrincham Union in 1863: the Lymm Local Board on March 6th, consisting of the 3,750-person parish of Lymm, and the Hollingworth Local Board on December 7th, consisting of the 2,300-person parish of Hollingworth. I consider these as one 6,050-person board. The second example demonstrates board-dividing. The Kingston-upon-Hull Local Board, adopted in 1851, consisted of the entirety of the 55,000-person Kingston-upon-Hull Union as well as the 2,000-person parish of Drypool, the 2,000-person parish of Garrison Side, the 27,000-person parish of Sculcoates, the 2,000-person parish of Southcoates, and the 8,000-person parish of Sutton in the Sculcoates Union. I consider this as two boards—one 55,000-person board in the Kingston-upon-Hull Union and another 41,000-person board in the Sculcoates Union. Since local boards were disproportionately adopted in high-population areas, and since unions were typically "arranged in a circle, taking a market town as [their] centre, and comprehending those surrounding parishes whose inhabitants [were] accustomed to resort to the same market," it was relatively rare for a local board to cross union boundaries. See the *First Report of the Poor Law Commission* (1835), p. 12 and Lipman (1949), p. 44.

[16] It was believed that metropolitan London "required special legislation because of its size." This legislation consisted of the Metropolitan Commission of Sewers Act of 1848 (11 & 12 Vict., c. 112) and the Metropolis Management Act of 1855 (18 & 19 Vict., c. 120). See Hamlin & Sheard (1998), p. 590.

[17] Board adoptions between 1867 and 1870 are given by Parl. Papers, 55 (1870), pp. 711-52.

Table 3 presents summary statistics for all of England, for England excluding metropolitan London, for adoption unions, and for adoption unions that remain in my sample. I find that adoption unions tended to be somewhat poorer, less agricultural, less conservative, and more likely to produce coal or cotton-textiles. A comparison of the second and third columns of Table 3 shows that the exclusion of the 20 unions within which a local board of health was adopted between 1867 and 1870 does not significantly alter the composition of unions in my dataset. Likewise, a comparison of the fifth and sixth columns of Table 3 shows that this exclusion does not significantly alter the composition of boards in my dataset.

2.2 The General Board of Health

In order to oversee the adoption of local boards of health, the Public Health Act established a national, three-member General Board of Health, equipped this Board with a veritable army of clerks, servants, and inspectors, and defined the precise procedure by which a "city, town, borough, parish, or place" could adopt a local board. Since the language of the Act did not require that the boundaries of boards conform to or lie within any other boundary, a board of any size could be adopted anywhere, no matter how small or large, how compact or straggling. Adoption, furthermore, could be voluntary or involuntary, at least in principle. Voluntary adoption required a petition containing the signatures of at least 10 percent of the inhabitants rated to the relief of the poor in a particular area. Involuntary adoption required an imposition by the General Board. If the General Board ascertained that the death rate in a particular area exceeded 23 per 1,000 persons for a period of no less than seven years, then it was authorized to impose a local board upon an area without the consent of its inhabitants.[18] In practice, however, local boards were rarely, if ever, imposed on areas "without substantial local enthusiasm."[19] Since sanitary improvements were undertaken at the discretion of the boards themselves, any attempt to impose a board on an area disinclined to sanitize itself would accomplish nothing. The General Board could impose adoption but could not compel action.

My data corroborate this point. By 1855, at least one local board was adopted in only 55 of the 120 non-London unions within which the average death rate between 1847

[18] This provision "in effect set a mortality rate, the then national average, as a minimum standard of health and as an administrative cue to permit action by the central health authority." See Eyler (1976), p. 340.
[19] Hamlin & Sheard (1998), p. 590.

and 1853 exceeded 23 per 1,000 persons. In only 12 of these 55 adoption unions did this adoption occur in 1854 or 1855, when the mortality statistics of the entire seven-year period would have been known to the General Board. These approximate proportions hold for every seven-year period between 1847 (the first year in which the General Register Office reported mortality statistics at the union level) and 1858 (the year in which the Local Government Act replaced the General Board of Health with the Local Government Act Office, and in so doing made inoperative the clause in the Public Health Act that authorized the involuntary adoption of local boards).[20] Thereafter, adoption was entirely optional with inhabitants in both principle and practice.

2.3 The Creation and Composition of Local Boards of Health

Both the creation and the composition of local boards of health depended on the geographical boundaries that they took.

Creation. A superintending inspector was sent to every area that petitioned for adoption to assess its general sanitary state and the sanitary state of its inhabitants. If, after inspection, the General Board determined that the Act should be applied "within the same boundaries as those of an [existing] city, town, borough, parish, or place," local board adoption required only on an Order in Council (i.e. an order of the Queen acting by and with the advice and consent of her Privy Council). If, however, the General Board determined that the Act should be applied within new boundaries—within boundaries "not being the same as those of an [existing] city, town, borough, parish, or place"—local board adoption required a Provisional Order (i.e. an order by the General Board to be confirmed by Parliament). I find that roughly half of all boards were created by Provisional Order.[21]

[20] Originally intended to expire in 1854, after a five-year phase-in period, the General Board was renewed annually four times. These acts of renewal were the Public Health Act of 1854 (17 & 18 Vict., c. 95), the General Board of Health Continued Act of 1855 (18 & 19 Vict., c. 115), the General Board of Health Act of 1856 (19 & 20 Vict., c. 85), and the General Board of Health Act of 1857 (20 & 21 Vict., c. 38). The Local Government Act of 1858 abolished the General Board of Health, permitted a counter-petition of 5 percent of an area's inhabitants, and permitted town councils of municipal boroughs to file for adoption directly. See Lumley (1859), p. 38; Lambert (1962), pp. 123-24.

[21] Among all local boards of health adopted in England and Wales between 1848 and 1858, 45 percent were created by Order in Council, 50 percent were created by Provisional Order, and the other 5 percent were created by Local Acts. Boards created by Local Acts were called improvement commissions. In this paper I do not distinguish between local boards and improvement commissions insofar as these commissions "incorporated parts at least of the Public Health Act." See Parl. Papers, 59 (1867), pp. 141-167.

The boundaries, therefore, of roughly half of all boards did not previously exist for any other administrative purpose.

Composition. Members of local boards were either elected or appointed. If a board's jurisdiction consisted exclusively of a municipal borough (or a part of a municipal borough), then all board members were to be appointed from among the borough's town councilors (by the borough's town council). If a board's jurisdiction consisted of no part of any municipal borough, then all board members were to be elected by ratepayers. If a board's jurisdiction consisted of both a municipal borough (or a part of a municipal borough) as well as other areas, then some board members were to be appointed and some board members were to be elected. This proportion was fixed by the Order in Council or Provisional Order by which the board was created.

The Act, in effect, established a distinct voting scale for each of these two types of local board members. Elected members, on the one hand, were elected directly according to a plural voting scale by which the wealthiest ratepayers were awarded disproportionate electoral influence. Ratepayers could receive up to six votes for property owned and up to six votes for property occupied.[22] Appointed members, on the other hand, were elected indirectly. Municipal voters (called "burgesses") elected town councilors on a one man, one vote basis. Town councilors, in turn, were entitled (if appointed) to serve on local boards of health. The dramatic difference in voting scales for directly- and indirectly-elected board members generated an asymmetry in power among voting blocs that varied with the location of the board. The plural voting scale used to elect board members in non-municipal areas concentrated power in the hands of the *haute bourgeoisie*. The singular voting scale used to elect town councilors in municipal boroughs concentrated power in the hands of the *petite bourgeoisie*, who were more numerous than their wealthier counterparts and still wealthy enough to qualify for the franchise. Table 4 provides a side-by-side comparison of who, precisely, qualified for the franchise in local board and municipal elections.

[22] The voting scale used for local board elections was identical to that established for the election of poor law boards of guardians by the Poor Law Amendment Act of 1844 (7 & 8 Vict., c. 101). See Keith-Lucas (1952), p. 229.

Szreter (1997) argues that this asymmetry effectively countermanded the Public Health Act—that the domination of a unified (and uniquely parsimonious) *petite bourgeoisie* over municipal politics obstructed urban sanitation efforts until the Municipal Franchise Act of 1869 extended the municipal franchise to the upper tier of the working class, whereupon the stranglehold of the so-called "shopocracy" was broken. The evidence that I present in this paper, however, contradicts this argument. First, I find that the reach of municipal politics was limited. In 1851, municipal boroughs contained less than one-quarter of the total English population and less than one-half of the English population living in towns of greater than 2,000 inhabitants. More than 50 towns returning members to Parliament (i.e. parliamentary boroughs) were not regulated by the Municipal Corporations Act of 1835 and, therefore, any local boards adopted within them would not have faced the penny-pinching pressures of an ascendant *petite bourgeoisie*.[23] Figure 8, which juxtaposes population density with the location of municipal boroughs by parish, illustrates the scope of municipal boroughs more clearly. Second, I find that there is a positive correlation between the percent of union population that fell under the jurisdiction of a municipal borough in 1851 and the percent of union population that fell under the jurisdiction of a local board of health by 1866, and that this correlation persists even after controlling for differences in population density (see Section 3.1 for a more detailed discussion of the determinants of board adoption). If municipal governments and the *petite bourgeoisie* that they disproportionately represented were, in fact, opposed to the adoption of local boards of health, there is little evidence that they succeeded in their opposition.

If municipal politics did not *deter* local board adoption, what, precisely, *induced* it? Why would the wealthier inhabitants of a given area (i.e. ratepayers) voluntarily pay for the provision of sanitation improvement, and in so doing subsidize the poorer inhabitants (i.e. non-ratepayers), to whom many, if not most, of the benefits of sanitation improvement

[23] According to the 1851 Census, there were 465 English towns of more than 2,000 inhabitants, 176 of which were municipal boroughs, 52 of which were parliamentary boroughs that were not also municipal boroughs, and 237 of which were neither a municipal nor a parliamentary borough. Therefore only 37% of all such English towns were regulated by the Municipal Corporations Act of 1835. Furthermore, there were 10,329,249 persons living in these 465 towns (roughly 60 percent of the English population), 4,300,864 of which lived in a municipal borough, 4,743,441 of which lived in a parliamentary borough that was not also a municipal borough, 146,639 of which lived in a parliamentary borough that was also a municipal borough but outside of the boundaries of the municipal part, and 1,138,305 of which lived in a town that was neither a municipal nor a parliamentary borough.

would accrue? The answer lies in the proximity of the wealthy to the poor. "Close to the splendid houses of the rich," wrote Engels in 1845, "the bitterest poverty [is often] found."[24] Booth (1889) corroborates this point. Figure 9 illustrates that behind and adjacent to the middle-class residences that lined the boulevards of London were some of the city's poorest residences. In most English cities of the nineteenth century, there was no enclave to which the rich retreated. Rich and poor lived side-by-side, and the consequences of an outbreak of disease in a city slum would quickly spill over elsewhere. It was in the self-interest of the wealthy ratepayer to prevent this from happening. The next section describes the means by which local boards of health could do so.

2.4 The Powers of Local Boards of Health

Once formed, local boards were required to hold meetings at least once a month and to appoint Inspectors of Nuisances to investigate industrial emissions, unsanitary dwellings, and accumulations of refuse and sewage, among other things. Boards were also encouraged to appoint legally qualified medical practitioners as Officers of Health, though "what such officers [were] to do remained vague."[25] In what follows, I divide the powers endowed to local boards by the Public Health Act into four broad categories.

Large Capital Outlays. This category contains two classic public health expenditures: sewers and waterworks. Edwin Chadwick, the architect of the Public Health Act, "had envisaged every urban house connected to both a clean water supply and to a waterborne mains sewerage system."[26] Though the realization of this vision took more than a few decades, its seed was sown in 1848. Boards could construct, repair, enlarge, redirect, clean, or empty sewers as they saw fit. All sewers, "whether existing or made at any time thereafter," were to be "entirely under the management and control of the local board of health."[27] Likewise, boards could construct waterworks "to provide their district with such a supply of water as [was considered] proper and sufficient," so long as no for-profit

[24] Engels (1845), p. 28.
[25] All questions were to be decided by a majority vote of local board members during these meetings. See Hamlin & Sheard (1998), p. 590.
[26] Szreter (1997), p. 708.
[27] An exception was made for sewers "made by any person or persons for his or their own profit." Nevertheless, boards were authorized to "purchase or contract for the use of any such sewers."

company was willing to do the same. If necessary, boards were authorized to "purchase, take upon lease, sell, or exchange any lands or premises" within their districts.

Small Capital Outlays. This category contains less ambitious but more immediate infrastructure improvements. Public streets could be "swept, cleansed, and watered" by local boards, and any "dust ashes, rubbish, filth, dung, or soil thereon" could be "collected and removed." Boards could pave, re-pave, repair, channel, level, or otherwise alter any street in order to minimize fetid standing water. Boards could also provide and maintain "boxes for the temporary deposit or collection of rubbish" and "waterclosets, privies, or other similar conveniences for public accommodation."

Regulations. Boards could require the registration of houses, businesses, or other individuals in order to ensure compliance with regulations—or bye-laws—that they passed. Once passed, bye-laws would be circulated in at least one newspaper in the district for at least one month prior to their official adoption, after which time they would be printed and hung in the office of the local board. Bye-laws oversaw a number of activities and business entities. Among them were the following.

i. *New Construction*. The builder of any house was required to report to the local board the "intended level of the lowest floor" and the "situation and construction of any privies or cesspools" at least fourteen days before groundbreaking. It was unlawful to build or re-build a house without "a covered drain for proper and effectual drainage," and if the house was within one-hundred feet of a public sewer, its drain was required to communicate with it.
ii. *Lodging Houses*. It was unlawful for landlords to let "cellars, vaults, or underground rooms" that were "ineffectually drained," less than seven feet in height, or less than three feet in "height above the surface of the street or ground adjoining." Occupancy, ventilation, and sanitation standards were to be set by local boards.
iii. *Offensive Trades*. Inspectors of nuisances were authorized to enter any slaughterhouse "at all reasonable times" in order to dispose of "unfit meat." Likewise, any "blood boiler, bone boiler, or other noxious or offensive business, trade or manufacture" was subject to periodic inspection.
iv. *Burial Grounds*. If it was determined that a graveyard was "in such a state as to be dangerous to the health of the persons living in the neighborhood thereof, by reason

of the surcharged state of the vaults or graves," and that "sufficient means of interment [existed] within a convenient distance," it was made unlawful to "bury any further corpses or coffins within it."

v. *Other*. Any undue accumulation of "waste, stagnant water, manure, dung, soil, or filth, or any other offensive or noxious matter" was prohibited. More generally, if a house was kept "in such a filthy or unwholesome condition that the health of any person [was] affected or endangered thereby," the local board could require that the owner or occupier of the house "whitewash, cleanse, or purify the same." Lastly, manufacturers were liable to penalty (and would incur the cost of the examination) if they were found to have "fouled" any "stream, reservoir, conduit, aqueduct, or other waterwork." By-products of gasworks manufactures were singled out by the language of the Act.

Revenues. Boards had access to two types of property taxes—the "general district rate" and the "special district rate," intended to defray short- and long-term expenditures, respectively—and boards could borrow on the security of either tax. Debt was necessary to finance lumpy public works projects that could not be built "bit by bit out of annual income."[28] The Exchequer offered subsidized loans for this purpose, subject to the approval, after inspection, of the General Board. Of relatively minor importance were fines and private improvement rates collected from offenders of bye-laws. Fine amounts were set at the discretion of local boards, though they could not exceed £5 per offense, and in the case of a continuing offense any additional penalty could not exceed forty shillings for each day after written notice. Private improvement rates were reimbursements made to boards by non-compliant individuals for any improvements undertaken by boards on their behalf. Lastly, private water rates might be levied "in respect of water supplied to private properties" in proportion to the "net annual values of the premises."

To what extent did boards actually *exercise* these powers? The literature suggests that they did so sparingly, only when it benefited industry, or not at all.[29] My claim is

[28] Hamlin (1998), p. 278

[29] Rosen (1858) claims that "even the most elementary proposals for the improvement of drainage and water supplies were opposed [by vested interests] in the sacred names of property and human freedom." Hassan (1985) and Szreter (1997) emphasize that "the significance of water as an industrial raw material was often the primary consideration, with commercial demand consuming in many cases half of the extra urban water

twofold. First, boards that did not spend with abandon need not have been inactive or ineffective. Regulation was such that disobedient individuals, households, or businesses—not district ratepayers—bore the cost of improvement. Furthermore, even trivial expenditures may well have yielded nontrivial improvements given the abysmal state of nineteenth century sanitation. Second, boards *were* spending. The *Return from Local Boards of Health* (1857) and the first through twelfth *Annual Reports of the Home Secretary* (1858-70) reveal that more than £7 million were borrowed by local boards from the Exchequer between 1848 and 1870. This amount to approximately $805 million in 2017 U.S. dollars.[30] Since I observe neither loans secured by local boards from private sources nor direct expenditures by local boards from out of general, private improvement, or private water rates, I interpret loans secured by local boards from the Exchequer as a lower bound for public health expenditures.

Table 5 illustrates these data in greater detail, by location and by type of borrowing. Somewhat surprisingly, I find that debt was neither limited to nor concentrated in industrial areas. On the contrary, local boards in unions that specialized in coal or cotton-textile production borrowed slightly less per person than did the average board between 1848 and 1870. Furthermore, nearly 62 percent of all borrowing by local boards between 1858 and 1870 was earmarked for what I have called "large capital outlays" (i.e. drainage, water supply, land purchases, and other permanent works).

