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ABSTRACT

This paper studies the immediate and long-run mortality effects of the first community-based health intervention in the world – the Framingham Health and Tuberculosis Demonstration, 1917-1923. The official evaluation committee and the historical narrative suggest that the demonstration was highly successful in controlling tuberculosis and reducing mortality. Using newly digitized annual cause-of-death data for municipalities in Massachusetts, 1901-1934, and different empirical strategies, we find little evidence to support this positive assessment. In fact, we find that the demonstration did not reduce tuberculosis mortality, all-age mortality, nor infant mortality. These findings contribute to the ongoing debate on whether public-health interventions mattered for the decline in (tuberculosis) mortality prior to modern medicine. At a more fundamental level, our study questions this particular type of community-based setup with non-random treatment assignment as a method of evaluating policy interventions.

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1 Introduction

In the United States, the tuberculosis (TB) mortality rate fell from above 200 in the beginning of the 20th century to about 60 per 100,000 in the mid-1930s (Cutler and Meara, 2004). Was this decline mainly due to public health policies? So far, research has provided different answers to this question. In his classic work, McKeown (1976) argued that public policy played a limited role in reducing TB mortality prior to antibiotics. By contrast, Preston (1975), Szreter (1988), Cutler et al. (2006), and others highlight the important role of various public health interventions that were set in motion by the germ theory of disease in the 1880s.[1]

In this paper, we provide a rigorous quantitative analysis of the effects of the first public health demonstration, the Framingham Community Health and Tuberculosis Demonstration, on TB mortality, total mortality, and infant mortality.[2] The Demonstration was made possible by a donation of 200,000 US dollars made by the Metropolitan Life Insurance Company to the National Association for the Study and Prevention of Tuberculosis (henceforth the National Association) in 1916. Later that year, Framingham, Massachusetts, was chosen as a typical American community, and the Demonstration was carried out from 1917 to 1923 with increased efforts to control TB through a consultation service and informational campaigns. After the Demonstration ended in 1923, an official evaluation found that TB and infant mortality decreased more in Framingham compared to similar pre-selected control communities during the Demonstration period 1917-1923. The TB mortality rate in Framingham fell 69 percent, compared with that of seven control communities in which the fall was 32 percent (Monograph No. 10, 1924: p.40).[3] It is still believed to have been successful. In fact, Kannel and Levy (2005) conclude that the Demonstration not only showed that TB could be controlled but that the approach taken by the Demonstration could be a foundation for the investigation of the causes and control of other chronic diseases that impact the population. Moreover, the Framingham Demonstration inspired a number of contemporary health demonstrations, and community-wide

[1]Empirical work supporting that clean water and sanitation mattered includes Cutler and Miller (2005), Ferrie and Troesken (2008), Clay et al. (2014), and Alsan and Goldin (forthcoming). On the contrary, Anderson et al. (2018b) find that the effect of different clean water actions was limited.

[2]An article in the Boston Globe from March 18, 2016 states that, according to Framingham History Center executive director Anne Murphy, the Framingham Demonstration was the first community-based participatory health study in the world (West, 2016).

[3]The National Association published 10 monographs on Framingham, see Framingham Community Health and Tuberculosis Demonstration of the National Association for the Study and Prevention of Tuberculosis (1918-1924). In the text, we refer to these volumes as, for example, Monograph No. 1 for the first volume, and so on.

demonstration projects are even used in developing countries today.

To evaluate the effects of the Framingham Demonstration, we use newly digitized vital statistics for municipalities (i.e., towns and cities) in Massachusetts. The official evaluation (Monograph No. 10, 1924) used seven pre-selected control municipalities in Massachusetts to measure whether the Demonstration reduced TB mortality in Framingham during the Demonstration period (1917-1923). We extend the number of potential control municipalities within Massachusetts to study whether the Demonstration reduced TB mortality. The Massachusetts cause-of-death data set allows us to study the Demonstration more systematically and to apply methods that take into account that we have only one treated unit and transitory shocks in the outcome. We apply the synthetic control method, pioneered by Abadie and Gardeazabal (2003) and Abadie et al. (2010), a recent extension of this method by Doudchenko and Imbens (2016), and standard differences-in-differences methods, but again taking into account that only one unit was treated.

In contrast to the positive conclusions found in Monograph No. 10 (1924) and the historical narrative, we find that the Framingham Demonstration did not have any effects on TB, infant mortality, or total mortality. We do, however, find some evidence that it increased the number of discovered TB cases.[4] These findings imply that the original conclusion regarding the effect of the Demonstration on tuberculosis is debatable.[5]

The paper makes at least two contributions. First, it contributes to the literature on the historical mortality decline. McKeown, along with Fogel (1994, 1997), emphasize the role of nutritional improvements as a main factor behind the mortality decline. Egedesø (2018) reports evidence on this based on data for US prisons. He finds that increases in spending on provisions per prisoner can explain about 26 percent of the prison mortality decline. Moreover, recent research by Anderson et al. (2018a) partly supports McKeown's conclusion regarding public health policy and finds that the first campaign against TB had limited success prior to 1918 in the United States. By contrast, research by Hollingsworth (2014) and Egedesø et al. (2017) suggest that interventions targeted at TB were, in fact, successful in the pre-antibiotic era. The evidence obtained on the effect of the Framingham Demonstration is more in line with the view of McKeown and Fogel.

[4]Positive evaluations are given in, e.g., Shryok (1957), Comstock (1980), and Kannel and Levy (2005). D'Antonio (2017) notes that the results of the Framingham Demonstration suggested that case finding and treatment could reduce tuberculosis mortality.

[5]We also do not find any evidence of spillover effects of the Demonstration to nearby communities when we exclude municipalities within 50 kilometers of Framingham.

Second, at a more fundamental level, our paper relates to the literature on the effects of demonstration projects in developing countries today, such as the Millennium Villages Project (Clemens and Demombynes, 2011) and the Southwest Project in China (Chen et al., 2009). This literature aims to evaluate the effects of demonstration projects using possible non-random assignment into treatment as was the case for Framingham. Focusing on a historical demonstration project offers a unique possibility to leverage annual panel data to study the effects over a longer period than in the development literature and to test maintained assumptions needed for the empirical strategy. By contrast, difference-in-differences estimation with two to three surveys and a shorter period are often used in the development literature. Clemens and Demonbynes (2011) and Chen et al. (2009), for example, only have data after initial treatment and are, therefore, unable to evaluate the parallel trend assumption needed for the validity of difference-in-differences estimation. Our historical study documents that it is difficult to evaluate such demonstration projects in terms of statistical precision, even when pre- and post-intervention data are available for a longer period of time, questioning this type of research design with one or a few treated units and non-random treatment assignment.

The rest of the paper is organized as follows. Section 2 provides historical background on the Framingham Demonstration explaining the intervention in detail. Section 3 describes the data collected. Section 4 presents the empirical strategy. Sections 5 reports the results. Section 6 concludes.

2 Historical background

This section provides more details on the Framingham Community Health and Tuberculosis Demonstration as well as other background material. We first describe the background for the donation to the National Association and why Framingham was chosen as the location for the Demonstration. Second, we describe the key elements of the Demonstration. Third, we discuss other Demonstrations that followed after the Framingham Demonstration. Finally, we take an initial look at the differences between Framingham and other municipalities in Massachusetts in terms of pulmonary TB death rates.

2.1 The donation and the choice of location

In May 1916, the Metropolitan Life Insurance Company donated 100,000 US dollars to the National Association for the Study and Prevention of Tuberculosis. The gift was given for the purpose of carrying out a community health and TB Demonstration. The insurance company had an interest in the Demonstration, as 16 percent of the deaths in its industrial department were due to TB. In 1915, the company paid claims of over 4 million dollars on the lives of 14,325 policy holders dying from the disease (Monograph No. 1, 1918: p.9). The purpose of the investigation was to demonstrate what may be possible with a united action of prevention and control of TB (Monograph No. 1, 1918: p.12). Soon after the Demonstration had begun, it was deemed impossible to fight TB without carrying out a program for improving the general health of the community. By mid-1919, all Demonstration activities were under way, and it was too soon to judge their effects (Shryock, 1957). To allow activities to continue, the insurance company increased the appropriation to 200,000 US dollars and the Demonstration was therefore able to run for a period of seven years (Hall, 1933).