3. Empirical Analysis

3.1 Model

My empirical strategy exploits two dimensions of variation—(i) the timing of local board adoption and (ii) the share of union population under the jurisdiction of a local board—in order to identify the effect of local boards on mortality rates. Figure 10 illustrates the first dimension of variation. There were two ill-defined waves of local board adoption:

supply capacity created after 1848." Only when "key local businessmen could see a commercial advantage was an initiative taken." Michael (1874) and Lipman (1949) refer to boards adopted "with the express intention of doing nothing under the [Public] Health Acts, but of avoiding liabilities incident to their districts." After the passage of the Highway Act of 1862, for example, parishes feared that "if they were put into a highway district, they would always be paying for the roads in the next parish." Small parishes, therefore, saw a "convenient loophole." Since local board of health districts retained control of their own highways, "these small parishes rushed to acquire the status of local boards, with no intention in fact of ever building a sewer or providing a drain."

[30] See Officer & Williamson (2016) for conversion.

one in the early 1850s and another in the early-to-mid 1860s. Figure 11 illustrates the second dimension of variation. The share of union population under the jurisdiction of a local board varied widely, from 1.5 to 100 percent among adoption unions, but the vast majority of local boards accounted for less than half of the population of the union within which they were adopted. I estimate an event study model that accommodates both of these dimensions of variation. In particular, I estimate:

$$\begin{aligned} \mathrm{DR}_{ut} = \beta_0 + \sum_{j=-4}^{-2} \pi_j \cdot \mathbf{1}(\mathrm{EY}_{ut} = j) \cdot \mathrm{BFRAC}_{u,j=0} \\ + \sum_{j=0}^{4} \pi_j \cdot \mathbf{1}(\mathrm{EY}_{ut} = j) \cdot \mathrm{BFRAC}_{ut} + \beta_1 \mathrm{BFRAC}_{ut} + \beta_2 \mathbf{X}_{ut} + \eta_u + \gamma_t + \epsilon_{ut} \end{aligned} \quad (1)$$

The subscript u indexes unions (from 1 to 522) and the subscript t indexes years (from 1847 to 1870). DR_{ut} is the crude death rate in union u in year t and $\mathbf{X}_{ut}$ is a vector of time-varying union-specific covariates that includes population density, rateable value per capita, and percent of adults employed in agriculture. EY_{ut} is the number of years (as of year t) since the first board adoption in union u (i.e. event years). I set EY_{ut} equal to -4 for all event years less than or equal to -4 and to 4 for all event years greater than or equal to 4. BFRAC_{ut} is the share of union u's population that fell under the jurisdiction of a local board or health in year t. $\mathrm{BFRAC}_{u,j=0}$ is the share of union u's population that fell under the jurisdiction of the *first* local board of health adopted within union u (i.e. the share of union u's population that fell under the jurisdiction of a local board of health in event year $j = 0$). For unions within which no local board of health was adopted between 1848 and 1870, $\mathrm{BFRAC}_{ut} = \mathrm{BFRAC}_{u,j=0} = 0$ for all t. For unions within which only one local board of health was adopted between 1848 and 1870, $\mathrm{BFRAC}_{ut} = \mathrm{BFRAC}_{u,j=0} > 0$ for all event years $j > 0$. For unions within which more than one local board of health was adopted between 1848 and 1870, BFRAC_{ut} exceeds $\mathrm{BFRAC}_{u,j=0}$ in some event years $j > 0$ in order to account for the effect of subsequent board adoptions on mortality. η_u are union fixed-effects. These control for any fixed differences in death rates across unions. γ_t are year fixed-effects. These control for any England-wide trends in death rates. ϵ_{ut} is an error term. All variables except EY_{ut}, BFRAC_{ut}, and $\mathrm{BFRAC}_{u,j=0}$ are in logarithms, each union-year observation is weighted by population, and standard errors are clustered at the union level in order to account for within-union serial correlation.

The coefficients of interest are the set of π_j. I interpret these as the flexibly estimated pattern of death rates in adoption unions relative to non-adoption unions, accounting for differences in board-share (i.e. $BFRAC_{ut}$) among adoption unions. I suppress π_{-1}, therefore each π_j for all $j \neq -1$ is measured relative to the year before the year of first board adoption. This amounts to normalizing π_{-1} to β_1—the estimated difference in death rates between adoption and non-adoption unions that is independent of event-time, again accounting for differences in board-share among adoption unions. Since Equation (1) does not privilege any one event year over another, a downward break in the trend of this pattern at $j = 0$ would indicate that local board adoption did, in fact, reduce mortality. A pattern without a trend break, or with a trend break that occurs either before or after $j = 0$, would indicate that local board adoption played an insignificant role in English mortality trends between 1848 and 1870.

Because of the possibility that boards were adopted when, where, and to the extent that they were adopted because mortality was worsening, I follow Finkelstein (2007) and interpret the *change* in relative mortality trends before and after adoption as my estimate of the impact of the adoption of a local board of health. Formally, I calculate $\tilde{\pi}_j$, the *cumulative* mortality effect of the adoption of a union-wide local board of health j years after adoption, using my estimates of π_j from Equation (1):

$$\tilde{\pi}_j = \hat{\pi}_j - \frac{j+1}{3}(\hat{\pi}_{-4}) \text{ for } j \in \{0, 1, 2, 3, 4\} \quad (2)$$

This amounts to measuring all post-adoption estimates of π_j against the relative pre-trend defined by the line formed between the points $(-4, \hat{\pi}_{-4})$ and $(-1, \hat{\pi}_{-1})$, where the first coordinate refers to event year and the second coordinate refers to estimated percent mortality change. I also calculate the *incremental* mortality effect of the adoption of a union-wide local board of health in the *j*th year after adoption by subtracting $\tilde{\pi}_{j-1}$ from $\tilde{\pi}_j$ for all $j > 0$. I calculate standard errors using the delta method.

This interpretation (and my empirical strategy more generally) relies on three main assumptions. First, I assume that the variation that I observe in the timing and extent of local board adoption across unions is largely idiosyncratic, and *not* simply an artifact of pre-Public Health Act differences in union characteristics that might themselves be correlated with mortality. Despite that I control for many of these characteristics (either

explicitly or implicitly using union fixed-effects), there remains the possibility that the relationship between these characteristics and the timing and/or extent of local board adoption is nearly deterministic, leaving little exogenous variation with which to identify Equation (1). Since board adoption was, for all intents and purposes, voluntary with the taxpayers in a given area, this possibility is of genuine concern. In order to test for this, I use various pre-Public Health Act union characteristics to predict (i) whether unions adopted local boards of health, (ii) the extent to which unions adopted local boards of health, and (iii) the year in which unions adopted local boards of health. Formally, I define BOARD_u as a dummy that takes a value of 1 if any portion of union u fell under the jurisdiction of a local board of health by 1866, $\text{BFRAC}_{u,1866}$ as the fraction of union u's population that fell under the jurisdiction of a local board of health by 1866, ADOPTYEAR_u as the year of first local board of health adoption in union u, and $\text{PRECHARACTERISTICS}_u$ as a vector of union-specific characteristics that includes the mortality rate in 1847, the population growth rate between 1841 and 1851, population density in 1847, the percent of adults working in agriculture in 1847, dummies for whether coal or cotton-textiles were "special occupations" in 1851, the proportion of acreage that consisted of water (i.e. harbors, creeks, rivers, etc.) in 1851, rateable value per capita in 1847, welfare expenditure per capita (used here as a proxy for poverty) in 1851, and the proportion of population that fell under the jurisdiction of a municipal borough in 1851.[31] I then estimate the following three OLS models:

$$\text{BOARD}_u = \alpha_0 + \alpha_1 \text{PRECHARACTERISTICS}_u + \epsilon_u \quad (3)$$

$$\text{BFRAC}_{u,1866} = \delta_0 + \delta_1 \text{PRECHARACTERISTICS}_u + \epsilon_u \quad (4)$$

$$\text{ADOPTYEAR}_u = \mu_0 + \mu_1 \text{PRECHARACTERISTICS}_u + \epsilon_u \quad (5)$$

The results, reported in Tables 6 and 7, include models with and without regional fixed effects. I find that less agricultural, less dense, and less impoverished unions were more likely to adopt a local board of health; that less agricultural and less dense unions within which population was growing more quickly and a greater share of population was under the jurisdiction of a municipal borough were more likely to adopt a *bigger* local board of

[31] Data limitations require that I draw some "pre" characteristics from the 1851 Census Report, despite that these characteristics (i.e. coal and cotton-textile dummies, percent water, and percent municipal borough) are measured three years *after* the Public Health Act was passed.

health (as a percentage of population); and that richer and less agricultural unions with higher rates of initial mortality were more likely to adopt a local board of health *earlier*.[32] Nevertheless, the quantitative importance of these predictors is small. More than 74 percent of the variation in $BOARD_u$, more than 66 percent of the variation in $BFRAC_{u,1866}$, and more than 88 percent of the variation in $ADOPTYEAR_u$ remains unexplained by $PRECHARACTERISTICS_u$. I interpret the weakness of the fit of these models as evidence of the strength of my identification strategy. Put differently, the vast majority of the variation in both the timing and extent of board adoptions across unions appears to be idiosyncratic—a consequence, for instance, of variation in the capacity to act collectively, as opposed to variation in mortality-related environmental or social conditions.

Second, I assume that relative mortality trends before board adoption would have continued into the post-adoption period had no local boards of health been adopted (i.e. the mortality rate in adoption unions would have continued to worsen at the same rate relative to the mortality rate in non-adoption unions had the Public Health Act not been passed). This assumption is implicit in Equation (2).

Third, I assume that that there are no unaccounted-for changes within unions over time that affected mortality and occurred contemporaneously with board adoption. In what follows I address three potentially confounding factors: (i) shifts in age distributions, (ii) the Lancashire Cotton Famine, and (iii) deaths in public institutions.

Shifts in Age Distributions. Mortality rates are extremely sensitive to the percentage of the population that is either very old or very young. Between 1841 and 1871, 65- to 74-year-olds died at roughly three times the rate of the English population as a whole, and infants died at more than twice the rate of 65- to 74-year-olds.[33] Consequently, unions with disproportionately tail-heavy age distributions had, ceteris paribus, disproportionately high mortality rates. In order to account for the possibility that many unions simultaneously experienced both a board adoption and a change in the share of the population that was either very young or very old, I estimate two alternative specifications of Equation (1). The

[32] The (counterintuitive) correlation between population density and board adoption is a consequence of a small number of very populous unions within which no board, or only a very small board, was adopted. When log(density) is included in lieu of density, the direction of this correlation is reversed.
[33] McKeown & Record (1962), p. 100.

first includes OLD_{ut} and $YOUNG_{ut}$, where OLD_{ut} is the percentage of union u's population aged greater than 60 in year t and $YOUNG_{ut}$ is the percentage of union u's population aged less than 5 in year t.[34] The second includes AGE_{utb}, a 20-bin age-share spline, where AGE_{ut1} is the percentage of union u's population between 0 and 5 in year t, AGE_{ut2} is the percentage of union u's population between 5 and 10 in year t, and so on. Demographic evidence suggests that neither of these alternative specifications will significantly alter my results. Figure 12 illustrates that it was not until the end of the nineteenth century that the English age distribution began its shift from a convex to a more familiar concave shape. This shift was the result of a precipitous decline in infant mortality and a slower, more persistent decline in the birth rate.[35]

Lancashire Cotton Famine. In the nineteenth century the United States was England's principal supplier of raw cotton. This commercial relationship was temporarily severed during the American Civil War (1861-65), and England's cotton-textile manufacturing towns fell into a short but severe recession. In order to account for any systematic relationship between board adoption, mortality, and textile manufacturing during these so-called "famine years," I include ($\gamma_t \times COTTON_u$), where $COTTON_u$ is an indicator for whether union u specialized in cotton-textile production in 1851, and γ_t, as before, are year fixed-effects.

Deaths in Public Institutions. Deaths were registered where they occurred. It is therefore likely that the reported number of deaths overstates the actual number of resident deaths in unions with large hospitals, workhouses, or asylums that serviced non-residents. Since any changes in DR_{ut} as a result of the erection, expansion, or demolition of such institutions are mechanical and unexplained by Equation (1), any correlation between the timing of these changes and the timing of board adoption will generate a bias in my estimates of π_j. Although there is no comprehensive record of deaths in public institutions at the union level until 1869, the evidence that does exist suggests that the number of, and the percentage of deaths in, public institutions changed minimally between 1851 and 1870. Figure 13 demonstrates that my sample predates the era of public institution-building in London. Insofar as London's experience reflects the experience of England as a whole (as

[34] Census reports did not disaggregate infants from 1-, 2-, 3-, and 4-year-olds within unions until 1861.
[35] See *Decennial Census Reports* (1841-1921) and *Annual Reports of the Registrar-General* (1841-1921).

it did between 1870 and 1900), it is unlikely that hospitals, workhouses, or asylums played even a peripheral role in determining changes in union death rates prior to 1870.

3.2 Results

Table 8 reports the results of Equation (1). The first column reports the basic specification, the second column includes OLD_{ut} and $YOUNG_{ut}$, the third column includes ($\gamma_t \times COTTON_u$), the fourth column includes region-by-year fixed-effects (my preferred specification), and the fifth column includes AGE_{utb}. In each of these specifications the pattern of $\hat{\pi}_j$ over event time exhibits a clear and considerable trend break in the year of board adoption (i.e. $j = 0$). Figure 14 plots this pattern. The upward-sloping pre-trend implies that mortality was worsening in adoption unions relative to non-adoption unions in the years preceding adoption. This is unsurprising, since unions experiencing the greatest deterioration in their sanitation conditions would have had the greatest incentive to improve their sanitation conditions. The downward-sloping post-trend implies that mortality was improving in adoption unions relative to non-adoption unions in the years following adoption.

I transform these estimates of π_j into estimates of the effect of local board adoption on mortality using Equation (2). Table 9 reports the results of this calculation. The first row reports the *cumulative* effect of local board adoption on the mortality rate zero, one, two, three, and four years after adoption (i.e. $\tilde{\pi}_0$, $\tilde{\pi}_1$, $\tilde{\pi}_2$, $\tilde{\pi}_3$, and $\tilde{\pi}_4$). These estimates suggest that the adoption of a union-wide local board of health would have reduced mortality by 2.5 percent in the year of adoption, 7.3 percent after one year, 10.7 percent after two years, 12.0 percent after three years, and 14.2 percent after four years. This amounts to 34, 49, 55, and 65 fewer deaths one, two, three, and four years after adoption, respectively, in a union of 20,000 people with an average mortality rate (i.e. 23 per 1,000). The second row reports the *incremental* effect of local board adoption on the mortality rate in the year of adoption and in the first, second, third, and fourth post-adoption years (i.e. $\tilde{\pi}_0 - 0$, $\tilde{\pi}_1 - \tilde{\pi}_0$, $\tilde{\pi}_2 - \tilde{\pi}_1$, $\tilde{\pi}_3 - \tilde{\pi}_2$, and $\tilde{\pi}_4 - \tilde{\pi}_3$). These estimates suggest that the effect of the adoption of a local board of health was greatest in the first and second full years after adoption.

Figure 15 reports the implied effects of local board adoption on the aggregate English mortality rate between 1848 and 1870, accounting for the proportion of the English population that fell under *j*-year-old boards in each year. Since boards were limited to less

than one-fourth of the English population before 1865, less than one-sixth of the English population before 1860, and less than one-tenth of the English population before 1851, these implied England-wide effects are muted in comparison with the direct effects of local boards, but are still quite large. In 1870, for instance, my estimates suggest that the aggregate English mortality rate was 3.7 percent lower than it would have been had the Public Health Act not been passed. Since there were approximately 525,000 total deaths in England in 1870, this implies that approximately 20,000 lives were saved in 1870 as a result of local board adoption. Repeating this exercise for each year between 1848 and 1870, I calculate that 227,598 lives were saved as a result of the Public Health Act. Figure 16, which plots the actual English mortality rate alongside this counterfactual English mortality rate, demonstrates that the relative "flatness" of aggregate English mortality prior to 1870 should not be interpreted as prima facie evidence of the ineffectiveness of local boards of health. Furthermore, the mortality gains that local boards of health achieved at the *local* level are no less significant for being nearly indiscernible at the *national* level until the 1860s.

I perform three robustness checks. First, I re-estimate Equation (1) excluding all non-adoption unions (i.e. unions within which no local board of health was adopted between 1848 and 1870). The results, reported in Table 10, reveal no significant changes. The up-and-down pattern of $\hat{\pi}_j$ over event time persists, and the implied effect of the adoption of a local board of health on mortality after four years (i.e. $\tilde{\pi}_4$) is only slightly larger than the implied effect from my preferred specification. Second, I estimate a modified, binary-treatment version of Equation (1) for which BFRAC_{ut} is replaced by BOARD_u, which is defined as before. Formally, I estimate:

$$\begin{aligned} \text{DR}_{ut} = \beta_0 + \sum_{j=-4}^{-2} \varphi_j \cdot \mathbf{1}(\text{EY}_{ut} = j) \cdot \text{BOARD}_{u,} \\ + \sum_{j=0}^{4} \varphi_j \cdot \mathbf{1}(\text{EY}_{ut} = j) \cdot \text{BOARD}_u + \beta_1 \mathbf{X}_{ut} + \eta_u + \gamma_t + \epsilon_{ut} \end{aligned} \tag{6}$$

In this way, I identify the effect of the adoption of a local board of health on mortality using only variation in the timing of local board adoption. The results, reported in Table 11, reveal an attenuated pre- and post-trend in the pattern of $\hat{\varphi}_j$ relative to the pattern of $\hat{\pi}_j$. The attenuation of the slope of the pre-trend suggests that the timing of local board adoption

is only partly responsible for the upward slope of $\hat{\pi}_j$ between $j = -4$ and $j = -1$. The attenuation of the slope of the post-trend is the expected result of characterizing both low- and high-share unions as adoption unions, without adjusting for exposure to adoption. Adoption unions for which $\text{BFRAC}_{u,j=0}$ is low were, ipso facto, only nominally affected by the adoption of a local board of health, and hence their inclusion diminishes $\hat{\varphi}_0$, $\hat{\varphi}_1$, $\hat{\varphi}_2$, $\hat{\varphi}_3$, and $\hat{\varphi}_4$ relative to $\hat{\pi}_0$, $\hat{\pi}_1$, $\hat{\pi}_2$, $\hat{\pi}_3$, and $\hat{\pi}_4$. Third, I re-estimate Equation (6) separately for high-share unions and low-share unions. The results, reported in Table 12, reveal that the effect of the adoption of a local board of health on mortality is proportional to board share. High-share unions saw greater post-adoption reductions in mortality than low-share unions. This decomposition strongly suggests that the source of the trend-reversal in relative mortality that I observe is board activity.

Lastly, I demonstrate the importance of the disaggregation of event-years that an event study model affords. Since the trend-reversal that I observe in the pattern of $\hat{\pi}_j$ is roughly symmetric about the year before board adoption (i.e. $j = -1$), a simple difference-in-differences model will underestimate the effect of local boards of health on mortality by effectively canceling the post-trend with the pre-trend. More formally, Table 13 reports estimates of a difference-in-differences model of the form

$$\text{DR}_{ut} = \beta_0 + \pi(\text{POST}_{ut} \cdot \text{BFRAC}_{ut}) + \beta_1 \text{BFRAC}_{ut} + \beta_2 \mathbf{X}_{ut} + \eta_u + \gamma_t + \epsilon_{ut} \qquad (7)$$

alongside estimates of my event study model (as defined in Equation (1)) with and without year fixed-effects, union fixed-effects, and controls (including population density, rateable value per capita, percent of adults employed in agriculture, percent of population aged less than 5, percent of population aged greater than 60, and region-by-year fixed-effects). I define POST_{ut} as a dummy variable that takes a value of 1 if union *u* had adopted a local board of health by year *t* and 0 otherwise. The difference-in-differences estimates range from -0.018 to 0.029, and none of them can be distinguished, statistically speaking, from zero. The corresponding event study estimates reveal that any simple before-after analysis will mischaracterize a trend-reversal as a non-effect.

3.3 Cost-Benefit Analysis

In this section I assess whether the Public Health Act was cost effective. More precisely, I assess whether the statistical value of all lives saved by local boards between

1848 and 1870 exceeded the total expenditure of local boards between 1848 and 1870.[36] Since I observe only board borrowing from the Exchequer, and neither board borrowing from private sources nor board spending, I proceed in the following way. Rather than commit to any one assumption about the relationship between board borrowing from the Exchequer and board spending in order to impute board spending, I ask the following question: Given a range of plausible estimates of the value of a statistical life (VSL), what is the strongest assumption about the relationship between board borrowing from the Exchequer and board spending that I would have to make in order to conclude that the benefits of local boards exceeded the costs?

In Section 2.4 I showed that boards borrowed £7,183,431 from the Exchequer between 1848 and 1870 and in Section 3.2 I estimated that boards saved 227,598 lives between 1848 and 1870. If I assume that all money spent by local boards was borrowed from the Exchequer, this implies that local boards cost English taxpayers £31.56 per life saved. If, however, I assume that only half of all money spent by local boards was borrowed from the Exchequer, and that the other half, which I do not observe, was either borrowed from private sources or spent directly from out of various rates, this implies that local boards cost English taxpayers £14,366,862 in total and £63.12 per life saved. In this way, I can trace out a cost-per-life-saved curve that varies inversely with the proportion of total board expenditure that I assume to be borrowed from the Exchequer. Figure 12 plots this curve in 2000 U.S. dollars and overlays various modern and historical VSL estimates.[37] The point at which the cost-per-life-saved curve intersects any particular VSL estimate is the break-even point. To the left of this point, estimated costs exceed estimated benefits. To the right of this point, estimated benefits exceed estimated costs.

Figure 17 plots four VSL estimates. The first estimate ($7.7 million in 2000 U.S. dollars) is a composite of 46 studies conducted on labor markets in seven developed countries between 1974 and 2001.[38] The second estimate ($1.2 million in 2000 U.S.

[36] This definition of the benefits of the Public Health Act is almost certainly an understatement. It assumes that local boards accrued no other benefits than the statistical value of the lives that they saved. It does not include, for example, the benefit from reductions in non-fatal illnesses or the aesthetic and social benefits of a cleaner environment as a result of the adoption of local boards.

[37] I convert 1870 pounds to 2000 U.S. dollars using Officer & Williamson (2016).

[38] See Viscusi & Aldy (2003), Tables 2 and 4. I obtained the $7.7 million estimate by calculating the median of 46 separate VSL estimates from the following seven countries: Australia, Austria, Canada, Japan,

dollars) is a composite of seven studies conducted on labor markets in four developing countries between 1993 and 2001.[39] The third estimate ($156,000 in 2000 U.S. dollars) is from Kim & Fishback's (1993) study of accident risk among American railroad workers between 1893 and 1909, perhaps the best available historical VSL estimate.[40] All three of these estimates likely overstate the true VSL for a typical nineteenth-century English laborer since safety is a normal good, and the average incomes of the samples from which these estimates are drawn are significantly higher than average English incomes between 1848 and 1870.[41] To account for this, I derive a fourth estimate ($40,000 in 2000 U.S. dollars) from the third estimate using (i) the difference in weekly incomes between English agricultural laborers in 1870 and American railroad workers between 1893 and 1909 and (ii) an income elasticity of VSL of 0.5.[42]

This fourth VSL estimate intersects the cost-per-life-saved curve at approximately 10 percent of expenditure borrowed from the Exchequer, which implies that local boards would have had to spend 10 times more than what I observe them to borrow from the Exchequer in order for their total expenditure to exceed, in dollar terms, the statistical value of all of the lives that they saved. This is extremely unlikely. The Public Health Act intended the Exchequer to provide a secure source of long-term credit for the costliest of board activities. If, in fact, expenditure on such activities amounted to less than one-tenth of total expenditure, it would mean that local boards spent at least £77 million between 1848 and 1870, or roughly $9 billion in today's U.S. dollars. I therefore conclude that, under reasonable assumptions, local boards not only saved lives, but did so in a cost-effective manner.

4. Conclusion

Switzerland, the United Kingdom, and the United States. The average income of these 46 samples is presented in Figure 17 below.

[39] See Viscusi & Aldy (2003), Table 4. I obtained the $1.2 million estimate by calculating the median of 7 separate VSL estimates from the following four countries: Hong Kong, India, South Korea, and Taiwan. The distinction between developed and developing is here arbitrary and irrelevant but for the difference in the average income of the samples used. The average income of these 7 samples is presented in Figure 17 below.

[40] See Kim & Fishback (1993), p. 811.

[41] See Viscusi & Aldy (2003), p. 36; Viscusi (1978).

[42] See Viscusi & Aldy (2003), pp. 36-43 for a discussion of "the effects of income on the value of a statistical life." The relationship between VSL and income is calculated using a meta-analysis of VSL estimates and the average incomes of the samples from which these estimates are derived. Based on Viscusi & Aldy (2003), 0.5 appears to be a middle-of-the-road estimate of the income elasticity of VSL. I use Bowley's (1898) estimate of the average wage of English agricultural laborers in 1870.

This paper examines the effect and cost-effectiveness of the sanitation efforts of English local government in the period before 1870. The Public Health Act of 1848 endowed local boards of health with broad powers, including the right to tax, to borrow, to construct infrastructure, to provide services, and to regulate the activities of households, businesses, and other individuals. Contrary to the prevailing view that English local government before 1870 was dominated by a class of penny-pinching petty capitalists, I find that local boards did, in fact, exercise these powers. They borrowed more than £7 million from the Exchequer between 1848 and 1870, about 62 percent of which was dedicated to the purposes of drainage, water supply, land purchases, and other permanent works. Moreover, the regulatory capacity of local boards should have enabled them to effect sanitary improvement at minimal public expense.

I estimate that the adoption of a union-wide local board of health is associated with a 14.2 percent decrease in the mortality rate after four years. Accounting for incomplete board take-up, this implies that England's mortality rate in 1870 was 3.7 percent lower than it would have been had no local boards been adopted in the preceding 23 years. I calculate that more than 225,000 lives were saved between 1848 and 1870, nearly ten times the number of British casualties during the Crimean War. A back-of-the-envelope comparison of cost per life saved with relevant VSL estimates suggests that the benefits of local board adoption exceeded the costs under all but the most extreme assumptions about the relationship between board borrowing and board spending.

More generally, this paper offers clear quantitative evidence of the capacity of public health interventions—even interventions that are decentralized and effectively voluntary with local taxpayers—to reduce mortality amidst industrialization. That English mortality was not increasing between 1848 and 1870, as it may have been under the then-uncharted pressures of rapid industrialization, is at least in part a consequence of the adoption of local boards of health. By extension, the precipitous decline in English mortality between 1870 and 1900 might be seen as a consequence of the Public Health Acts of 1872 and 1875, in effect expansions of and extensions to the Public Health Act of 1848. The former subdivided the whole of England into a geographically exhaustive network of rural and urban sanitary districts not unlike local boards. The latter made mandatory many of the provisions of the Act of 1848 that had been voluntary for local boards. All told, the large effects that I find should serve as some encouragement to

developing countries experiencing similarly high rates of industrialization, urbanization, and population growth.

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Table 1. "Turning Points" in GDP per Capita & Life Expectancy at Birth

	Approximate Turning Point (TP)	Level In Year of Turning Point	*Change in Half-Century*†	
			Before TP	After TP
Panel A. GDP per Capita (1990 $)				
England & Wales	1820	1,756	0.4	1.3
Sweden	1850	1,289	0.2	1.3
France†	1820	1,218	0.3	0.9
Japan	1870	741	0.1	1.7
Brazil	1900	737	0.1	1.7
Panel B. Life Expectancy at Birth (Years)				
England & Wales	1871	41.0	3.0	12.0
Sweden	1875	45.4	4.6	17.2
France††	1893	44.9	3.4	20.3
Japan	1923	42.6	5.8	30.8
Brazil	1940	36.7	8.0	28.9

Source: Easterlin (2000).

† In Panel A, these columns refer to the growth rate in real GDP per capita (in percent per year) in the fifty years before and the fifty years after the approximate turning point. In Panel B, these columns refer to the change in life expectancy at birth (in years) in the fifty years before and the fifty years after the approximate turning point.

†† Female-only.

Table 2. Declines in Stature During Industrialization

	Decline?	Birth Cohorts	Amount
United Kingdom (men)	Yes	1820-50	5.4 cm
United Kingdom (women)	Yes	1835-55	2.5 cm
United States	Yes	1830-90	4.0 cm
France	No		
Netherlands	No		
Sweden	No		
Germany†	Yes	1860-72	2.5 cm
		1879-85	2.0 cm
Australia	Yes	1867-93	3.0 cm
Japan	No		

Source: Steckel & Floud (1997)

† There were two downturns and one upturn in heights among German birth cohorts between 1860 and 1885. There was a downturn of 2.5 cm among German birth cohorts between 1860 and 1872, an upturn of 3.3 cm among German birth cohorts between 1872 and 1879, and another downturn of 2.0 cm among German birth cohorts between 1879 and 1885. The net downturn, therefore, between 1860 and 1885 was 1.2 cm.

Table 3. Summary Statistics

	All Unions (1)	Non-Ldn Unions (2)	Adoption Unions (3)	Aptn Uns in Sample (4)	All Boards (5)	Boards in Sample (6)
Deaths per 1,000	20.63	22.03	22.98	23.03		
(1847)	(4.302)	(4.923)	(4.856)	(4.919)		
Population Density†	6.026	1.919	2.087	2.166	3.931††	3.924††
(1847)	(26.255)	(8.821)	(5.410)	(5.601)	(8.230)	(8.571)
Percent in Agriculture	23.80	24.87	19.68	19.85		
(1847)	(12.75)	(12.04)	(11.51)	(11.67)		
Coal Dummy	0.155	0.162	0.232	0.219		
(1851)	(0.362)	(0.369)	(0.423)	(0.414)		
Cotton Dummy	0.068	0.071	0.114	0.120		
(1851)	(0.251)	(0.257)	(0.319)	(0.325)		
Fraction Water		0.024	0.031	0.029		
(1851)		(0.064)	(0.076)	(0.070)		
RV per Capita†	3.794	3.797	3.413	3.467	3.881	3.797
(1847)	(1.411)	(1.359)	(1.203)	(1.212)	(2.059)	(1.937)
PL Expenditure per Capita		0.326	0.287	0.292		
(1851)		(0.646)	(0.116)	(0.118)		
Church Attendance		0.646	0.627	0.630		
(1851)		(0.173)	(0.160)	(0.162)		
Fraction Non-Conformist		0.406	0.446	0.444		
(1851)		(0.142)	(0.138)	(0.139)		
Fraction Conservative		0.720	0.643	0.648		
(1852)		(0.330)	(0.355)	(0.357)		
Fraction Mun. Borough		0.152	0.223	0.233		
(1851)		(0.276)	(0.316)	(0.321)		
No. of Unions	576	549	272	252	272	252
No. of Boards	444	444	444	402	444	402

Notes: Columns (1), (2), (3) and (4) report the averages of each variable across all 576 unions in England, across all 549 non-Metropolitan London unions in England, across all 272 adoption unions in England, and across all 252 adoption unions in England within my sample (i.e. excluding the 20 adoption unions within which a local board was adopted between 1867 and 1870), respectively. Columns (5) and (6) report the averages of each variable across all 444 local boards of health adopted between 1848 and 1866 and across all 402 local boards of health within my sample (i.e. excluding the 42 local boards of health adopted within unions excluded from my sample). Standard deviations are reported in parentheses.

† Columns (1), (2), (3), and (4) report the average population density and rateable value capita of unions in 1847. Columns (5) and (6) report the average population density and rateable value per capita of local boards of health in 1861.

†† I do not observe the total area in acres of every local board of health, and therefore cannot calculate the population density of every local board of health. The reported average population density of local boards of health reported in Columns (5) and (6) is missing 39 and 36 observations, respectively.

Table 4. Qualifications for Franchise

	Local Board Elections	*Municipal Elections*
Ratepayer Restriction	Yes	Yes
Pauper Restriction	Yes	Yes
Occupancy Restriction	None†	Occupiers of "Tenements"††
Geographic Restriction	Within 7 Miles of District	Within 7 Miles of Borough†††
Minimum Duration of Residency	None	2.5 Years
Method of Election††††	Voting Papers	Voting Papers
Votes per Voter	Up to 12	1

Notes: The "ratepayer restriction" refers to the requirement that voters possess and/or dwell in property that was assessed for the poor rate, and that this rate was paid in full. The "pauper restriction" refers to the requirement that voters not be in receipt of any form of poor relief during the previous year. The "occupancy restriction" refers to the requirement that voters live in (or do not live in) certain types of residences (e.g. "tenements"). The "geographic restriction" refers to the eligibility of voters residing just outside the boundaries of the local board and/or borough.

† Though there was no minimum occupancy requirement, the working class was for all intents and purposes disenfranchised. First, paupers were ineligible to vote. A considerable number of would-be voters were disqualified on account of accepting alms. Second, non-ratepayers were ineligible to vote. This disqualified those without occupancy (e.g. the homeless), occupiers of un-rated property (e.g. occupiers of the smallest houses/apartments), and occupiers of property for which only the landlord's name appeared in the rate book (e.g. "compound" tenants for whom the landlord tendered the rate). Compound tenants could tender the rate themselves in order to have their names included in the rate book, but "very few" of them troubled to do so since "application had to be made each time a new rate was made, which would entail four or even six claims a year." Third, the votes of tenants and/or employees were in some cases co-opted by malevolent landlords and/or employers via threats of eviction and/or termination. See *The Westminster Review* (1881), p. 217; Keith-Lucas (1952), pp. 63-66.

†† Unlike the occupancy restriction for the parliamentary franchise (£10 per year), the occupancy restriction for the municipal franchise was categorical. Municipal voters (or "burgesses") were defined by the Municipal Corporations Act of 1835 as "all male householders occupying a house, warehouse, counting house, or shop." Then-Prime Minister Russell had rejected an amendment to add the word "tenement," as this, he said, would "admit every place rated even at the lowest possible amount, and thereby entrust the franchise to a class of persons who may not exercise it in the manner contemplated by the Bill." This omission was repealed by the Municipal Franchise Act of 1869, which expanded the list of qualifying households to include "other buildings." See Keith-Lucas (1952), pp. 55-56, 228-29, 231.