Initially, the location of the Demonstration had not been determined. In November 1916, the choice fell on Framingham, a town located 21 miles west of Boston (D'Antonio, 2017; Monograph No. 1, 1918); see also the map of Massachusetts in Figure 1 with the location of the municipalities in the sample. It was a "typical community" of second and third generation white Irish Americans, whose immigrant population of 27 percent mirrored that of the United States as a whole (d'Antonio, 2017). Monograph No. 1 (1918) describes Framingham as a community with mixed industries, varied racial groups, a good health organization linked with an excellent State Department of Health, a normal amount of disease – particularly TB, well trained physicians, and good hospitals. Moreover, Monograph No. 10 (1924) adds that the town was an autonomous, economically independent, and essentially non-commuting settlement. Framingham is also described as an average town with the properties mentioned above and "a sufficient promise of cooperation from medical, industrial, commercial and social organizations to give reasonable assurance of success" (Monograph No. 10, 1924: p.17).

[Figure 1 about here]

2.2 The elements of the Demonstration

As mentioned above, the Demonstration ran from 1917 to 1923. It included several elements that may be grouped under primary research activities and health services which we explain below. We also provide a description of the evolution of health services based on the Board of Health Reports.

2.2.1 Primary research activities

The first year of the Demonstration was mainly devoted to primary research activities. As detailed in the Monographs No. 2, 5, and 6, these research activities included a sickness survey,[6] the Von Pirquet Tuberculin Survey of children, and studies of the sanitary conditions in schools and factories. In 1918, a tuberculin survey of cattle was carried out. Research and investigation constituted roughly 52 percent of the costs incurred as part of the Demonstration in 1917, which had decreased to 17 percent by 1922 (Monograph No. 10, 1924).

Shryock (1957) notes that the research activities produced a number of by-products. They not only resulted in a medical survey of the population in the course of which many children were tuberculin tested, but also in the systematic use of X-ray as a diagnostic aid.

2.2.2 Establishment and expansion of services

Consultation service During the first year of the Demonstration, a consultation service was established. Dr. P.C. Bartlett was the chief medical examiner and expert consultant. His job included helping local Framingham physicians with diagnosing TB. This helped to increase the number of known TB cases from 27 to 185 as well as the number of active cases from 13 to 59 (Monograph No. 10, 1924). Related to diagnosis, Comstock (2005) points out that the use of methods such as "fluoroscopy was almost routine and chest radiographs were made when indicated. Both were rarely available in small towns at that time." In line with this, Shryok (1957) emphasizes that Framingham was the earliest instance in which expert consultation services were made available to local practitioners for the diagnosis of pulmonary and cardiac conditions. The consultation service also acted as a connecting link between "physicians and patients, between the patients and treatment, and between physicians and scientific knowledge and methods" (Monograph No. 10, 1924). Matson (1924) believed that the consultation service was the most valuable of the services set up by the Demonstration. He described the service as

[6] Shryock (1957) notes that the sickness survey covered 38.7 percent of the Framingham population.

"an expert consultation service, offering consultations to local physicians, factory medical and nursing staffs on cases of suspected tuberculosis, or respiratory infections" (p.1243).[7]

Infant welfare work Initially, infant welfare work was carried out and expanded by a private organization called the Civic League, which itself was established in 1917. From 1920, this work was taken over and expanded by the Board of Health, which established infant welfare clinics. According to the 1921 Framingham Board of Health report, the work of the infant welfare department consisted in ensuring that 1) prospective mothers received adequate care; 2) mothers were taught the value of fresh milk for their babies and were instructed not to wean them too soon; 3) mothers who were not fortunate enough to have mother's milk, obtained good cow's milk for their babies; and 4) mothers were taught when and how to begin to give their children foods other than milk. The 1920 Framingham Board of Health report explains that babies attending the clinic would be weighed and examined by a clinic physician and that directions would be given to see the family physician when necessary. Other activities after 1919 included hiring one visiting TB nurse, two infant and pre-school nurses, and three part-time infant welfare physicians as well as establishing an infantile paralysis clinic and one venereal disease clinic (Monograph No. 10, 1924).

Existing services The Demonstration also implied an expansion of existing services. The budget for health work in the Framingham schools quadrupled from USD 1,500 to USD 6,000. The health department was also more active in TB work and work on sanitary conditions. The leading industry in Framingham increased its nursing and clinical work. Moreover, there was also increased coordination among voluntary health agencies. Other changes to health services included provision of dental services in the industries and the increased fraction of pasteurized milk available in the community. In addition, the Demonstration published "Health Letters," which provided health education and ran five children's summer camps (Monograph No. 10, 1924).

Spending on health services The spending on health services increased from USD 6,400 in 1916 to USD 50,000 in 1923, with both Demonstration spending and the spending by private

[7] Monograph No. 10 (1924) lists the possible treatments being offered to TB patients. These include TB dispensaries providing home treatment and sanatoria providing institutional treatment. It is well-known that none of these offered an effective cure prior to the invention of streptomycin.

and public agencies contributing to the increase. In per capita terms, this was an increase from USD 0.40 per capita in 1916 to USD 2.75 in 1923 (Monograph No. 10, 1924).[8]

2.2.3 Services provided by the Board of Health

To obtain information on which services were publicly provided before, during, and after the Demonstration, we have read through the annual reports of the Framingham Board of Health for the years 1910-1930. The annual reports of the Board of Health reveal how health spending was distributed within one of the central units in the Framingham Demonstration. Moreover, they contain information on some of the services provided by the Board of Health.

The spending in the years 1913-1916 reveals that there were some developments taking place prior to the Demonstration. In the years 1913-1914, about a quarter of the budget went towards care of "contagious cases." Other significant spending was on inspections of slaughtering and on plumbing. In 1915, a small amount was spent on a TB dispensary, which was founded in that year. This appears to have been the main new activity of the Board of Health prior to the Demonstration. There is no budget printed in 1917, but as of 1918 expenses on laboratory equipment and management are included. From 1920, spending on the Infant Welfare department is included along with the names of two infant welfare nurses, and the reports from 1920-1930 all contain descriptions of or references to infant welfare clinics. In line with the narrative above, the 1920 report mentions that the Board of Health took over the infant welfare work from the Civic League.

The 1924 report (p.255) states that the death of Dr. Bartlett had left Framingham without an expert on TB. His death had led to the suspension of the consultation service (p.259). The 1925 report further states that the consultation service, which focused on TB and was established as a vital part of the Demonstration, had been replaced by a weekly clinic. Moreover, a monthly clinic was operated by the State Board of Health, which also provided services for 13 surrounding municipalities.[9] For the subsequent years, there are only references to one consultation service in the Framingham Board of Health reports.

[8]Shryock (1957) notes that the spending levels per capita at the end of the Demonstration became the desirable public health expenditure levels for other communities.

[9]The Annual Report of the State Board of Health of Massachusetts also mentions this clinic in 1925, but there is no reference to it in later volumes.

2.3 Other health demonstrations

According to Monograph No. 10 (1924), the Demonstration was a forerunner of many demonstrations of similar character. Monograph No. 10 (1924) contains the following list of demonstrations ongoing or planned in 1924: the Hagerstown, Maryland, health demonstration; the Mansfield child health demonstration; the child health demonstrations by the American Child Health Association in Fargo, North Dakota, in Athens, Georgia, in Rutherford County, Tennessee, and on the Pacific Coast; the Detroit tuberculosis demonstration; the Metropolitan Life Insurance Company infant welfare demonstration in Thetford Mines, Quebec; the tuberculosis and health demonstration in Montreal; the expanded tuberculosis program for the Province of Quebec; and the Milbank Memorial Fund health demonstrations in Cattaugarus County, N.Y., in Syracuse, and in New York City. The list illustrates that demonstrations were carried out in different parts of the United States and also spread to Canada.[10]

2.4 Tuberculosis in Massachusetts, 1901-1934

As the Demonstration had a strong focus on TB, we provide a brief description of the disease and how it evolved in Framingham and the rest of Massachusetts. As for TB itself, the disease is caused by the bacteria of the Mycobacterium tuberculosis complex discovered by Robert Koch in 1882. The most common type of TB is pulmonary TB, but TB can also affect other organs.[11]

As shown in Figure 2, pulmonary TB mortality was high in the early 20th century but was declining throughout the period as demonstrated by the mortality rate in Framingham and other municipalities in Massachusetts from 1901 to 1934 (Panel B).[12] The level for Framingham is mostly seen to be lower than the one for the other municipalities. There is no clear break during the period of the Demonstration. In Panel A of Figure 2, we compare Framingham to the seven control municipalities in Massachusetts chosen prior to the Demonstration: Chicopee, Clinton, Fitchburg, Gardner, Marlboro, Milford, and North Adams. The Framingham monographs are silent on why these municipalities were chosen, but they do mention that the control

[10] Health demonstrations were also carried out in France by the Rockefeller Foundation.

[11] Transmission of TB occurs by inhalation of infectious droplet nuclei containing viable bacilli, known as aerosol spread. Mycobacteria-laden droplet nuclei are formed when a patient with active pulmonary TB coughs or sneezes, and they can remain suspended in the air for several hours. After the initial infection with Mycobacterium tuberculosis, the individual either clears the infection, contains a latent TB infection without symptoms but with the bacilli remaining, or develops active TB (Hemskerk et al., 2015).

[12] We use municipalities with a population from 5,000 inhabitants up to 50,000 inhabitants to facilitate a reasonable comparison to Framingham.

municipalities were chosen with the advice of the Massachusetts State Health Department. Relatively lower pulmonary TB death rates become visible a few years prior to 1917 and remain during the Demonstration in Framingham, but then at the end of the 1920s Framingham looked like the control municipalities. In the early 1930s, Framingham experienced some reductions but these were later reversed. Thus, the visual impression is that Framingham had lower pulmonary TB mortality rates than other Massachusetts municipalities, but compared to the control municipalities, the differences are only clearly visible a few years before and during the Demonstration.

[Figure 2 about here]

3 Data

Our data are from the following sources: first, the "Annual report on the vital statistics of Massachusetts" published by the Division of Vital Statistics for the Commonwealth contain cause-of-death statistics and infant mortality for municipalities in Massachusetts over the period 1901-1934. Second, data on TB cases from the years 1906-1934 are digitized from the "Annual Report of the State Board of Health of Massachusetts." From the "Annual report on the vital statistics of Massachusetts" we define two categories of causes of death as controls: 1), Infectious diseases, composed of death by diphteria and croup, whooping cough, bronchitis, pneumonia, measles, erysipelas, and meningitis and 2), non-communicable diseases, composed of deaths by stroke and appendicitis. Finally, we have obtained the following municipality level variables as controls from the full-count US Census microdata in 1910 (Ruggles et al., 2015): share aged 0-14, share aged 45-59, share aged 60 and above, share foreign born, share literate, and average occupational based earning scores.

We obtain a balanced panel of 267 municipalities for pulmonary TB death rates and 92 municipalities when considering municipalities with a population between 5,000 and 50,000 inhabitants in 1915 as used in the analysis. We refer the reader to Figure 1 and Appendix Table A.1 for an overview of exactly which municipalities are included.[13] For infant mortality the data are only available for 47 municipalities and this is reduced to 36 when we impose the restriction on population size. We generally use log rates and the smallest rate larger than zero when

[13]Appendix Figure A.3 plots the total mortality rate for Framingham and the Massachusetts municipalities for comparison.

deaths are equal to zero to obtain a balanced panel. We interpolate to avoid gaps in the data.[14]

Regarding the quality of cause-of-death statistics for Massachusetts, Shryock (1957) observes that "Massachusetts led the way in the United States when, about 1870, it inaugurated the first reliable registration of deaths and their causes." The main features of an adequate system had been adopted and put into operation by 1890. Only one or two percent of the births and deaths that occurred in the state were not registered. Moreover, the returns of the causes of death had attained a high degree of accuracy and reliability according to Gutman (1959). Even so, this does not mean that the data contained no errors. During the period of the Demonstration, some causes of death from bronchitis were mistaken for deaths from pulmonary tuberculosis (Monograph No. 3, 1918: p.15): "It is unquestionable that the work of the Demonstration will lead to better diagnosis of tuberculosis, and an increase in the registered mortality from the disease reasonably might be expected if this factor alone were operative."[15]

4 Empirical strategy

As our aim is to isolate the effect of the Framingham Demonstration on TB and other causes of death, we outline several empirical strategies designed to deal with the fact that the design only has one treated unit as well as other empirical challenges. First, we apply synthetic control estimators (SCE), which are typically applied when only one unit is treated. Specifically, we use the SCE suggested by Abadie and Gardezaval (2003) and Abadie et al. (2010). Yet, this method is known to deal inadequately with transitory shocks in the outcome (Powell, 2018). As the TB mortality series for Framingham is much more volatile than the average TB mortality for the control groups, we also apply a new SCE suggested by Doudchenko and Imbens (2016), which better deals with transitory shocks. Both SCEs compare TB mortality in Framingham to a "synthetic Framingham." Second, we apply a difference-in-differences (DD) framework for comparison. We note that the DD framework requires that Framingham was on a parallel trend to the control group prior to treatment and is not designed to deal with transitory shocks to the outcome.

[14]The difference-in-differences results are robust to dropping missing values due to log transformations of zero deaths instead of this procedure. The synthetic control estimates require balanced panels.

[15]For the case of Denmark, Egedesø et al. (2017) emphasize that methods of diagnosis, such as X-rays and tuberculin tests, were in existence by 1910. The problem of misclassifying TB as bronchitis is mentioned but was mainly an issue in the 1890s according to these authors. In the case of Framingham, the use of X-rays was not common prior to the Demonstration, and as noted above this was uncommon for smaller municipalities. Also, tuberculin testing does not seem to have been common.

The SCE provide a treatment effect in the case of a single treated unit and a number of control units, with pre-treatment and treatment periods being observed for all units (Doudchenko and Imbens, 2016). Consider the following panel data setting with $N+1$ cross-sectional units observed in time periods $t = 1, \ldots, T$. Each of the cross-sectional units in each of the time periods is characterized by a pair of potential outcomes, $Y_{i,t}(0)$ and $Y_{i,t}(1)$, of the control and treatment, respectively, where the causal effects at the unit and time level are given by $\tau_{i,t} = Y_{i,t}(1) - Y_{i,t}(0)$ for $i = 0, 1, \ldots, N$ and $t = 1, \ldots, T$. Units $i = 1, \ldots, N$ are control units, which do not receive the treatment in any of the time periods. Unit 0 receives the control treatment in periods $1, \ldots, T_0$ and the active treatment in periods $t = T_0 + 1, \ldots, T_0 + T_1$. We are interested in the treatment effects of unit 0 denoted by $\tau_{0,t}$. Let treatment received during the active treatment period be the indicator, $W_{i,t}$. Hence, we observe:

$$Y_{i,t}^{obs} = Y_{i,t}(W_{i,t}) = \begin{cases} Y_{i,t}(0) & \text{if } W_{i,t} = 0 \\ Y_{i,t}(1) & \text{if } W_{i,t} = 1 \end{cases} ,$$

with the following data structure:

$$\boldsymbol{Y}^{obs} = \begin{pmatrix} \boldsymbol{Y}_{t,pre}^{obs} & \boldsymbol{Y}_{t,post}^{obs} \\ \boldsymbol{Y}_{c,pre}^{obs} & \boldsymbol{Y}_{c,post}^{obs} \end{pmatrix} = \begin{pmatrix} \boldsymbol{Y}_{t,pre}(0) & \boldsymbol{Y}_{t,post}(1) \\ \boldsymbol{Y}_{c,pre}(0) & \boldsymbol{Y}_{c,post}(0) \end{pmatrix} ,$$

where $\boldsymbol{Y}_{t,pre}^{obs}$ is a row-vector of dimension T_0 with the (t)th entry equal to $Y_{0,t}^{obs}$, $\boldsymbol{Y}_{c,pre}^{obs}$ is a $N \times T_0$ matrix with the (i,t)th entry equal to $Y_{i,c}^{obs}$ and similarly for the post-treatment row vector and matrix, $\boldsymbol{Y}_{t,post}^{obs}$ and $\boldsymbol{Y}_{c,post}^{obs}$.

We are interested in the pair $\boldsymbol{Y}_{t,post}(1)$ and $\boldsymbol{Y}_{t,post}(0)$, but we only observe $\boldsymbol{Y}_{t,post}(1)$. The problem lies in imputing $\boldsymbol{Y}_{t,post}(0)$ using the three different sets of control outcomes $\boldsymbol{Y}_{c,post}(0)$, $\boldsymbol{Y}_{t,pre}(0)$, and $\boldsymbol{Y}_{c,pre}(0)$, and then using the imputed values to estimate the causal effect, $\tau_{0,t}$. Setting aside covariates, Doudchenko and Imbens (2016) show that the estimators we use in this paper share a common linear structure for imputing $\boldsymbol{Y}_{0,post}(0)$, here shown for the post-treatment period, χ:

$$\hat{Y}_{0,\chi}(0) = \mu + \sum_{i=1}^{N} \omega_i \cdot Y_{i,\chi}^{obs} , \tag{1}$$

where the imputed outcome is a linear combination of the control units with intercept μ and weight ω_i for unit i. The methods differ in the way the parameters μ and $\boldsymbol{\omega} = (\omega_1, \ldots, \omega_N)'$ are chosen based on the aforementioned three sets of control outcomes. One strategy might be to estimate $(\mu, \boldsymbol{\omega})$ by regressing $\boldsymbol{Y}_{t,pre}(0)$ on $\boldsymbol{Y}_{c,pre}(0)$, but this is only possible if $T_0 > N+1$, which in many application is not the case. This highlights the need for regularization or restrictions on μ and $\boldsymbol{\omega}$ which the three methods used in this paper achieve in different ways.