††† The Reform Act of 1832, which adopted the seven-mile geographic restriction for the parliamentary franchise, "did not specify how the seven miles were to be measured. In default of any clear statement, distances were measured as the crow flies." This method of measurement was upheld by the Registration Act of 1843. The Municipal Corporations Act of 1835, however, "stated that [the seven miles] was to be measured by the nearest public road or way by land and water," hence "any new road or canal might at any time extend the municipal limits" (and, in so doing, the municipal franchise). See Keith-Lucas (1952), p. 148.

†††† The secret ballot was not introduced in England until the Ballot Act of 1872, and only then for parliamentary and municipal elections (i.e. it left elections of Poor Law boards of guardians unaffected). Voting papers, to be completed at and collected from voters' homes "in [relative] quiet and seclusion," were an alternative to open declarations of 'yea' or 'nay' on-site at the hustings. Though not strictly "secret"—they could be "examined" by any elector—voting papers in principle circumnavigated the taunts, threats, and intimidation of the "mob." In practice, however, voting papers deprived the disenfranchised among the "mob" of their lone political forum. See Keith-Lucas (1952), pp. 124-25; Brundage (1975), p. 203.

Table 5. Borrowing by Local Boards (in 1870 £)

		Average Annual Loans from Exchequer Per 100 Population				
	Total Sanctions	All England	Local Boards (LBs)	LBs in Cotton Unions	LBs in Coal Unions	LBs in Industrial Unions
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. All Loans, 1848-70						
Total Loans, 1848-57	1,729,295	1.026	10.501	13.181	8.204	12.223
Total Loans, 1858-70	5,454,136	2.356	10.751	6.807	7.152	9.780
Total Loans, 1848-70	7,183,431	1.795	10.690	8.205	7.391	10.346
Panel B. Loans by Purpose, 1858-70						
Drainage, Water Supply	2,729,218	1.179	5.380	2.991	3.946	3.789
Street Cleaning, Paving	1,683,802	0.727	3.319	1.674	1.211	3.899
Purchase of Land, Bldgs.	424,345	0.183	0.837	0.750	0.498	0.911
Plans, Surveying	3,239	0.001	0.006	0.015	0.007	0.009
Purchase of Pub. Offices	49,455	0.021	0.097	0.069	0.096	0.087
Debt Payment	149,872	0.065	0.295	0.000	0.217	0.128
Lighting	12,023	0.005	0.024	0.017	0.018	0.016
Slaughter Houses	5,874	0.003	0.012	0.019	0.020	0.009
Burial Grounds	9,785	0.004	0.019	0.088	0.000	0.036
Pleasure Grounds	10,262	0.004	0.020	0.000	0.009	0.006
Erection of Markets	167,747	0.072	0.331	0.175	0.557	0.470
Other Permanent Works	208,513	0.090	0.411	1.008	0.573	0.420
No. of Unions	576	576	272	39	89	143

Notes: Loan data for the years 1848-57 derive from the *Return of Local Boards of Health* (1857) and for the years 1858-70 derive from the 1st through the 12th *Annual Report Presented by the Secretary of State for the Home Department on the Execution of the Local Government Act* (1858-70). Column (1) reports total loans. Column (2) reports average annual loans per 100 Englanders living under the jurisdiction of a local board of health. Columns (4) through (6) report average annual loans per 100 Englanders living under the jurisdiction of a local board of health among only a subset of unions. Column (4) isolates the 39 unions for which cotton-textile production was a "special occupation" according to the 1851 Census. Column (5) isolates the 89 unions for which coal production was a "special occupation" according to the 1851 Census. Column (6) isolates industrial unions, where "industrial union" is defined as any union in the top quartile of "percent of adults working in industry," again according to the 1851 Census.

Table 6. Determinants of Board Adoption & Board-Share

	(1)	(2)	(3)	(4)	(5)	(6)
Deaths per 1,000†	0.005	0.003	0.002	0.003	-0.052	-0.031
(1847)	(0.005)	(0.005)	(0.002)	(0.002)	(0.062)	(0.065)
Population Growth Rate†	0.135	0.136	0.116	0.147*	0.028*	0.035**
(1841-51)	(0.144)	(0.145)	(0.067)	(0.068)	(0.012)	(0.013)
Population Density†	-0.011**	-0.011**	-0.006**	-0.006**	0.033	0.043
(1847)	(0.003)	(0.003)	(0.001)	(0.001)	(0.023)	(0.025)
Percent in Agriculture†	-0.013**	-0.014**	-0.009**	-0.009**	-0.031	-0.022
(1847)	(0.003)	(0.003)	(0.001)	(0.001)	(0.037)	(0.038)
Coal Dummy	-0.003	0.042	-0.012	-0.013	0.042	0.038
(1851)	(0.061)	(0.068)	(0.028)	(0.032)	(0.033)	(0.036)
Cotton Dummy	0.042	-0.117	0.096*	0.090*	0.078	0.097
(1851)	(0.082)	(0.094)	(0.038)	(0.044)	(0.046)	(0.053)
Fraction Water	0.320	0.263	0.194	0.189	0.174	0.170
(1851)	(0.317)	(0.325)	(0.147)	(0.152)	(0.161)	(0.166)
RV per Capita†	-0.010	-0.009	0.003	0.002	-0.060	-0.067
(1847)	(0.018)	(0.019)	(0.008)	(0.009)	(0.037)	(0.040)
PL Expenditure per Capita†	-0.522*	-0.209	-0.092	0.039	-0.035	0.007
(1851)	(0.195)	(0.240)	(0.090)	(0.112)	(0.033)	(0.040)
Fraction Mun. Borough	0.148	0.166	0.291**	0.285**	0.237**	0.218**
(1851)	(0.092)	(0.092)	(0.043)	(0.043)	(0.054)	(0.055)
Dependent Variable	BOARD	BOARD	BFRAC	BFRAC	BFRAC	BFRAC
Census Division Dummies		✓		✓		✓
Variables with "†" in Logs					✓	✓
Observations	549	549	549	549	549	549
R-Squared	0.228	0.258	0.428	0.440	0.381	0.399

Notes: Columns (1) and (2) report the results of Equation 3, for which the dependent variable is whether or not a local board of health was adopted within the union between 1848 and 1866 (i.e. BOARD). Columns (3), (4), (5), and (6) report the results of Equation 4, for which the dependent variable is the share of union population that fell within the jurisdiction of a local board of health by 1866. In Columns (5) and (6) the cross symbol (i.e. "†") denotes that the variable is in logs.

** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 7. Determinants of First Board Adoption Year

	(1)	(2)	(3)	(4)
Deaths per 1,000†	-0.185*	-0.194*	-2.698	-3.018
(1847)	(0.090)	(0.096)	(2.271)	(2.370)
Population Growth Rate†	-2.530	-2.152	-0.764	-0.895
(1841-51)	(2.252)	(2.295)	(0.491)	(0.510)
Population Density†	0.056	0.040	0.047	-0.442
(1847)	(0.086)	(0.087)	(0.974)	(1.058)
Percent in Agriculture†	0.143**	0.161**	1.571	1.306
(1847)	(0.054)	(0.057)	(1.428)	(1.501)
Coal Dummy	1.337	2.135	0.744	1.366
(1851)	(1.036)	(1.204)	(1.110)	(1.284)
Cotton Dummy	1.746	1.107	1.800	1.211
(1851)	(1.310)	(1.542)	(1.476)	(1.709)
Fraction Water	-2.926	-3.604	-0.624	-1.588
(1851)	(5.147)	(5.303)	(5.428)	(5.563)
RV per Capita†	-1.070**	-1.220**	-3.065*	-3.896*
(1847)	(0.401)	(0.432)	(1.418)	(1.537)
PL Expenditure per Capita†	2.711	4.358	0.515	1.096
(1851)	(4.059)	(5.161)	(1.203)	(1.488)
Fraction Mun. Borough	0.630	1.164	0.776	1.502
(1851)	(1.528)	(1.563)	(1.733)	(1.823)
Census Division Dummies		✓		✓
Variables with "†" in Logs			✓	✓
Observations	272	272	272	272
R-Squared	0.080	0.116	0.065	0.113

Notes: Columns (1), (2), (3), and (4) report the results of Equation 5. Columns (2) and (4) include regional fixed effects (i.e. census division dummies). In Columns (5) and (6) the cross symbol (i.e. "†") denotes that the variable is in logs.

** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 8. Effect of LBs of Health on Mortality

	(1)	(2)	(3)	(4)	(5)
BFRAC × EY=-4	-0.066*	-0.065*	-0.064*	-0.052*	-0.053*
	(0.031)	(0.030)	(0.029)	(0.026)	(0.023)
BFRAC × EY=-3	-0.055*	-0.055*	-0.057*	-0.040	-0.041
	(0.027)	(0.027)	(0.025)	(0.022)	(0.022)
BFRAC × EY=-2	-0.023	-0.023	-0.026	-0.023	-0.023
	(0.032)	(0.033)	(0.032)	(0.029)	(0.029)
BFRAC × EY=0	-0.022	-0.022	-0.023	-0.008	-0.5007
	(0.023)	(0.023)	(0.023)	(0.025)	(0.025)
BFRAC × EY=1	-0.049	-0.049	-0.046	-0.038	-0.038
	(0.026)	(0.026)	(0.024)	(0.024)	(0.024)
BFRAC × EY=2	-0.060*	-0.060*	-0.062*	-0.055*	-0.056*
	(0.028)	(0.028)	(0.025)	(0.025)	(0.025)
BFRAC × EY=3	-0.055*	-0.055*	-0.062*	-0.051*	-0.051*
	(0.026)	(0.026)	(0.024)	(0.025)	(0.025)
BFRAC × EY=4	-0.059*	-0.057*	-0.059**	-0.056*	-0.056*
	(0.025)	(0.025)	(0.023)	(0.023)	(0.023)
BFRAC	0.184**	0.195**	0.166**	0.143**	0.160**
	(0.049)	(0.048)	(0.044)	(0.047)	(0.047)
Log RV per Capita	0.090**	0.083**	0.085**	0.094**	0.095**
	(0.035)	(0.031)	(0.031)	(0.035)	(0.034)
Log Population Density	-0.119	-0.163	-0.160	-0.159	-0.176*
	(0.069)	(0.083)	(0.084)	(0.085)	(0.087)
Log Percent in Agriculture	-0.044	-0.025	-0.020	-0.017	-0.015
	(0.030)	(0.027)	(0.027)	(0.027)	(0.025)
Log Percent Under 5 Years		-0.051	-0.052	-0.044	
		(0.042)	(0.042)	(0.039)	
Log Percent Over 60 Years		-0.184*	-0.195*	-0.191*	
		(0.083)	(0.083)	(0.083)	
Cotton × Year FEs			✓	✓	✓
Census Division × Year FEs				✓	✓
Twenty-Bin "Age Share" Spline					✓
Observations	12,488	12,488	12,488	12,488	12,488
R-Squared	0.718	0.719	0.726	0.754	0.756

Notes: Columns (1) through (5) report the results of Equation 1. Column (2) includes the percent of people aged less than five and more than sixty. Column (3) includes interactions of cotton-textile production dummies and year fixed-effects. Column (4) includes region-by-year fixed effects. Column (5) includes a 20-bin age-share spline.

** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 9. Adjusted Effect of LBs of Health on Mortality

	Adoption Year (j=0)	First Year (j=1)	Second Year (j=2)	Third Year (j=3)	Fourth Year (j=4)
Cumulative Effect	-0.025	-0.073*	-0.107**	-0.120**	-0.142**
	(0.031)	(0.037)	(0.045)	(0.052)	(0.059)
Incremental Effect	-0.025	-0.048**	-0.034*	-0.013	-0.022
	(0.031)	(0.021)	(0.018)	(0.018)	(0.017)

Notes: The first row reports the results of the calculation defined by Equation 2 for each post-adoption event-year (i.e. each event-year between j=0 and j=4). "Cumulative effect" refers to the total mortality effect of the adoption of a union-wide local board of health *by* the jth event-year. The second row reports one-year differences of the estimates in the first row. "Incremental effect" refers to the total mortality effect of the adoption of a union-wide local board of health *in* the jth event-year. All standard errors are calculated using the delta method.

** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 10. Effect of LBs of Health on Mortality (Non-Adopters Omitted)

	(1)	(2)	(3)	(4)	(5)
BFRAC × EY=-4	-0.052	-0.054	-0.053	-0.042	-0.048*
	(0.031)	(0.030)	(0.028)	(0.024)	(0.022)
BFRAC × EY=-3	-0.045	-0.045	-0.046	-0.030	-0.032
	(0.028)	(0.028)	(0.024)	(0.022)	(0.022)
BFRAC × EY=-2	-0.020	-0.020	-0.024	-0.026	-0.026
	(0.032)	(0.032)	(0.031)	(0.029)	(0.029)
BFRAC × EY=0	-0.025	-0.025	-0.027	-0.014	-0.014
	(0.023)	(0.023)	(0.023)	(0.024)	(0.024)
BFRAC × EY=1	-0.055*	-0.055*	-0.050*	-0.041	-0.041
	(0.026)	(0.026)	(0.023)	(0.024)	(0.024)
BFRAC × EY=2	-0.072*	-0.072*	-0.070**	-0.059*	-0.059*
	(0.028)	(0.028)	(0.025)	(0.024)	(0.024)
BFRAC × EY=3	-0.069**	-0.069**	-0.074**	-0.065*	-0.066**
	(0.026)	(0.027)	(0.025)	(0.025)	(0.025)
BFRAC × EY=4	-0.082**	-0.081**	-0.082**	-0.078**	-0.080**
	(0.023)	(0.023)	(0.021)	(0.021)	(0.021)
BFRAC	0.155**	0.160**	0.141**	0.125**	0.145**
	(0.046)	(0.045)	(0.041)	(0.045)	(0.045)
Log RV per Capita	0.078**	0.070*	0.072*	0.076*	0.070*
	(0.030)	(0.029)	(0.029)	(0.031)	(0.027)
Log Population Density	-0.030	-0.048	-0.045	-0.049	-0.059
	(0.041)	(0.049)	(0.050)	(0.054)	(0.055)
Log Percent in Agriculture	-0.012	0.002	0.006	0.002	0.007
	(0.033)	(0.034)	(0.033)	(0.037)	(0.028)
Log Percent Under 5 Years		-0.085	-0.084	-0.080	
		(0.055)	(0.057)	(0.051)	
Log Percent Over 60 Years		-0.104	-0.113	-0.115	
		(0.077)	(0.079)	(0.082)	
Cotton × Year FEs			✓	✓	✓
Census Division × Year FEs				✓	✓
Twenty-Bin "Age Share" Spline					✓
Observations	6,021	6,021	6,021	6,021	6,021
R-Squared	0.660	0.661	0.674	0.706	0.710

Notes: Columns (1) through (5) report the results of Equation 1, omitting all 270 non-London unions within which no local board of health was adopted between 1848 and 1866. Column (2) includes the percent of people aged less than five and more than sixty. Column (3) includes interactions of cotton-textile production dummies and year fixed-effects. Column (4) includes region-by-year fixed effects. Column (5) includes a 20-bin age-share spline.

** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 11. Effect of LBs of Health on Mortality (Binary Treatment)

	(1)	(2)	(3)	(4)	(5)
BOARD × EY=-4	-0.038**	-0.036**	-0.033**	-0.028**	-0.029**
	(0.012)	(0.012)	(0.011)	(0.010)	(0.010)
BOARD × EY=-3	-0.018	-0.018	-0.016	-0.011	-0.011
	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)
BOARD × EY=-2	-0.003	-0.003	-0.003	-0.002	-0.002
	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)
BOARD × EY=0	-0.013	-0.013	-0.011	-0.005	-0.005
	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)
BOARD × EY=1	-0.023	-0.023	-0.019	-0.014	-0.014
	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)
BOARD × EY=2	-0.024	-0.024	-0.023	-0.020	-0.020
	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)
BOARD × EY=3	-0.022	-0.021	-0.022	-0.018	-0.018
	(0.014)	(0.014)	(0.014)	(0.013)	(0.013)
BOARD × EY=4	-0.010	-0.008	-0.010	-0.008	-0.007
	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)
Log RV per Capita	0.088**	0.082**	0.084**	0.094**	0.095**
	(0.034)	(0.031)	(0.030)	(0.035)	(0.034)
Log Population Density	-0.114	-0.152	-0.152	-0.153	-0.167
	(0.069)	(0.084)	(0.084)	(0.084)	(0.087)
Log Percent in Agriculture	-0.051	-0.035	-0.025	-0.023	-0.021
	(0.031)	(0.028)	(0.027)	(0.027)	(0.026)
Log Percent Under 5 Years		-0.052	-0.054	-0.046	-0.008
		(0.042)	(0.042)	(0.039)	(0.035)
Log Percent Over 60 Years		-0.165*	-0.184*	-0.180*	-0.058
		(0.083)	(0.083)	(0.082)	(0217)
Cotton × Year FEs			✓	✓	✓
Census Division × Year FEs				✓	✓
Twenty-Bin "Age Share" Spline					✓
Observations	12,488	12,488	12,488	12,488	12,488
R-Squared	0.717	0.718	0.726	0.754	0.755

Notes: Columns (1) through (5) report the results of Equation 6. Column (2) includes the percent of people aged less than five and more than sixty. Column (3) includes interactions of cotton-textile production dummies and year fixed-effects. Column (4) includes region-by-year fixed effects. Column (5) includes a 20-bin age-share spline.

** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 12. Effect of LBs of Health on Mortality (Binary Treatment, by Board-Share)

	Only $BFRAC_{u,j=0} < 0.27$			Only $BFRAC_{u,j=0} > 0.27$		
	(1)	(2)	(3)	(4)	(5)	(6)
BOARD × EY=-4	-0.039*	-0.034*	-0.029	-0.040*	-0.040*	-0.042*
	(0.016)	(0.016)	(0.015)	(0.018)	(0.018)	(0.017)
BOARD × EY=-3	-0.014	-0.014	-0.004	-0.026	-0.026	-0.031*
	(0.017)	(0.017)	(0.015)	(0.017)	(0.017)	(0.015)
BOARD × EY=-2	0.002	0.002	0.005	-0.009	-0.009	-0.011
	(0.016)	(0.016)	(0.015)	(0.020)	(0.020)	(0.020)
BOARD × EY=0	-0.011	-0.011	-0.007	-0.015	-0.015	-0.016
	(0.018)	(0.018)	(0.017)	(0.013)	(0.013)	(0.013)
BOARD × EY=1	-0.013	-0.017	-0.006	-0.022	-0.022	-0.025
	(0.019)	(0.019)	(0.017)	(0.016)	(0.016)	(0.015)
BOARD × EY=2	-0.007	-0.006	-0.001	-0.014	-0.014	-0.022
	(0.018)	(0.018)	(0.016)	(0.020)	(0.019)	(0.018)
BOARD × EY=3	-0.007	-0.006	-0.001	-0.030	-0.030	-0.037*
	(0.023)	(0.023)	(0.022)	(0.017)	(0.017)	(0.016)
BOARD × EY=4	0.002	0.001	0.008	-0.010	-0.008	-0.014
	(0.020)	(0.020)	(0.019)	(0.017)	(0.017)	(0.016)
Log RV per Capita	0.080*	0.073*	0.076*	0.095*	0.091*	0.091*
	(0.040)	(0.034)	(0.035)	(0.042)	(0.037)	(0.036)
Log Population Density	-0.144	-0.194	-0.192	-0.197	-0.259*	-0.259*
	(0.087)	(0.100)	(0.102)	(0.102)	(0.120)	(0.119)
Log Percent in Agricltre	-0.078	-0.058	-0.047	-0.035	-0.011	-0.003
	(0.042)	(0.037)	(0.035)	(0.032)	(0.030)	(0.029)
Log Percent Under 5		-0.028	-0.033		-0.033	-0.035
		(0.035)	(0.035)		(0.046)	(0.046)
Log Percent Over 60		-0.212*	-0.235*		-0.230*	-0.245*
		(0.101)	(0.103)		(0.107)	(0.106)
Cotton × Year FEs			✓			✓
Observations	9,489	9,489	9,489	9,489	9,489	9,489
R-Squared	0.739	0.740	0.746	0.731	0.733	0.740

Notes: Columns (1) through (6) report the results of Equation 6. Columns (1) through (3) omit all 126 unions within which the first board adopted accounted for less than 27.27 percent of its population (i.e. above-median board-share unions). Column (4) through (6) omit all 126 unions within which the first board adopted accounted for more than 27.27 percent of its population (i.e. below-median board-share unions). Columns (2) and (5) include the percent of people aged less than five and more than sixty. Columns (3) and (6) include interactions of cotton-textile production dummies and year fixed-effects.

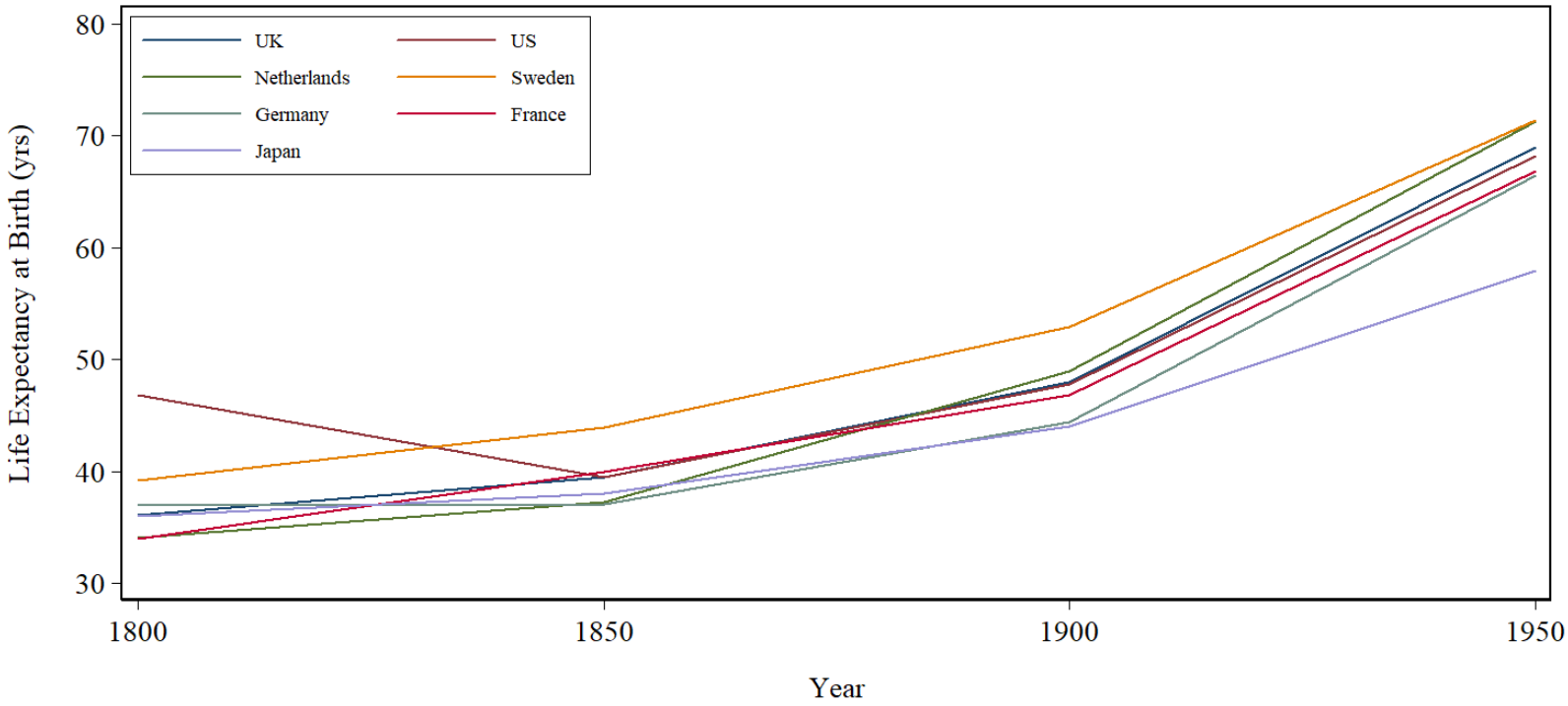
** Significant at the 1 percent level.
* Significant at the 5 percent level.

Table 13. Effect of LBs of Health on Mortality (DiD vs. Event-Study Estimates)

	(1)	(2)	(3)	(4)
Panel A. Difference-in-Differences Estimates				
BFRAC × POST	-0.015	0.029	-0.018	-0.012
	(0.021)	(0.028)	(0.015)	(0.017)
Observations	12,488	12,488	12,488	12,488
R-Squared	0.051	0.089	0.711	0.753
Panel B. Event-Study Estimates				
BFRAC × EY=-4	-0.075**	-0.092*	-0.061*	-0.052*
	(0.029)	(0.030)	(0.030)	(0.026)
BFRAC × EY=-3	-0.043	-0.052*	-0.051	-0.040
	(0.028)	(0.026)	(0.027)	(0.022)
BFRAC × EY=-2	0.000	-0.023	-0.022	-0.023
	(0.038)	(0.032)	(0.033)	(0.029)
BFRAC × EY=0	-0.035	-0.023	-0.023	-0.008
	(0.023)	(0.023)	(0.023)	(0.025)
BFRAC × EY=1	-0.062*	-0.050	-0.051*	-0.038
	(0.025)	(0.028)	(0.026)	(0.024)
BFRAC × EY=2	-0.062*	-0.056*	-0.062*	-0.055*
	(0.027)	(0.028)	(0.028)	(0.025)
BFRAC × EY=3	-0.061*	-0.050	-0.059*	-0.051*
	(0.026)	(0.027)	(0.026)	(0.025)
BFRAC × EY=4	-0.071**	-0.037	-0.069**	-0.056*
	(0.028)	(0.032)	(0.023)	(0.023)
Observations	12,488	12,488	12,488	12,488
R-Squared	0.052	0.090	0.712	0.754
Year FEs		✓	✓	✓
Union FEs			✓	✓
Controls				✓

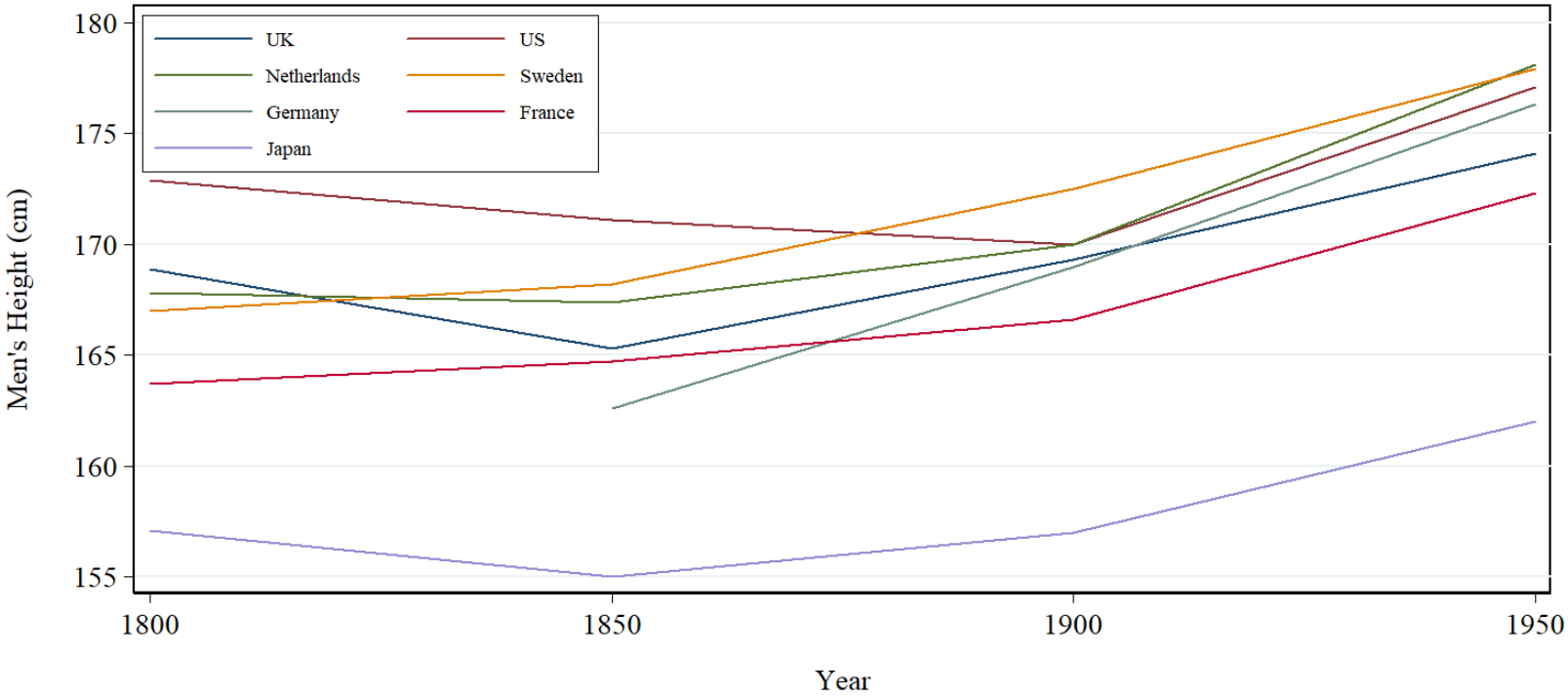
Notes: Panel A reports estimates of the effect of the adoption of a local board of health on the rate of morality using a difference-in-differences model (i.e. a model of the form $\text{DR}_{ut} = \beta_0 + \pi(\text{BFRAC}_{ut} \times \text{POST}_{ut}) + \beta_1 \text{BFRAC}_{ut} + +\epsilon_{ut}$, where POST_t is a dummy variable that takes a value of 1 if union *u* had adopted a board by year *t* and 0 otherwise). Panel B reports estimates of the effect of the adoption of a local board of health on the rate of mortality using an event-study model (i.e. a model of the form of Equation (5)). Column (2) includes year fixed-effects, Column (3) includes union fixed-effects, and Column (4) includes controls (i.e. rateable value per capita, population density, percent in agriculture, percent of population aged less than five and more than sixty, interactions of cotton-textile production dummies and year fixed-effects, and region-by-year fixed effects).

Figure 1. Life Expectancy at Birth, 1800-1950



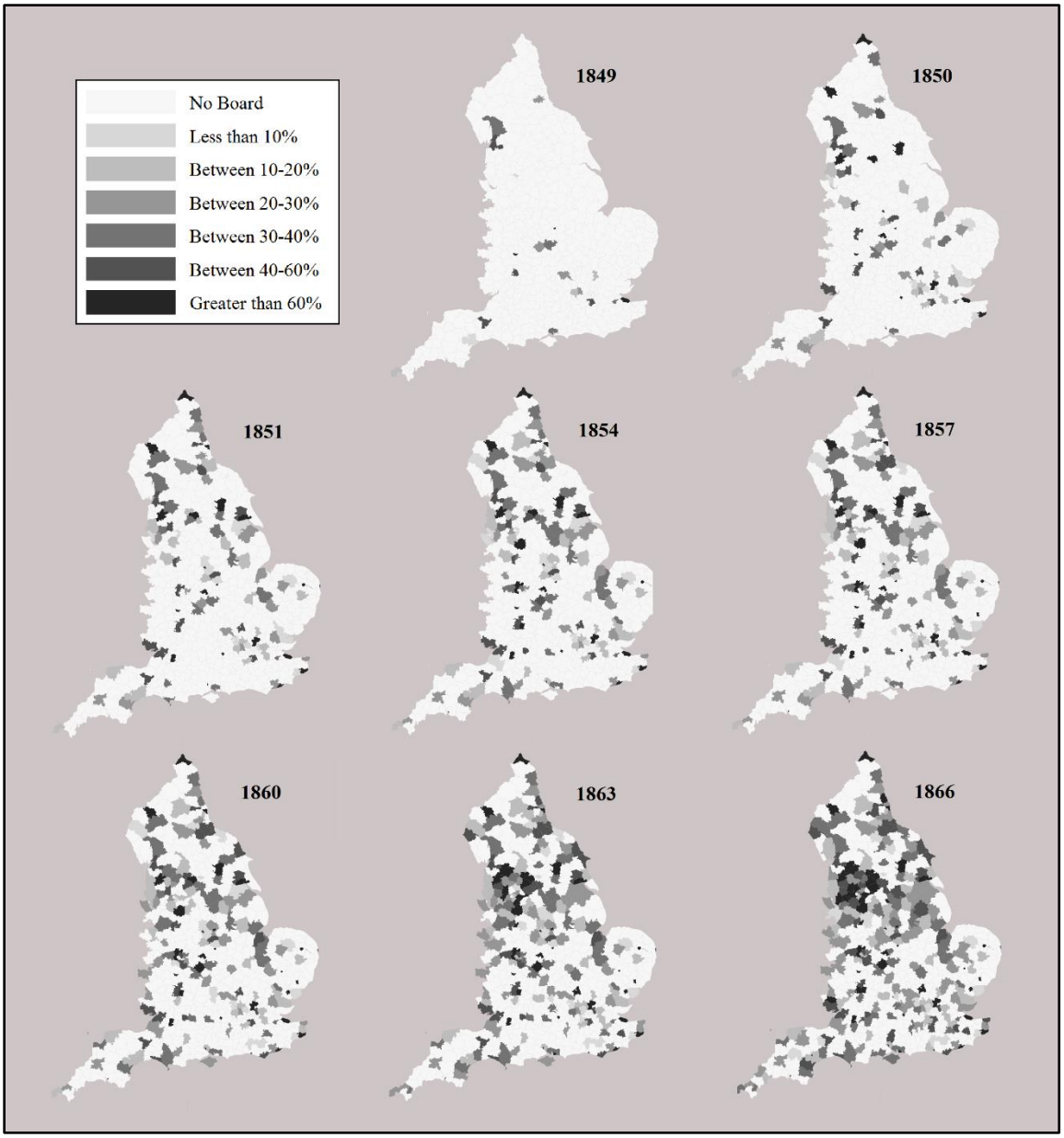
Source: Steckel & Floud (1997)