The SCM method of Abadie et al. (2010) imposes the following restrictions: no intercept, $\mu = 0$; the weights sum to one, $\sum_{i=1}^{N} \omega_i = 1$; and no-negative weights, $\omega_i \geq 0\,,\ i = 1, \ldots, N$. The weights, $\hat{\boldsymbol{\omega}}^{SCM}$, are chosen such that they minimize the squared distance between the pre-treatment outcome and possibly a set of pre-treatment covariates for the treated unit and the weighted control units.[16]

Doudchenko and Imbens (2016) suggest a method of estimating equation (1) using regularization of the parameters, allowing the researcher to impose fewer restrictions on the parameters. Compared to the SCM of Abadie et al. (2010), we relax the restriction of non-negative weights and that the weights sum to one, but we keep the restriction of no intercept. Imposing that the weights sum to one and no intercept requires that the treated unit is not systematically smaller or larger than the control units. Yet, we allow for more flexibility compared to the SCM by relaxing the restriction that the weights sum to one. Assuming non-negative weights is important for the SCM to regularize estimation results with many control units and could be justified if raw correlations between the treatment and control units are positive but positive raw correlations do not imply that the partial correlations are positive and lifting the restriction may improve out-of-sample prediction; see Doudchenko and Imbens (2016). The weights $\hat{\boldsymbol{\omega}}^{DI}$ are chosen using Elastic net regularization, which implies regressing $\boldsymbol{Y}_{t,pre}(0)$ on $\boldsymbol{Y}_{c,pre}(0)$ including

[16]Specifically, the weights $\hat{\boldsymbol{\omega}}^{SCM}$ are chosen to match the pre-treatment outcomes and a set of pre-treatment covariate matrices $(\boldsymbol{X}_t, \boldsymbol{X}_c)$ of dimensions $M \times N$, by solving:

$$\hat{\boldsymbol{\omega}}(\boldsymbol{V}) = \arg\min_{\boldsymbol{\omega}} \left\{ (\boldsymbol{X}_t - \boldsymbol{\omega}'\boldsymbol{X}_c)' \, \boldsymbol{V} \, (\boldsymbol{X}_t - \boldsymbol{\omega}'\boldsymbol{X}_c) \right\}$$
$$\text{s.t.} \ \sum_{i=1}^{N} \omega_i = 1 \text{ and } \omega_i \geq 0, \, i = 1, \ldots, N\,,$$

where the covariates may include the pre-treatment outcomes. $\boldsymbol{V}$ is an $M \times M$ diagonal weight-matrix chosen to match the lagged outcomes, such that:

$$\hat{\boldsymbol{V}} = \underset{\boldsymbol{V} = \text{diag}(v_1, \ldots, v_M)}{\arg\min} \left\{ \left(\boldsymbol{Y}_{t,pre}^{obs} - \hat{\boldsymbol{\omega}}(\boldsymbol{V})'\boldsymbol{Y}_{c,pre}^{obs}\right)' \left(\boldsymbol{Y}_{t,pre}^{obs} - \hat{\boldsymbol{\omega}}(\boldsymbol{V})'\boldsymbol{Y}_{c,pre}^{obs}\right) \right\}$$
$$\text{s.t.} \ \sum_{m=1}^{M} v_m = 1 \text{ and } v_m \geq 0, \, m = 1, \ldots, M\,.$$

a loss term consisting of the weighted L^1 norm and squared L^2 norm of $\boldsymbol{\omega}^{DI}$.[17] We refer to this SCE as the Elastic net estimator. We follow Doudchenko and Imbens (2016) and do not include additional predictor variables, as they tend to play a minor role in practice.

For inference both Abadie et al. (2010) and Doudchenko and Imbens (2016) suggest using permutation inference. An empirical p-value is obtained from the position of the estimated treatment effect of the actual treated unit within a distribution of counterfactual treatment effects. This distribution is formed by calculating a counter factual treatment effect for each control city.

The Elastic net estimator has the advantage of imposing a more flexible set of restrictions than the SCM and the DD estimators. The fewer imposed restrictions on the weights compared to the SCM and DD estimators will generally lead to a better pre-treatment match between the synthetic unit and the treated unit, a match on which the consistency properties of the SCEs are derived (Abadie et al., 2010).

Finally, we apply a DD framework, comparing TB in Framingham to other municipalities before and after the Demonstration started. Compared to the SCEs the DD estimator imposes the restrictions of equal, non-negative weights that sum to one for the control municipalities. The estimation equation takes the following form:

$$Y_{i,t} = \beta Demo_{i,t} + \phi_i + \phi_t + \varepsilon_{i,t} \,, \tag{3}$$

where $Y_{i,t}$ is the dependent variable in municipality i in year t, $Demo_{i,t}$ is an indicator switching on in 1917 for Framingham, and ϕ_i and ϕ_t are municipality and year fixed effects respectively. The standard errors, $\varepsilon_{i,t}$, are clustered at the municipality level in order to take possible serial correlation into account. However, this approach is problematic as our framework includes only one treated unit, Framingham (Conley and Taber, 2011). For this reason, we will rely on empirical p-values as suggested by Conley and Taber (2011) akin to the inference method suggested by Abadie et al. (2010) and Doudchenko and Imbens (2016) outlined above.

[17] Specifically, let $\boldsymbol{\omega}^{DI}$ be the weight vector that minimizes:

$$\hat{\boldsymbol{\omega}}^{DI}(\alpha, \lambda) = \underset{\boldsymbol{\omega}^{DI}}{\arg\min} \left\{ \|\boldsymbol{Y}^{obs}_{t,pre} - \boldsymbol{\omega}^{DI'} \boldsymbol{Y}^{obs}_{c,pre}\|_2^2 + \lambda \left(\frac{1-\alpha}{2} \|\boldsymbol{\omega}^{DI}\|_2^2 + \alpha \|\boldsymbol{\omega}^{DI}\|_1 \right) \right\} \,, \tag{2}$$

where α and λ are tuning parameters, and $\|z\|_p$ represents the L^p norm of z. The estimation equation is an Elastic net regression, including both a Ridge, $\|\boldsymbol{\omega}^{DI}\|_2^2$, and a Lasso, $\|\boldsymbol{\omega}^{DI}\|_1$, regularization term. The tuning parameters are chosen by k-fold cross validation to be the set that minimizes the cross validation error; see Doudchenko and Imbens (2016).

The inference problem of the DD estimator can be solved by permutation inference (Conley and Taber, 2011). Yet, the assumption of parallel trends, which we test by event studies, can be violated if the single treated unit differs substantially from the control units, and the DD estimator is not well suited to handle transitory shocks. The SCE strategies are more likely to improve the match on both the trend and volatility in the pre-treatment period.

5 Results

5.1 The original results of the Framingham monographs

The final publication in the Framingham series of monographs (Monograph No. 10, 1924) provides an overview of the most important findings of the Demonstration. This includes an evaluation of TB mortality in Framingham, compared to the original seven Massachusetts control municipalities: Chicopee, Clinton, Fitchburg, Gardner, Marlborough, Milford, and North Adams. To evaluate the original findings, we start by investigating the similarity between Framingham and the original control municipalities. Table 1 reports balancing tests comparing TB mortality and TB case rates, infectious and non-communicable disease mortality rates, population size, share aged 0-14, 45-59, and 60 and above, share literate and foreign born, and income per worker (occupational earnings score). The variables are measured for 1910, as most are derived using Census data in 1910. Investigating the table, we observe that in particular the population size and structure appear different in Framingham compared to the average of the control municipalities. Also, the TB case rate and the share of literate residents are smaller in Framingham.[18]

[Table 1 about here]

Data on TB mortality before and after the Demonstration from the original evaluation makes it possible to calculate DD estimates. The original TB mortality rates in Framingham and the MA control municipalities are shown in columns (1) and (2) of Table 2.[19] We calculate the DD

[18]With eight observations formal tests of differences in means are likely not valid.