Figure 2. Men's Height, 1800-1950



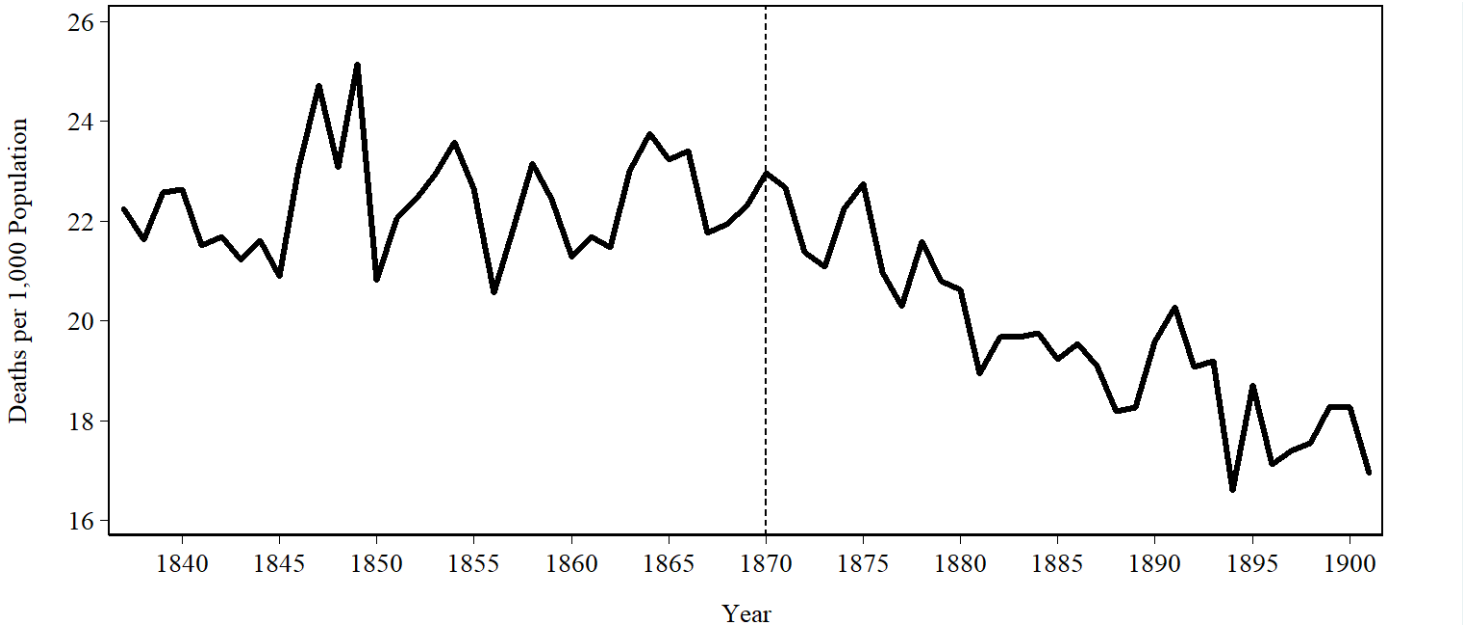
Source: Steckel & Floud (1997)

Figure 3. Fraction of Union Population Under a Local Board



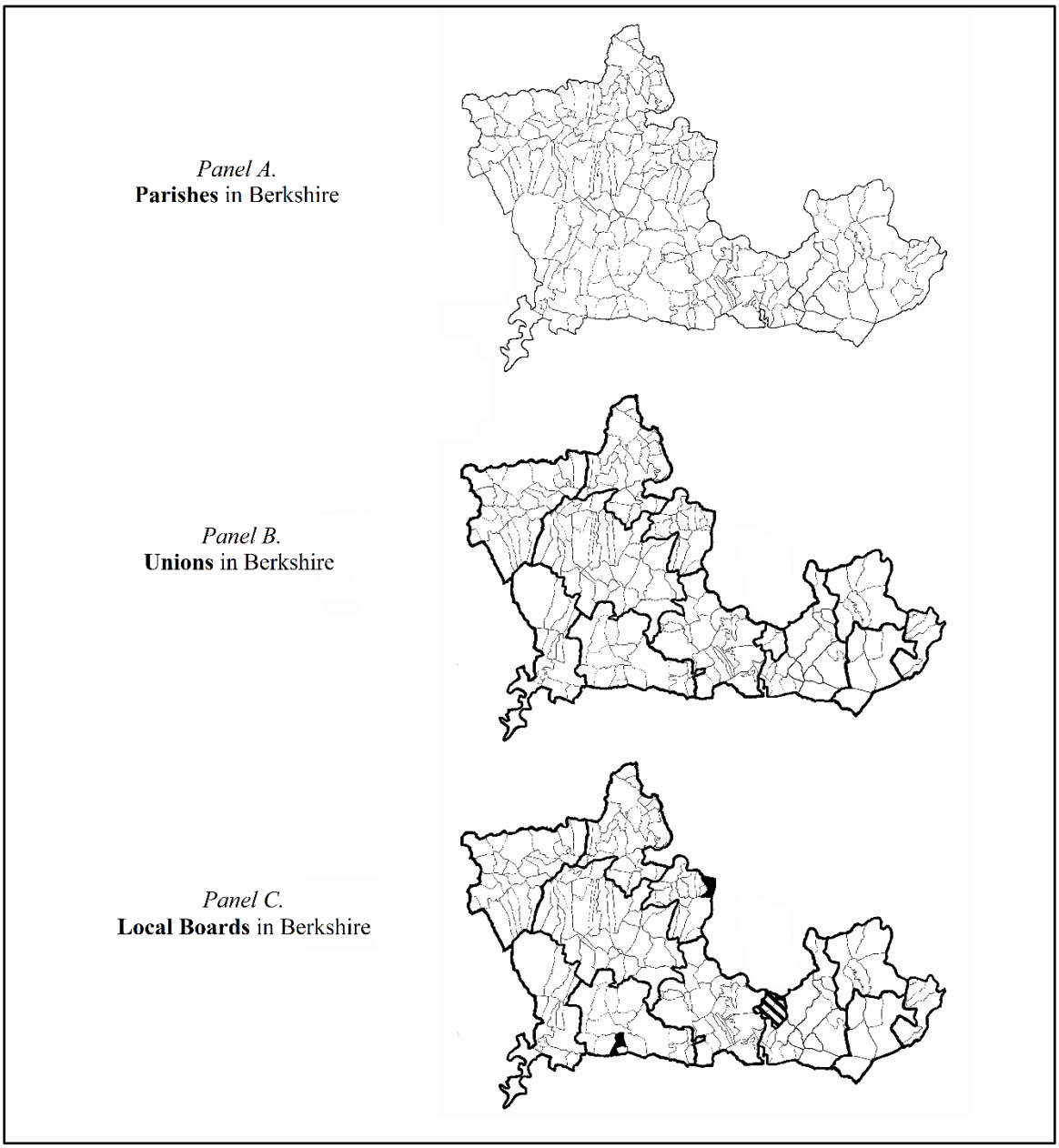
Source: Local board locations, populations, and adoption dates derive from the *Return of Local Boards* (1868). Union populations derive from *Decennial Census Reports* (1841-71). Union "polygons" used in the construction of these maps have been provided through www.VisionofBritain.com and use historical material which is copyright of the Great Britain Historical GIS Project and the University of Portsmouth.

Figure 4. Aggregate Mortality in England & Wales



Source: Annual Reports of the Registrar General (1837-1901)

Figure 5. English Local Government Areas



Notes: Panel A illustrates the boundaries of the parishes in the county of Berkshire in 1851. Panel B illustrates the boundaries of the Poor Law unions in the county of Berkshire in 1851, as well as each parish contained therein. Panel C illustrates the location of each of the three local boards of health adopted in Berkshire between 1848 and 1870. Solid black shading indicates that a parish is wholly within the jurisdiction of a local board. Striped black shading indicates that a parish is only partly within the jurisdiction of a local board.

Figure 6. Distribution of Board Adoptions per Union, 1848-66

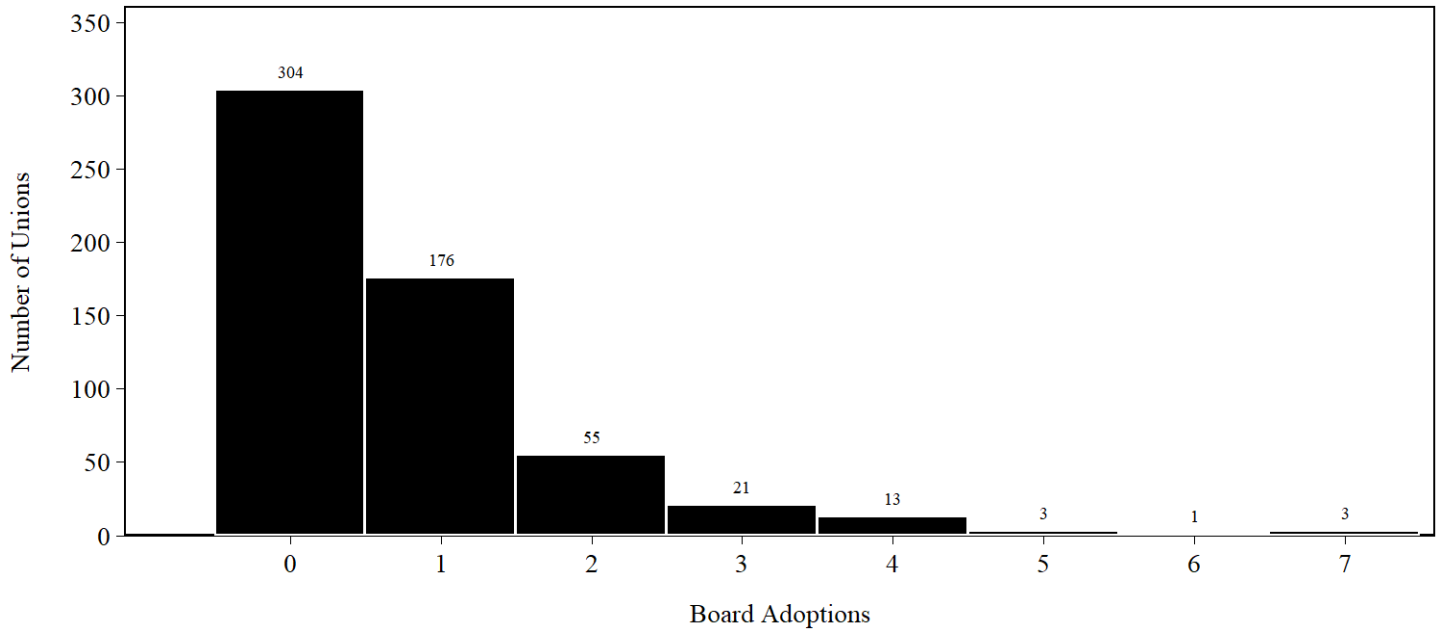
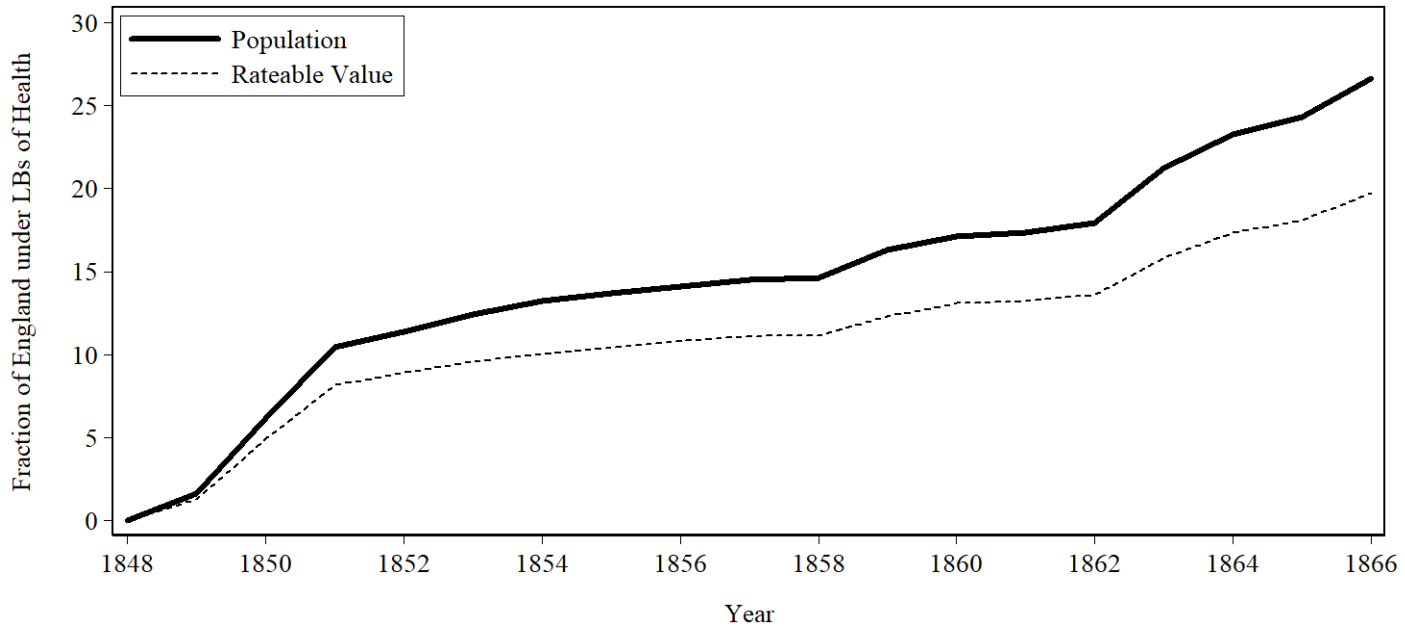
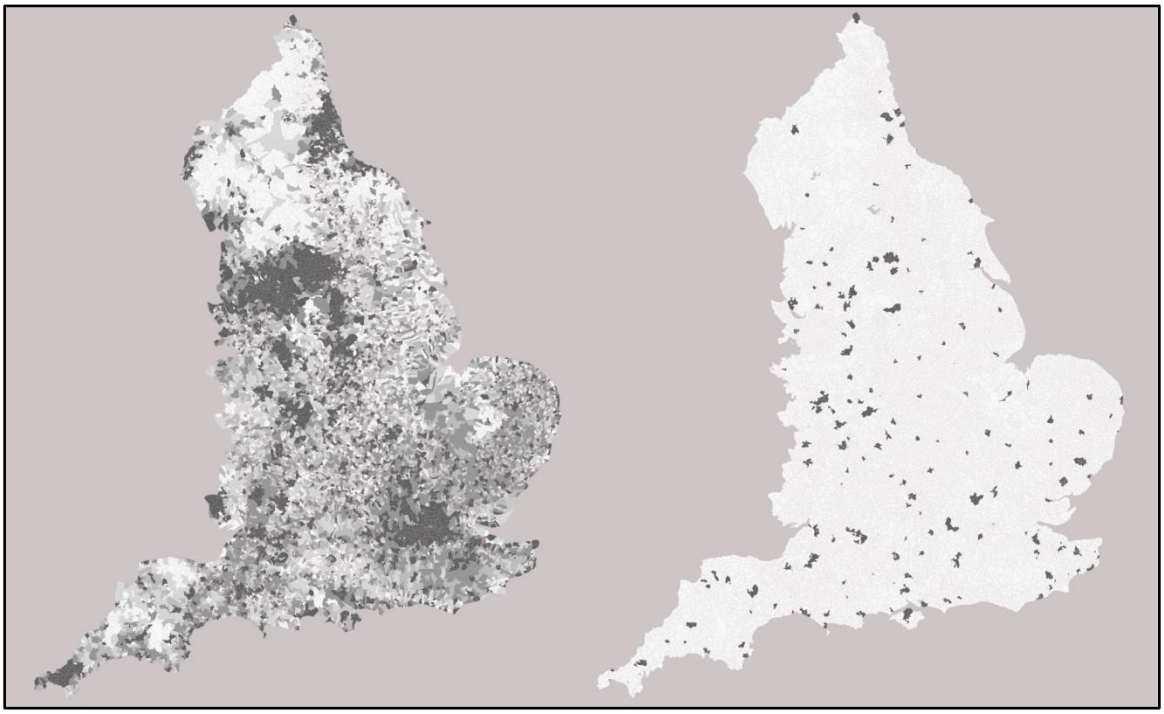


Figure 7. Rollout of Local Boards of Health



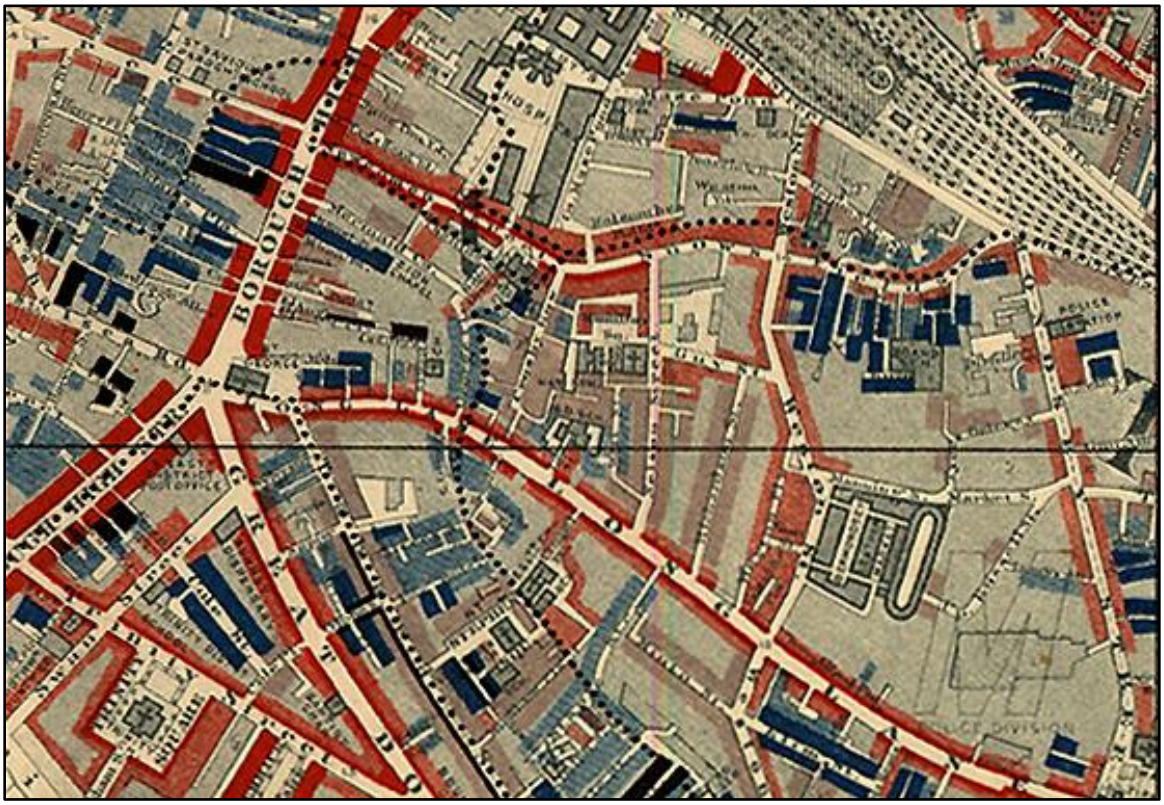
Source: The population, rateable value, and adoption date of local boards derive from the *Return of Local Boards* (1868).

Figure 8. Location of Municipal Boroughs



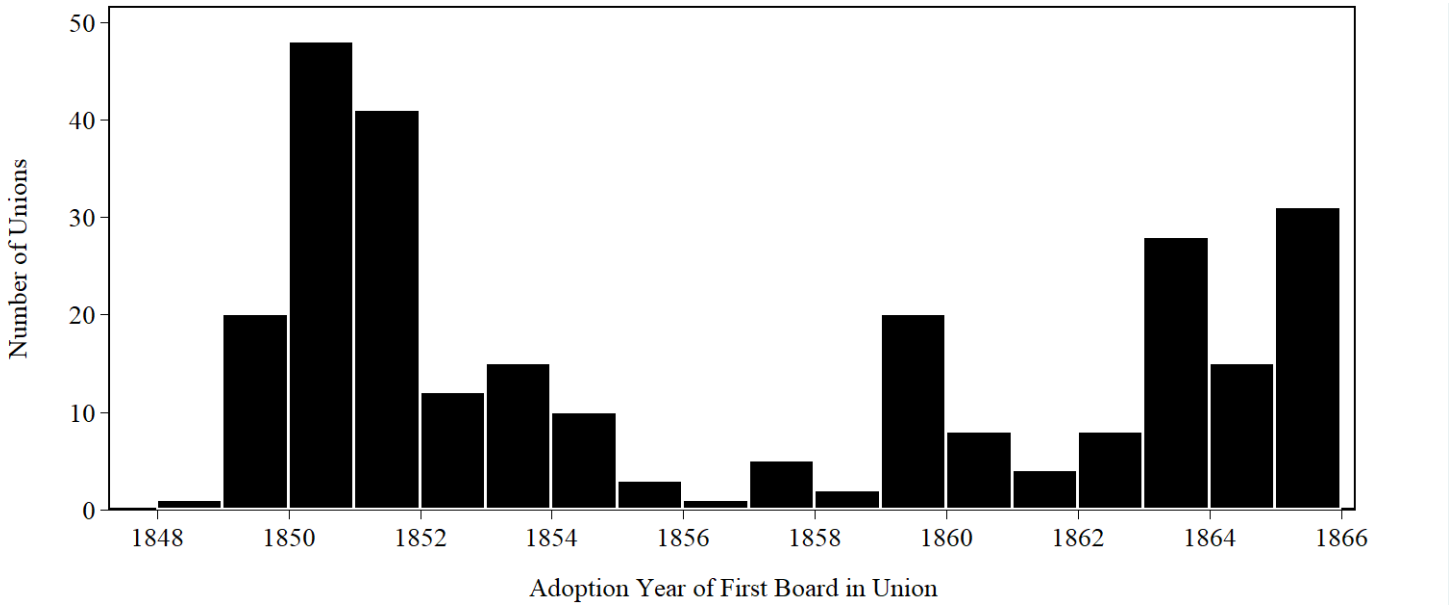
Notes: The rightmost map plots the location of municipal boroughs according to the 1851 Census Report. Civil parishes colored black are either entirely or partially under the jurisdiction of a municipal borough (i.e. any place regulated by the Municipal Corporations Act of 1835, not to be confused with a "parliamentary borough," which returned members to Parliament, though there is significant overlap between the two borough "types"). Civil parishes colored white contain no part of any municipal borough. The leftmost map plots quintiles of population density by civil parish in 1871. Quintile cutoffs, from light to dark, are as follows. The first quintile consists of parishes with fewer than 0.11 persons per acre; the second, between 0.11 and 0.17 persons per acre; the third, between 0.17 and 0.23 persons per acre; the fourth, between 0.23 and 0.42 persons per acre; and the fifth, greater than 0.42 persons per acre. Parish populations, areas, and "polygons" used in the construction of these maps have been provided through www.VisionofBritain.com and use historical material which is copyright of the Great Britain Historical GIS Project and the University of Portsmouth.

Figure 9. Booth's Poverty Maps



Notes: Pictured is a sample of Charles Booth's poverty maps from *Life and Labour of the People of London, Vol. I* (1889). Residences are colored according to the general economic condition of their inhabitants. Red shading denotes middle class or well-to-do residences. Beige shading denotes mixed residences (i.e. "some comfortable, others poor"). Blue shading denotes poor to very poor residences (i.e. "chronic want"). Black shading denotes the lowest class residences (i.e. "vicious, semi-critical").

Figure 10. Adoption Years of Local Boards of Health

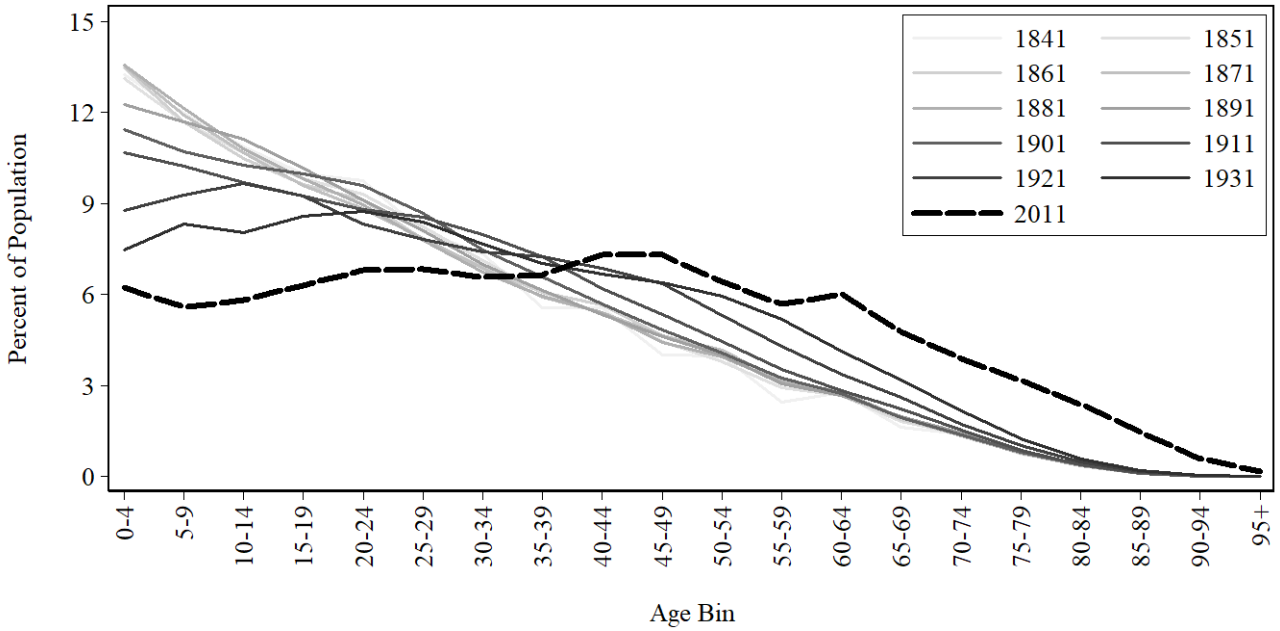


Source: Board adoption years derive from the *Return of Local Boards* (1868).

Figure 11. Population Share of Local Boards of Health

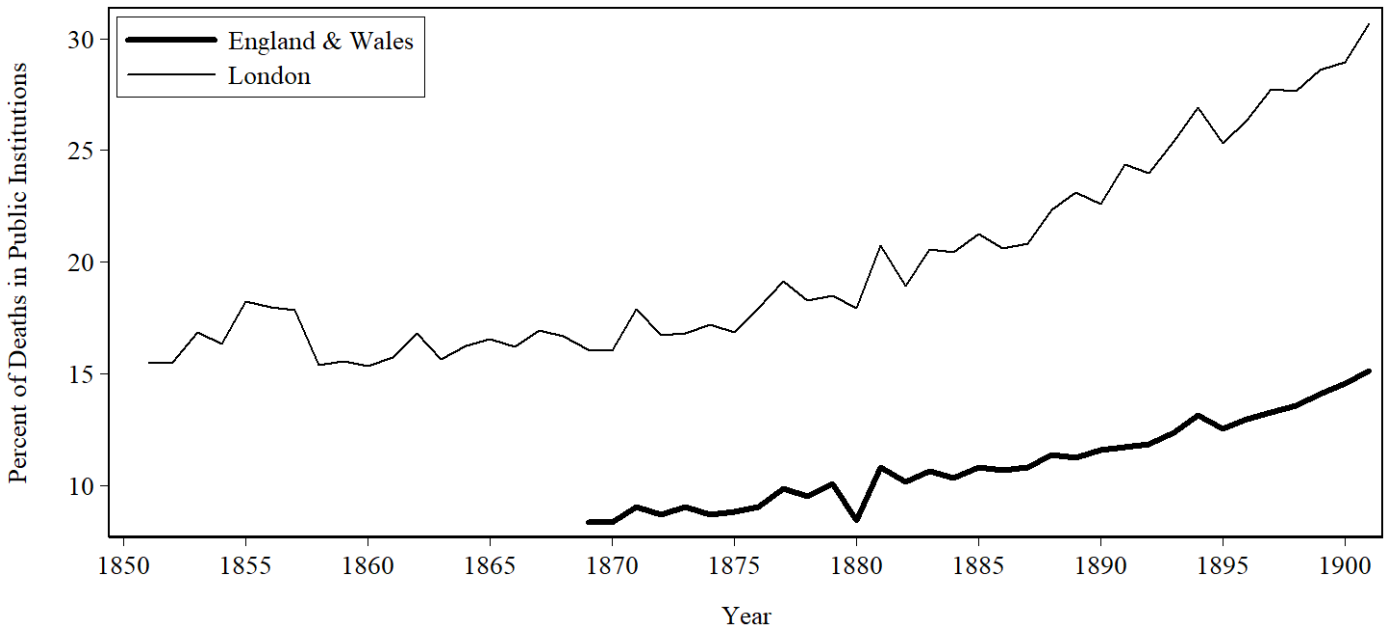
Source: Board populations derive from the *Return of Local Boards* (1868). Union populations derive from *Decennial Census Reports* (1861-71).

Figure 12. Age Distributions of England, 1841-2011



Source: Decennial Census Reports (1841-1931, 2011)

Figure 13. Percent of Deaths in Public Institutions



Source: Annual Reports of the Registrar-General (1851-1901)