[19]It is worthwhile to notice that the TB mortality rates for Framingham, reported in the summary report, are based on whether the deceased had any contact with the town of Framingham within a certain time period, which then includes both residents and non-residents. It was not possible to do a similar detailed correction for the control municipalities, although an effort was made to correct the mortality on a residence basis (see Monograph No. 10, 1924). Our analysis is based on municipality tabulated mortality data, and such adjustments are, therefore, impossible.

estimates in column (3) of Table 2 by obtaining the difference in TB mortality rates between Framingham and the control municipalities for the years 1917, ..., 1923 and then subtract the corresponding difference in average TB mortality rate during the pre-Demonstration years 1906 to 1917. We report the effect in percent in column (4). The estimates show that the Demonstration reduced the TB mortality rate during the entire Demonstration period with an average effect of 36 percent. Yet, there are reasons to believe that this naive DD estimate should not be given a causal interpretation which is why we focus on the methods outlined above.

[Table 2 about here]

5.2 Synthetic control results

Figure 2 illustrates why we turn to Synthetic Control Estimators. In Panel A, we compare the development of the TB mortality rate in Framingham to the seven original control municipalities. Both series exhibit a downward trend prior to the beginning of the Demonstration. Yet, the TB rate in the control municipalities appears to be trending slightly upwards in the years immediately before the Demonstration. In panel B, we compare the TB mortality rate in Framingham to the average rate in the extended sample of 92 municipalities. Again, we observe a declining trend in the TB mortality with a plateau before the Demonstration. In both Panels A and B, we observe that the TB mortality rate exhibits high volatility in Framingham. Together with non-parallel trends, higher volatility could obscure the potential effect of the Demonstration in a naive DD estimate.

To implement the SCM, we include predictors to establish which municipalities receive weight in the synthetic control. These include the mean of the dependent variable over the pre-treatment period and always the mean over the pre-treatment period of the log death rates of: TB, infectious diseases, non-infectious diseases, and the log TB case rate. We also include the following variables from the 1910 census: log population, share aged 0-14, 45-59, and 60 above, share of foreign born, share literate, and log occupational earnings score per worker, which provides a good pre-treatment fit.

Figure 3 depicts the estimates from the SCM strategy. We also note that the weights assigned to municipalities in the donor pool are reported in Appendix Table A.2, and Table A.3 reports the balance between the synthetic control and the treated unit. The SCM inherently assigns weights to few units, and interestingly none of these units are the original control municipalities. The weights assigned to the nine municipalities are: Franklin (0.132), Hingham (0.030), Ipswich (0.063), Monson (0.075), Montague (0.058), Orange (0.213), Swampscott (0.039), Wareham (0.223), and Wellesley (0.167) with the weights reported in parentheses. The remaining municipalities are assigned zero weight. Considering next the balance between the synthetic unit and Framingham in Table A.3, we observe that the synthetic control unit resembles Framingham along most of the dimensions, although Framingham appears to have a larger population and a smaller share aged 0-14. Turning to the synthetic control estimates in Figure 3, the synthetic unit matches the TB mortality rate in Framingham quite well, though not perfectly, in the pre-Demonstration period from 1901 to 1916 in Panel A. Panel B shows the effect of the Demonstration as the difference between the synthetic unit and Framingham represented by a solid line. Panel B also shows Placebo results for the rest of the sample, which are displayed as shaded lines. After the Demonstration started in 1917, the results suggest that there was little effect of the Demonstration. Thus, the SCM estimation cannot confirm the negative effect on TB mortality found in the original study. In fact, the Demonstration had no statistically significant effect according to the empirical p-values reported in Panel C.

[Figure 3 about here]

The fact that the SCM does not find an effect of the Demonstration can be an artifact of the highly volatile nature of TB mortality and difficulties in matching the pre-Demonstration mortality changes. Although the match between Framingham and the synthetic unit in Figure 3 is indeed improved compared to the match between the MA municipalities and Framingham in Panel B of Figure 2, the volatility is not captured perfectly. Theoretically, the Elastic net SCE of Doudchenko and Imbens (2016), described in section 4, can provide a better pre-treatment match between the treated and the synthetic unit with fewer imposed restrictions. This is evident in Figure 4 which presents the results of using the Elastic net regressions. In Panel A, we observe a much better pre-treatment match between the synthetic unit and Framingham, but as is apparent it does not change the conclusion. Judging by both the point estimates of the effect displayed in Panel B and the statistical significance in Panel C, we fail to find discernible effects of the Demonstration. The Elastic net regression assigns positive weights to 32 municipalities and negative weights to 12 municipalities; see Appendix Table A.4. 11 municipalities receive weights of 0.05 or larger in absolute magnitude: Rockland (0.122), Walpole (0.094), Newburyport (0.068), Hudson (0.065), Great Barrington (−0.055), Braintree (−0.055), Athol (0.055), Wakefield (0.054), Concord (−0.051), Easthampton (0.050), and Abington (0.050).

In Appendix Figures A.8 and A.9, we consider a sample that excludes municipalities within 50 kilometers of Framingham to address concerns about spillovers being important for our conclusions. For both SCEs, we still do not find that the Demonstration reduced TB mortality in Framingham.

[Figure 4 about here]

As described in Section 2, the first year of the Demonstration was devoted to primary research activities, and a sickness survey of the population was carried out. Along with the establishment of the consultation service, this increased the number of known TB cases according to Monograph No. 10 (1924). Hence, we now turn to investigating the effect of the Demonstration on the number of active TB cases per year, which we expect to increase in the initial years. The development of the log TB case rate in Framingham and the MA sample is depicted in Appendix Figure A.1. Figures 5 and 6 show SCM and Elastic net estimation results on the log TB mortality case rate, respectively. We use the same predictors for the case rate in the SCM estimation as we did for the TB mortality rate. The SCM estimator achieves a good balance for the predictors and assigns weight to four municipalities; see Appendix Tables A.5 and A.6 for the weights and balance of the predictors. The data on TB cases are available only from 1906, and the SCM estimator achieves a somewhat poor fit in the pre-treatment period; see Panels A and B of Figure 5. Inspecting the path of Framingham and the synthetic unit in the first years of the Demonstration in Panel A, we observe what could be considered a spike in TB cases in the initial year, consistent with the narrative in the monographs. However, the volatility of the effect in Panel B before and after the start of the Demonstration likely favors the null hypothesis of no effect, which is also the conclusion to be drawn from the empirical p-values reported in Panel C. The Elastic net estimation on the log TB mortality case rate in Figure 6 performs much better in matching the synthetic unit and Framingham in the pre-Demonstration period. The Elastic net estimator uses 26 of the municipalities to construct the synthetic unit with a positive weight placed on 23 of the municipalities and a negative weight placed on three; see Appendix Table A.7. Investigating Panels A and B of Figure 6 reveals a spike in the initial year of the Demonstration and a spike in 1924-25, the two years after the end of the Demonstration. Panel C shows that only the initial spike in 1917 is significant at the 10 percent level, although the spike in 1925 is close to being significant at this level. These findings are consistent with the narrative in the monographs, where the initial health survey uncovered a larger rate of TB in the population of Framingham. The spike in 1924-25 could be consistent with the Demonstration ceasing its activities in 1923, but the p-values and the lack of evidence of a change in the TB mortality after the Demonstration had ended casts doubt upon this interpretation.

[Figure 5 about here]

[Figure 6 about here]

While the Demonstration had a particular focus on controlling TB, the public health activities carried out by the Demonstration might have improved the general health environment in Framingham as well. Along with the TB activities of the Demonstration infant welfare services with home visiting nurses were expanded. Monograph No. 10 (1924) highlights that the infant mortality rate was down by 40 percent compared to 1916 and that the crude death rate was down by 9 percent in the last two years of the Demonstration compared to 1907 to 1916. To investigate this further, we evaluate the effect of the Demonstration on infant mortality and total mortality rate. Unfortunately, in both cases data are only available for 38 municipalities; e.g. Appendix Figures A.2 and A.3 for a depiction of development of infant mortality rate and the total mortality rate in Framingham and the municipalities in the MA sample, respectively. We note that both trend downwards and that the total mortality rate is less volatile than, for example, the TB mortality rate.[20]

First, we consider the results for infant mortality in Figures 7 and 8, which present the SCM and Elastic net results on the log infant mortality rate. The SCM includes the same predictors as previously as well as the log infant mortality rate. The weights assigned to control municipalities and the balance of the predictor variables can be found in Appendix Tables A.8 and A.9. The estimator achieves a good balance of the predictors but performs badly in the pre-treatment period with a somewhat poor fit between the synthetic unit and Framingham, and we cannot establish an effect of the Demonstration on the log infant mortality rate with the SCM. Turning to the Elastic net results, the pre-treatment match between the synthetic unit and Framingham performs much better, but despite a more convincing fit we still cannot establish an effect on infant mortality. For the weights assigned to the control municipalities in Elastic net estimation, see Appendix Table A.10.