Figure 14. Event Study

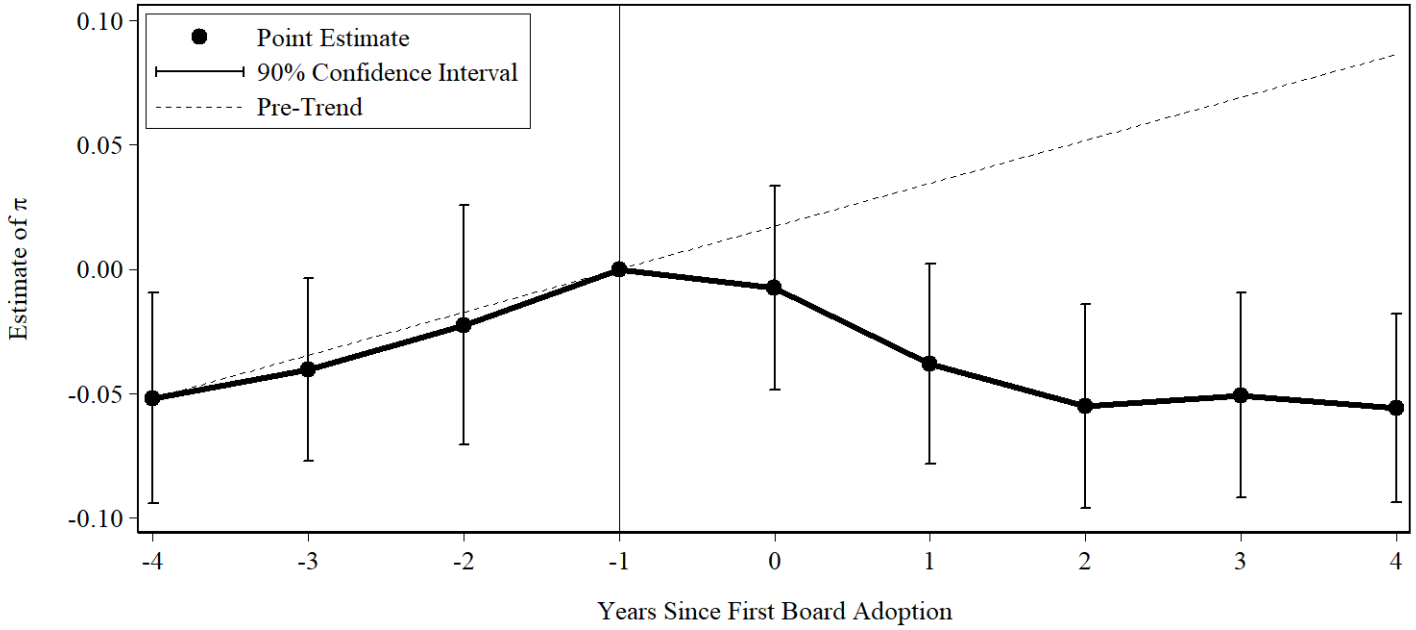


Figure 15. Implied England-Wide Effect of Local Boards

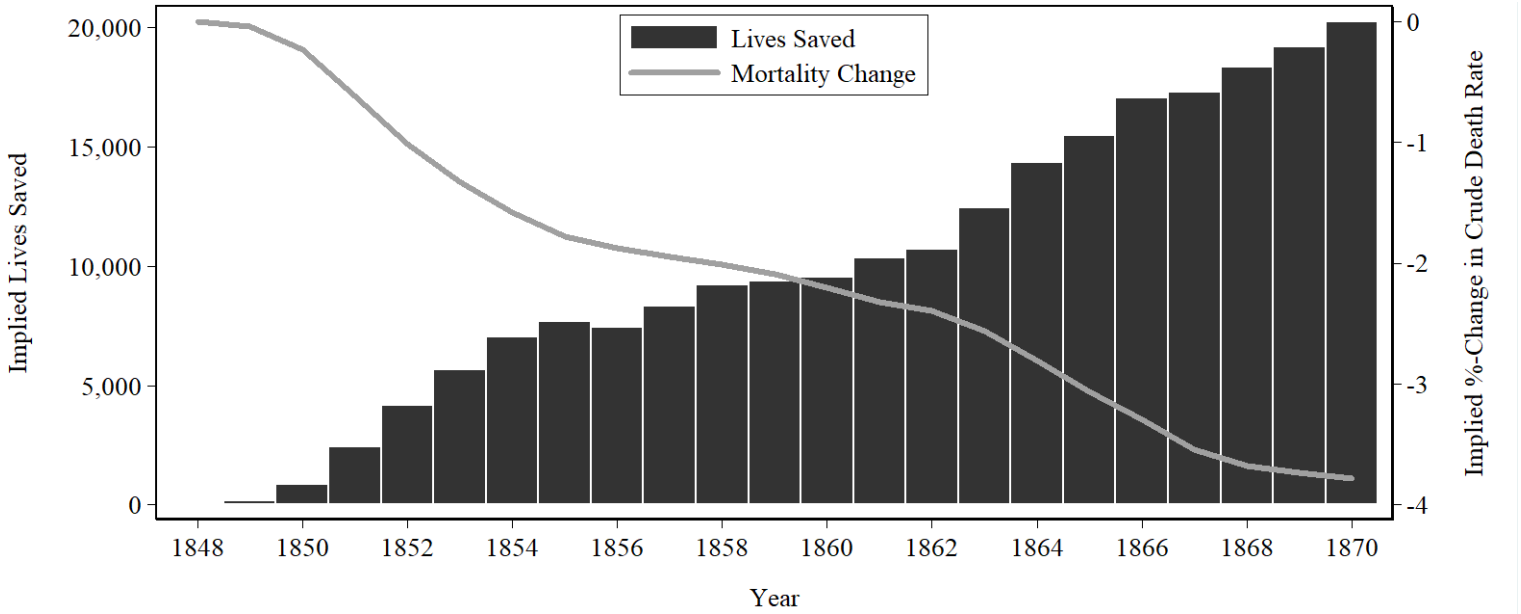


Figure 16. Actual & Counterfactual English Mortality Rate

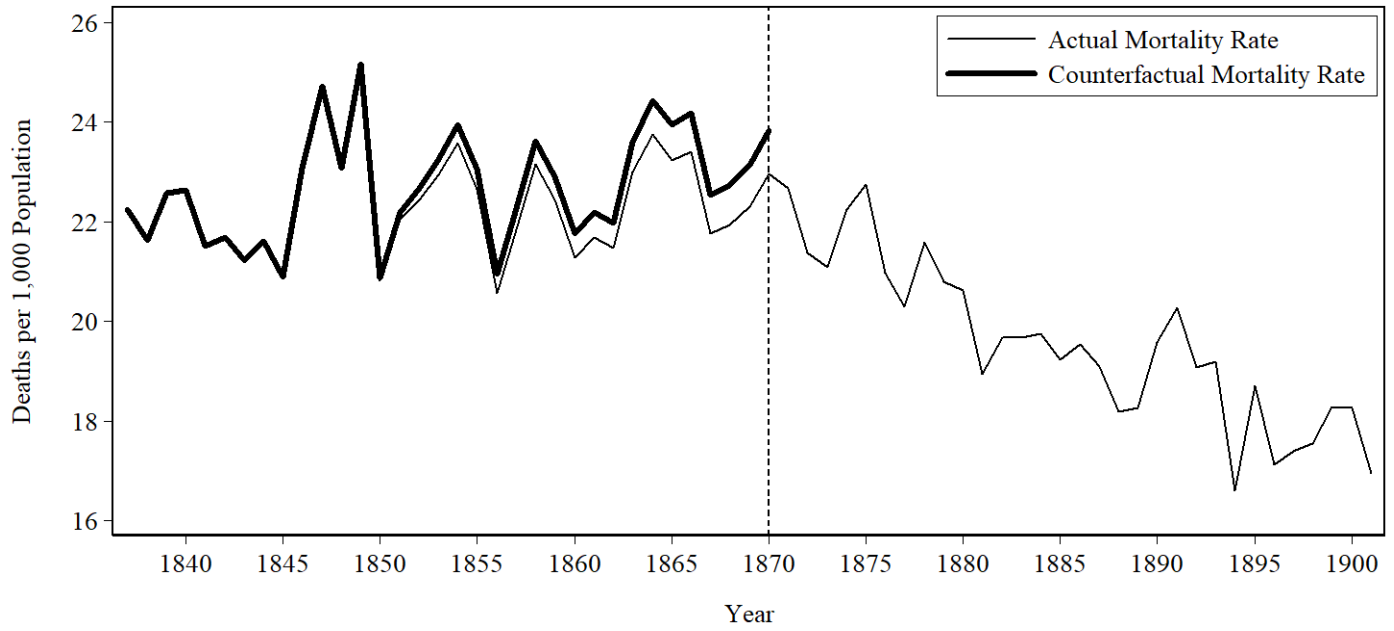
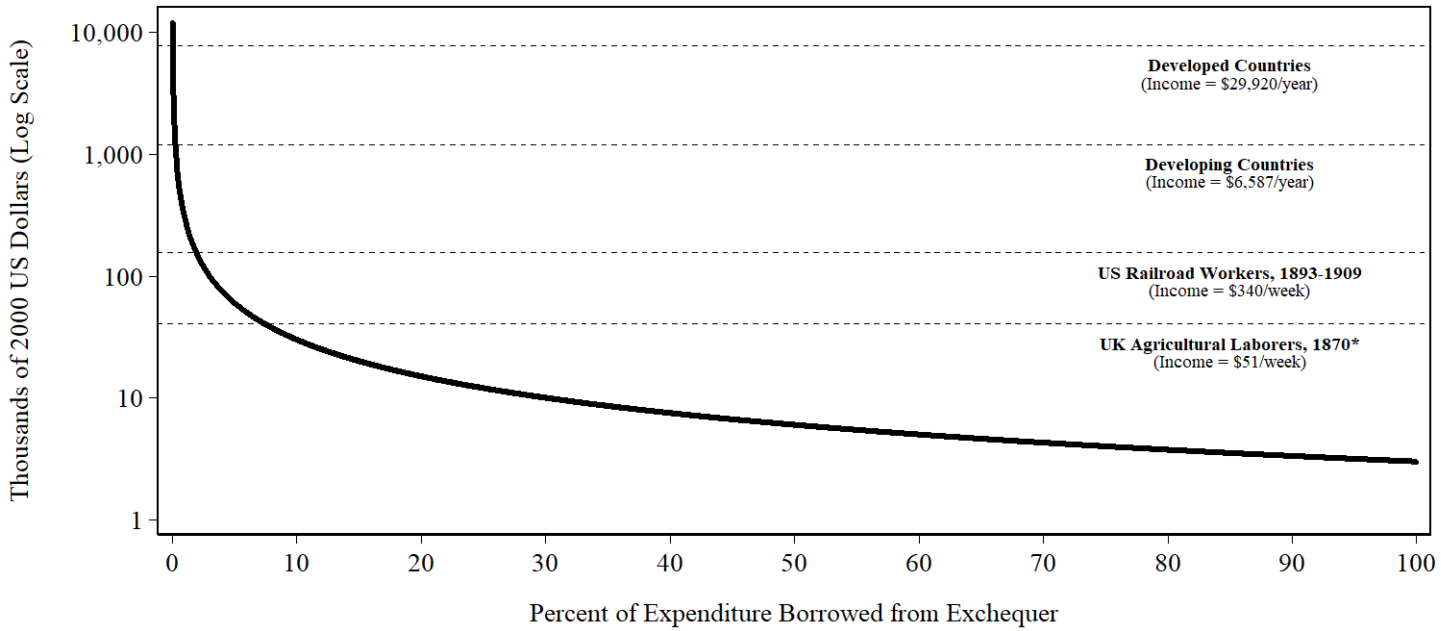


Figure 17. Cost Per Life Saved (With VSL Estimates)



Notes: The solid line plots the cost-per-life-saved curve. The dashed lines plot VSL estimates. The VSL estimates of developed and developing countries are medians of groups of VSL estimates obtained from Viscusi & Aldy (2003). The VSL estimate of US railroad workers is obtained from Kim & Fishback (1993). The VSL estimate of UK agricultural laborers is derived from the VSL estimate of US railroad workers using the difference in average weekly income between the two samples and an income elasticity of VSL of 0.5. The average weekly income of UK agricultural laborers is obtained from Bowley (1898).

Data Appendix

The panel dataset that I construct consists of 576 English poor law unions between 1848 and 1870. In this section I demonstrate in greater detail the method by which each variable is constructed, the source or sources from which each variable derives, and the procedure by which these sources are transcribed and combined. I refer to primary sources by the abbreviations enumerated below.

A1. Primary Sources

Abbr.	Source Title	Year(s)	Source Citation†
RRG	Annual Reports of the Registrar-General	1849-72	
DCR	Decennial Census Reports	1841-71	
RHS	Annual Reports of the Home Secretary	1858-70	
RLB1	Return of Boards Acting Under the PHA	1868	PP, 58 (1867-68), pp. 789-23
RLB2	Return of Number & Names of Local Boards	1870	PP, 55 (1870), pp. 711-52
RLB3	Return of Districts where PHA is in Force	1867	PP, 59 (1867), pp. 141-167
RLB4	Return of Local Boards of Health	1857	PP, 41 (1857), pp. 3-23
RSC	Religious Supplement to the 1851 Census	1853	PP, 89 (1852-53), pp. 279-422
RV1	Return of the Gross Estimated Property	1861	PP, 54 (1861), pp. 141-67
RV2	Return of Rateable Value	1869	PP, 53 (1868-69), pp. 33-58
PLB	Fourth Annual Report of the Poor Law Board	1851	PP, 23 (1852), pp. 43-74
GHC	Guide to the House of Commons	1857	See References

† PP refers to the House of Commons Parliamentary Papers.

A2. Variables

Mortality Rate, or DR_{ut}, is defined as the number of deaths per 1,000 population (i.e. the "crude" mortality rate) in union *u* and year *t*. I obtain the total deaths in each union in each year between 1848 and 1870 from RRG and the total population in each union in 1841, 1851, 1861, and 1871 from DCR. I (linearly) interpolate union population between census years.

Local Board Share, or $BFRAC_{ut}$, is defined as the share of the total population of union *u* in year *t* that fell under the jurisdiction of a local board of health. Since the boundaries of

local boards of health, of which more than 600 were adopted between 1848 and 1870, did not match the boundaries of poor law unions, it is necessary to determine the unions with which each local board of health intersected and the extent of each intersection. I obtain the names of the constituent parishes of poor law unions from DCR, the names and 1861 populations of the constituent parishes or parts of parishes of all local boards of health adopted between 1848 and 1866 from RLB1, and the names and 1861 populations of the constituent parishes or parts of parishes of all local boards of health adopted between 1867 and 1870 from RLB2. I also obtain the adoption years of all local boards of health adopted between 1848 and 1866 from RLB3. I do not observe the exact adoption years of local boards of health adopted between 1867 and 1870, and therefore I exclude all 20 unions within which at least one local board of health was adopted between 1867 and 1870. For all remaining unions, I define POP_u as the population of union u in 1861, POP_{uh} as the 1861 population of the constituent parishes or parts of parishes of local board of health h that fell under the jurisdiction of union u, and AY_h as the year in which local board of health h was adopted. I calculate the proportion of union u's population that fell under the jurisdiction of a local board of health in year t in the following way:

$$\text{BFRAC}_{ut} = \sum_h \left(\frac{\mathbf{1}(\text{AY}_h \geq t) \times \text{POP}_{uh}}{\text{POP}_u} \right)$$

Population Density is defined as the population per area (in acres) in union u in year t. I obtain the total acreage in each union from DCR. Union population is obtained as before.

Percent in Agriculture is defined as the percent of persons aged twenty and upwards (i.e. "adults") that were employed in agriculture in union u and year t. I obtain these data for 1841, 1851, and 1861 from DCR. I obtain these data for 1881 from a machine-readable version of the 1881 Census Enumerators' Books made available by the UK Data Archive via the Vision of Britain website. I (linearly) interpolate these data between census years.

Coal Production Dummy is defined as whether or not coal production was "a special occupation pursued" within union u in 1851. These data are obtained from DCR.

Cotton-Textile Production Dummy is defined as whether or not cotton-textile production was "a special occupation pursued" within union u in 1851. These data are obtained from DCR.

Fraction Water is defined as the proportion of union *u*'s total area (in acres) that consisted of water (i.e. harbors, creeks, rivers, etc) in 1851. I obtain both the total acreage and the total water-acreage in each union in 1851 from DCR. In the case of unions bordering on the sea coast, "a certain proportion of the beach or sands" was included as water-acreage.

Rateable Value per Capita is defined as the amount of owned or occupied property that is rated to the relief of the poor (i.e. assessed for local taxation) per population in union *u* and year *t*. This is tantamount to property wealth per population. I obtain rateable value in 1856 and 1868 from RV1 and RV2, respectively. I (linearly) interpolate these data between 1856 and 1868 and (linearly) extrapolate these data between 1848 and 1856 and between 1868 and 1870. Union population is obtained as before.

Poor Law Expenditure per Capita is defined as the amount expended per population by the poor law board of guardians representing union *u* in 1851. Expenses included cash or in-kind welfare benefits (i.e. outdoor relief), the provision of room and/or board in a workhouse (i.e. indoor relief), and any fees and salaries associated with the maintenance of workhouses, the cost of all of which was passed along to union ratepayers (i.e. taxpayers) in the form of a so-called "poor rate." I obtain total expenditure in each union from PLB. Union population is obtained as before.

Church Attendance is defined as the proportion of union *u*'s population that attended a church service of any denomination on the 30th of March, 1851. I obtain total church attendance in each union from RSC. Union population is obtained as before. Although a day-count may over- or under-state average church attendance, Eli & Slater (1994) demonstrate that there is little evidence of any widespread falsification or manipulation of church attendance data by religious actors on behalf of their denominations in order to buoy attendance numbers, lest their denominations be cast in poor light.

Fraction Non-Conformist is defined as the proportion of religious sittings in union *u* in 1851 that were classified as non-Anglican Protestant (e.g. Presbytarian, Baptist, Unitarian, Wesleyan Methodist, etc). I obtain the number of Anglican, non-Anglican Protestant, Roman Catholic, and total sittings in each union in 1851 from Table H of RSC. I then divide non-Anglican Protestant sittings by total sittings.

Fraction Conservative is defined as the proportion of union *u*'s political representatives (i.e. MPs) that were affiliated with a conservative political party in 1852, after that year's general election. I obtain the party affiliation of all 496 English members of Parliament—broadly defined as liberal, conservative, or liberal-conservative (i.e. Peelite)—from GHC. Since the distinction between conservative and Peelite was a matter of international trade (and, hence, irrelevant in terms of public health), I re-classify all liberal-conservatives as conservatives. As with the boundaries of local boards of health, the boundaries of parliamentary constituencies, of which there were 282 in England and Wales in 1851, did not match the boundaries of poor law unions. It is therefore necessary to determine the unions with which each constituency intersected and the extent of each intersection. I obtain the names and populations of the constituent parishes of every parliamentary constituency in 1851 from DCR and match these parishes to unions. I then define POP_u as the population of union *u* in 1851, POP_{uc} as the population of parliamentary constituency *c* that fell under the jurisdiction of union *u* in 1851, MPS_c as the number of members of Parliament representing constituency *c* in 1852, and CON_{cm} as a dummy that takes a value of 1 if member *m* of constituency *c* was affiliated with a conservative political party in 1852. I calculate the proportion of union *u*'s political representatives that were affiliated with a conservative political party in the following way:

$$\text{CFRAC}_u = \sum_c \left(\frac{\text{POP}_{uc}}{\text{POP}_u} \left(\sum_m \frac{\text{CON}_{cm}}{\text{MPS}_c} \right) \right)$$

The inner sum represents the proportion of the members of Parliament representing constituency *c* that were conservative. The outer sum weights each constituency *c* by the proportion of the population of union *u* that it contained.

Fraction Municipal Borough is defined as the proportion of union *u*'s population that fell under the jurisdiction of a municipal borough. As with the boundaries of local boards of health and of parliamentary constituencies, the boundaries of municipal boroughs, of which there were 176 in England in 1851, did not match the boundaries of poor law unions. It is therefore necessary to determine the unions with which each municipal borough intersected and the extent of each intersection. I obtain the names and 1851 populations of the constituent parishes of every municipal borough in 1851 from DCR and match these

parishes to unions. I then define POP_u as the population of union u in 1851 and POP_{ub} as the population of municipal borough b that fell under the jurisdiction of union u in 1851. I calculate the proportion of union u's population that fell under the jurisdiction of a municipal borough in the following way:

$$\text{MFRAC}_u = \sum_b \left(\frac{\text{POP}_{ub}}{\text{POP}_u} \right)$$

Census Division Dummies are regional indicators that I employ as fixed effects. DCR defines ten regions of England that do not change between 1841 and 1871. The following table enumerates the counties or parts of counties of which each census division was comprised.

CD #	CD Name	Counties
I	The Metropolis	Kent†, Middlesex†, Surrey†
II	South Eastern	Berkshire, Kent†, Southampton, Surrey†, Sussex
III	South Midland	Bedford, Bucks, Hertford, Huntington, Middlesex†, Northampton, Oxford
IV	Eastern	Essex, Norfolk, Suffolk
V	South Western	Cornwall, Devon, Dorset, Somerset, Wilts
VI	West Midland	Gloucester, Hereford, Monmouth††, Salop, Stafford, Warwick, Worcester
VII	North Midland	Derby, Leicester, Lincoln, Nottingham, Rutland
VIII	North Western	Chester, Lancaster
IX	York	East Riding, North Riding, West Riding
X	Northern	Cumberland, Durham, Northumberland, Westmorland
XI	Wales	Excluded from Dataset

† Indicates that only part of county is included in the corresponding census division.

†† The classification of Monmouth is inconsistent across sources. Some, including DCR, classify Monmouth as a part of Census Division XI (i.e. Wales). Others classify Monmouth as a part of Census Division VI (i.e. West Midlands). I use the latter classification.

Board Borrowing, as shown in Table 5, refers only to the amount that Local Boards of Health borrowed from the Exchequer. It, therefore, excludes all borrowing from private sources and all expenditures that were not borrowed. I obtain total borrowing by local boards of health from the Exchequer between 1848 and 1857 from RLB4 and annual

borrowing by local boards of health from the Exchequer between 1858 and 1870 from RHS.

A3. Changes in Union Boundaries

There were a small number of boundary changes among unions between 1848 and 1870, each of which took one of two forms. First, some unions were dissolved and incorporated into other unions. In 1869, for example, the two parishes that comprised the Brinton Union in the county of Norfolk joined the Walsingham Union. In these cases, I agglomerate the dissolved union (e.g. Brinton) and the union or unions into which it was incorporated (e.g. Walsingham) in all years prior to the boundary change. Second, some unions were divided into multiple unions. In 1861, for example, nine parishes were withdrawn from the Wirral Union in the county of Cheshire to form the Birkenhead Union. In these cases, I agglomerate the parent union (e.g. Wirral) and the union or unions into which it was divided (e.g. Birkenhead) in all years after the boundary change.