[20] The mortality rates in Framingham and the MA municipalities sample trend nicely together, both with a spike in 1918 due to the Spanish Flu.

[Figure 7 about here]

[Figure 8 about here]

We next investigate the effects on the total mortality rate. Figures 9 and 10 show the SCE and Elastic net results, respectively. Like in the case of infant mortality, the SCE do not achieve the best pre-treatment match. Two years, 1920 and 1921, display a significantly positive effect at the 10 percent level, but the poor pre-treatment match of the synthetic unit and Framingham calls the validity of the inference into question. For the weights assigned and the balance of the pre-treatment predictors, see Appendix Tables A.11 and A.12.

The Elastic net estimate on the log mortality rate in Figure 10 achieves a better match between the synthetic unit and Framingham in the pre-treatment period. The weights assigned to the control municipalities by the Elastic net estimator can be found in Appendix Table A.13. Focusing on the path of mortality in Framingham and the synthetic unit in Panel A and the net effect in Panel B, we see that the spike in mortality in 1918 around the Spanish Flu, is larger in Framingham than in the control municipalities and is significant at the 10 percent level. Apart from the jump in mortality in 1918, the mortality in Framingham and the synthetic unit trend together in the Demonstration period, without us being able to establish an effect. However, the rates diverge significantly with a fall in mortality in Framingham from 1930 and onwards. We are hesitant to attribute this fall in mortality to an effect of the Demonstration, as the last year of treatment was in 1924.

[Figure 9 about here]

[Figure 10 about here]

5.3 Difference-in-differences results

Next, we present DD results of a comparison to the results of the SCE. We start by presenting balance tests between Framingham and the MA municipalities and a number of event studies.

Table 3 presents balance tests comparing Framingham and the MA municipalities across the same variables as used in the balance tests of the original control municipalities in Table 1. Compared to the latter, formal statistical testing of differences in means is possible with a larger sample of 92 observations. We do not observe a difference in means across the TB mortality rate, income per worker, and share of foreign born between Framingham and the average of the MA municipalities. However, we find significant differences in the disease environment, TB case rate, share literate, and the population structure, leading us to conclude that there are differences between Framingham and the control municipalities.

[Table 3 about here]

Now, we turn to event studies on log TB mortality rate, log TB case rate, log infant mortality rate, and log total mortality rate depicted in Appendix Figures A.4 to A.7. The event-studies enable us to assess the validity of the parallel-trends assumption and how we should interpret the DD results.

From the event study on TB mortality, we observe that the estimates are volatile both before and after the start of the Demonstration. There is no particular trend or jump in the estimates indicating an effect of the Demonstration. Perhaps a rise in the TB mortality after the end of the Demonstration in 1923, but the coefficients are reverting to around zero. From the event study on TB cases, we observe less volatility in the pre-treatment period with a jump in the case rate in 1917 when the Demonstration started and in 1925, two years after the Demonstration ended. In the last period, the coefficients are estimated to be around zero. In the event study on infant mortality, we observe a high volatility of the estimates in the period of investigation. There is an increasing trend in the coefficients on the infant mortality rate throughout the sample period. Lastly, the event study on total mortality shows a positive trend in the estimated coefficients prior to the Demonstration, a large and negative estimate in the first period of the Demonstration, which reverts to a zero estimate in 1918. The event studies and the balance tests suggest that DD estimation will be neither appropriate nor informative with the type of estimation problem that we face.

[Table 4 about here]

We next present DD results in Panel A of Table 4 of estimating equation (3) on the log TB mortality rate, log TB case rate, log infant mortality rate, and log total mortality rate. In Panel B we present estimation results with the same dependent variables, but with the intervention indicator split into two – one indicating Framingham during the Demonstration (1917-1923), another indicating Framingham after the Demonstration (1924-1934). In brackets we show empirical p-values from permutation inference. Clustered standard errors are reported in parentheses, but we emphasize that these are not valid; see the discussion in Section 4. Hence, inference should be done using only the empirical p-values.

The results on TB mortality shown in column (1) in Table 4 display no significant effect of the Demonstration in neither Panel A nor B. Although not close to being statistical significant, the point estimate of the effect during the Demonstration in Panel B shows a 13.5 percent decline in TB. In comparison, the numbers in the Framingham monographs suggested an effect of 36 percent.

The estimates on TB cases in column (2) are large but statistically insignificant. Panel A shows a increase of 26 percent in the case rate, and Panel B shows an increase of 25 percent during the Demonstration and an increase of 8.5 percent after. This is consistent with the results of the SCEs showing a spike in the case rate in the first year of the Demonstration.

Column (3) presents the results on infant mortality. The point estimates are large but not significant. In Panel A, the point estimate suggests that the Demonstration increased the infant mortality rate by 40.6 percent and with a p-value of 10.5, which is borderline significant. In Panel B, the estimates show an increase of 18.2 percent in the Demonstration period, with a very large increase of 44.8 percent after the Demonstration ended. In the event study of the infant mortality rate, we observed positively trending estimates, which potentially explain these results.

Finally, in column (4) we also find a statistically, insignificant effect on the total mortality rate. The point estimate in Panel A suggests an increase of 6.8 percent in the mortality rate, and Panel B shows an increase of 10.7 percent during the Demonstration, and 3.5 percent after. Thus, the DD estimates cannot establish any effects of the Demonstration on total mortality.

6 Conclusion

This research has challenged the conventional view that the Framingham Demonstration succeeded in reducing TB mortality. Contrary, to the beliefs of the National Association and historical accounts, the systematic evidence we offer suggests that the Demonstration cannot be leveraged as evidence for the success of pre-antibiotic era health policies.

The implication of these findings is that the Framingham Demonstration was not as successful as believed by the National Association and would tend to support McKeown's (1976) contention that public health policy was not a decisive factor in the reduction of TB mortality. Yet, Hollingsworth (2014) presents evidence that sanatoria may have played some role for TB mortality in North Carolina through health education and isolation, and Egedesø et al. (2017)

show that personalized information on how to avoid spreading TB reduced mortality in Danish cities. What is true about the Framingham Demonstration is that it relied very much on general health education through the health letters, and none of the monographs emphasize a role for more personalized information for the TB patients. This could be one reason that the Demonstration was not as effective as hitherto believed.

The bottom line for our knowledge on the effectiveness of efforts to reduce TB in the past is that this seems to have depended on the intervention. We leave it for future research to expand our knowledge on which other past interventions were effective.

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Tables

Table 1: Balance: Framingham and the original control municipalities

	Original control municipalities			Framingham	
	Obs.	Mean	Std. Dev.	Obs.	Mean
TB mortality rate	7	0.911	0.0951	1	1.004
TB case rate	7	1.363	0.990	1	1.004
Infectious disease rate	7	2.654	1.164	1	2.780
Non-communicable disease rate	7	1.022	0.415	1	1.236
Population	7	20,093	9,171	1	12,948
Share aged 0-14	7	0.294	0.0612	1	0.182
Share aged 45-59	7	0.132	0.0349	1	0.169
Share aged 60-	7	0.0804	0.0345	1	0.0843
Share literate	7	0.933	0.0224	1	0.857
Share foreign born	7	0.306	0.0576	1	0.300
Earnings score	7	667.2	68.59	1	686.4

Note: This table reports balancing tests where we compare the original control municipalities to Framingham. The variables compared across are: TB mortality rate; TB case rate; infectious disease moratlity rate excl. TB; non-communicable disease mortality rate; population size; share aged 0-14; share aged 45-59; share aged 60 or above; share literate; share foreign born; and income per worker using earnings score. All variables are measured in 1910.

Table 2: The original results of the Framingham Demonstration 1917-1923, and DD estimates

	Framingham TB rate	Control Munici-palities TB rate	DD estimates	DD estimates in percent
	(1)	(2)	(3)	(4)
Pre-Demo., 1907-1916	121.0	125.9		
1917	97.5	129.4	−27.0	−22.3%
1918	84.7	146.7	−57.1	−47.2%
1919	90.2	128.8	−33.7	−27.9%
1920	64.5	133.7	−64.3	−53.1%
1921	40.1	103.8	−58.8	−48.6%
1922	67.2	92.3	−20.2	−16.7%
1923	38.2	84.6	−41.5	−34.3%
Demo. period, 1917-1923	68.9	117.0	−43.2	−35.7%

Note: This table reports the original findings from Framingham mongraph No. 10. The TB mortality rate of Framingham is shown in column (1), the TB mortality rate of the Massachusetts control municipalities is shown in column (2), DD estimates are shown in column (3) based on the numbers in columns (1) and (2) by our calculations, and the DD estimates in percent are shown in column (4).

Table 3: Balance: Framingham and the extended MA sample

	MA municipalities			Framingham		t-test
	Obs.	Mean	Std. Dev.	Obs.	Mean	p-value
TB mortality rate	91	1.028	0.507	1	1.004	0.659
TB case rate	91	0.834	0.791	1	1.004	0.045
Infectious disease rate	91	2.261	0.950	1	2.780	0.000
Non-communicable disease rate	91	1.043	0.484	1	1.236	0.000
Population	91	12,851	10,428	1	12,948	0.930
Share aged 0-14	91	0.266	0.0754	1	0.182	0.000
Share aged 45-59	91	0.150	0.0458	1	0.169	0.000
Share aged 60-	91	0.0802	0.0432	1	0.0843	0.363
Share literate	91	0.948	0.0514	1	0.857	0.000
Share foreign born	91	0.282	0.116	1	0.300	0.148
Earnings score	91	673.4	153.3	1	686.4	0.423

Note: This table reports balancing tests where we compare the Massachusetts municipalities with a population of between 5,000 and 50,000 inhabitants to Framingham. The variables compared across are: TB mortality rate; TB case rate; infectious disease mortality rate excluding TB; non-communicalble disease mortality rate; population size; share aged 0-14; share aged 45-59; share aged 60 or above; share literate; share foreign born; and income per worker using earnings score. In the last column we report p-values from tests of differences in means between the MA municipalities and Framingham. They are obtained by regressing the variable in question on a constant and a Framingham indicator using robust inference. All variables are measured in 1910.

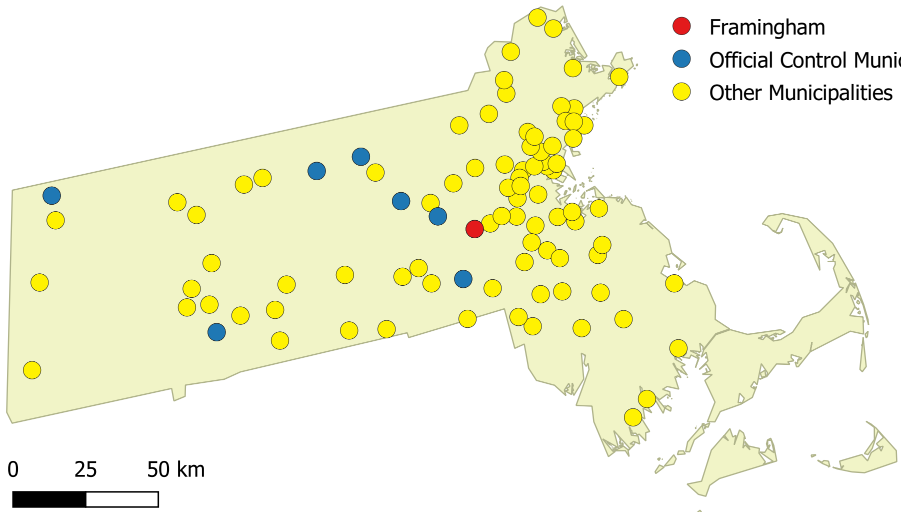
Table 4: DD estimation results

Panel A				
	(1)	(2)	(3)	(4)
	log TB rate	log TB case rate	log IMR	log CDR
$Framingham_{i,t\geq 1917}$	0.0551	0.260	0.406	0.0675
	[0.696]	[0.522]	[0.105]	[0.632]
	(0.249)	(0.000)	(0.000)	(0.017)
R-squared	0.640	0.522	0.834	0.792
Panel B				
	(1)	(2)	(3)	(4)
	log TB rate	log TB case rate	log IMR	log CDR
$Framingham_{i,1917\geq t\geq 1923}$	−0.135	0.250	0.182	0.107
	[0.717]	[0.500]	[0.263]	[0.158]
	(0.000)	(0.000)	(0.000)	(0.000)
$Framingham_{i,t\geq 1924}$	0.0684	0.0824	0.448	0.0353
	[0.696]	[0.783]	[0.158]	[0.895]
	(0.186)	(0.116)	(0.000)	(0.227)
R-squared	0.640	0.521	0.834	0.792
Municipalities	92	92	38	38
Years	1901-1934	1906-1934	1901-1934	1901-1934
Observations	3,128	2,668	1,292	1,292
Municipality & Year FE	Yes	Yes	Yes	Yes

Note: The table reports least squares estimates. In Panels A and B the dependent variable is log TB mortality per 1,000 in column (1); log TB cases per 1,000 in column (2); log infant mortality per 1,000 in column (3); and log total mortality per 1,000 in column (4). The panel is the Massachusetts municipalities with a population of between 5,000 and 50,000 inhabitants. In Panel A the causes of death are regressed on an indicator for Framingham turning on when the Demonstration starts in 1923. In Panel B the causes of death are regressed on an indicator for Framingham turned on in the Demonstration years 1917 to 1923 and an indicator for Framingham turned on after the Demonstration ended in 1924. All regressions include municipality and year fixed effects. P-values based upon permutation inference suggested by Conley and Taber (2011) are reported in brackets. Robust standard errors clustered at the municipality level are in parentheses.

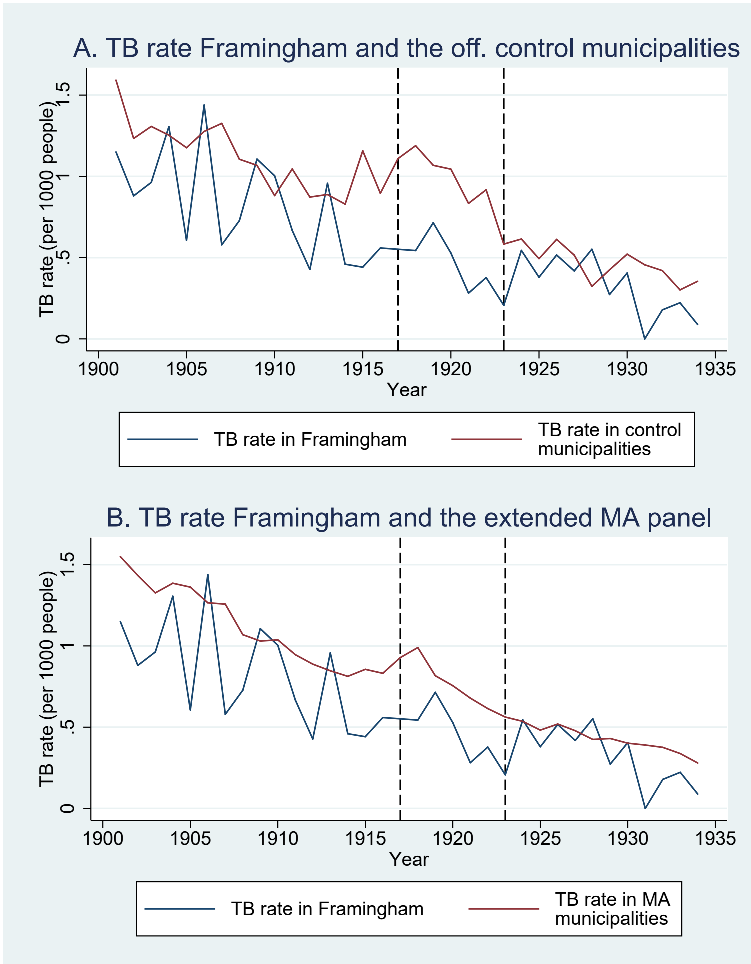
Figures

Figure 1: Map of the municipalities in the Massachusetts sample



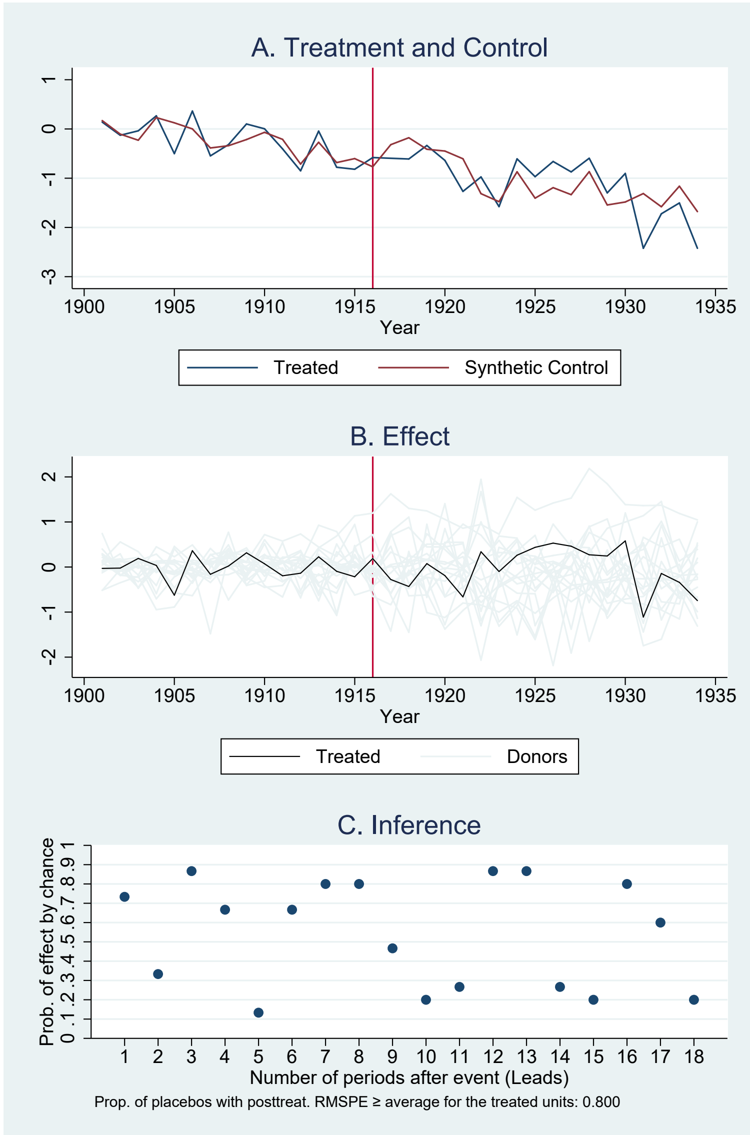
Note: The map plots the position of Framingham; the original control municipalities from the Framingham monographs; and the other municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants.

Figure 2: TB mortality per 1,000 in Framingham, the original control municipalities, and the extended MA panel



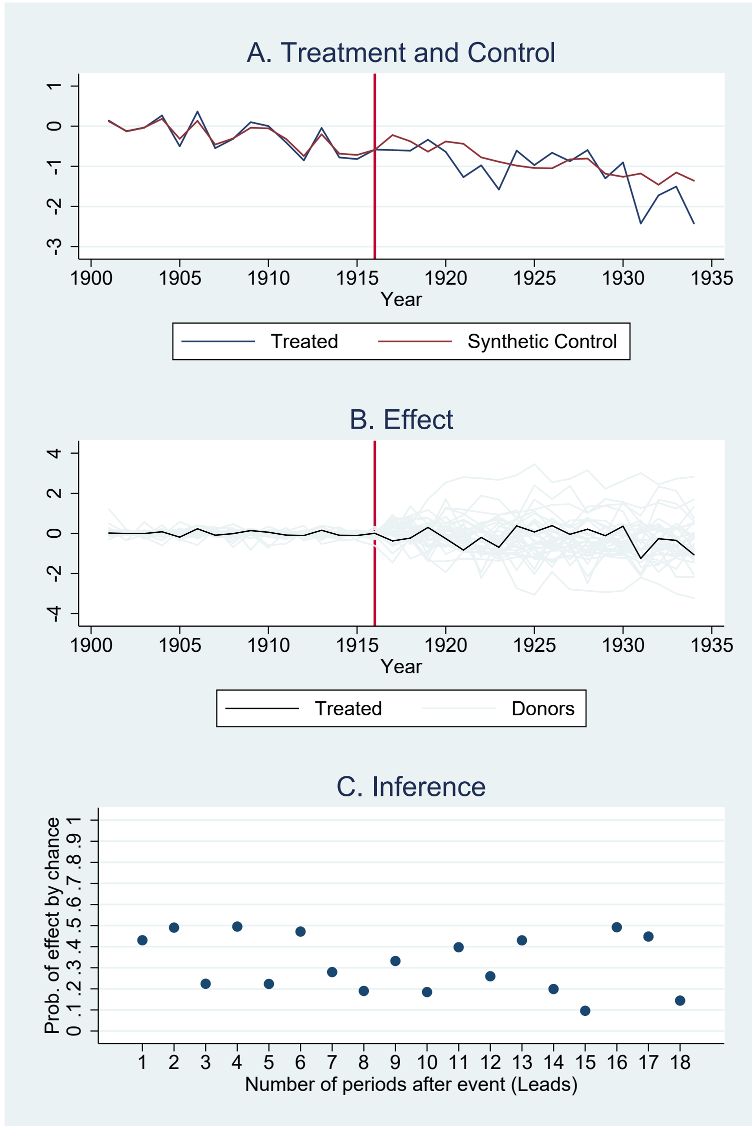
Note: The graph plots the development of the aggregate TB mortality per 1,000 in Framingham compared to the TB rate in the original control municipalities in Panel A, and compared to the TB rate of the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants in Panel B. The vertical dotted lines enclose the Demonstration period from 1917 to 1923.

Figure 3: Synthetic control results on log TB mortality per 1,000



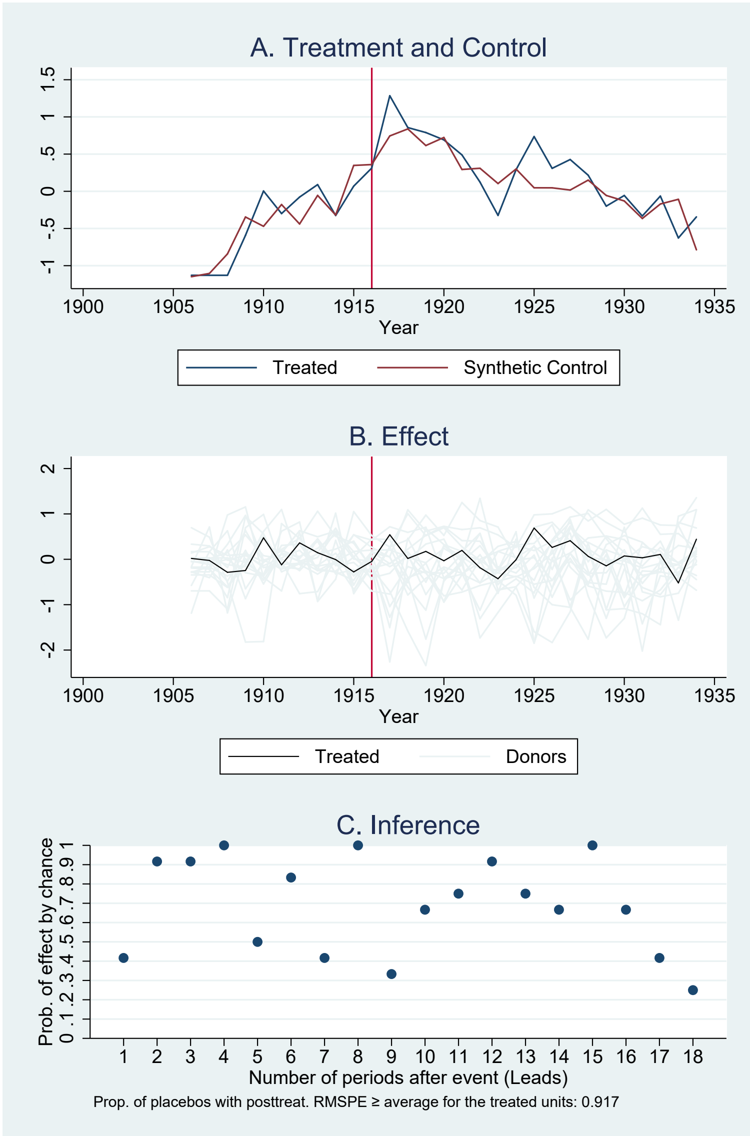
Note: This figure shows the estimation results of the SCM on log TB mortality per 1,000, where the predictors of the log TB rate in the pre-Demonstration period (1901-1916) are: log TB mortality rate (1901-1916), log TB case rate (1906-1916), log infectious disease rate (1901-1916), log non-infectious disease rate (1901-1916), log population (1901-1916), share aged 0-14 (1910), share aged 45-59 (1910), share aged 60 and above (1910), share foreign born (1910), share literate (1910), and log occupational earnings score per worker (1910). The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log TB mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. Placebo municipalities in the pool for inference are excluded if their pre-treatment RMSPE is greater than two times the pre-treatment RMSPE of the synthetic Framingham. The vertical red line indicate the start of the Demonstration in 1917. See Appendix Tables A.2 and A.3 for the weights assigned to the municipalities forming the synthetic control and the balance between the synthetic control and the treated unit before 1917, respectively.

Figure 4: Elastic net results on log TB mortality per 1,000



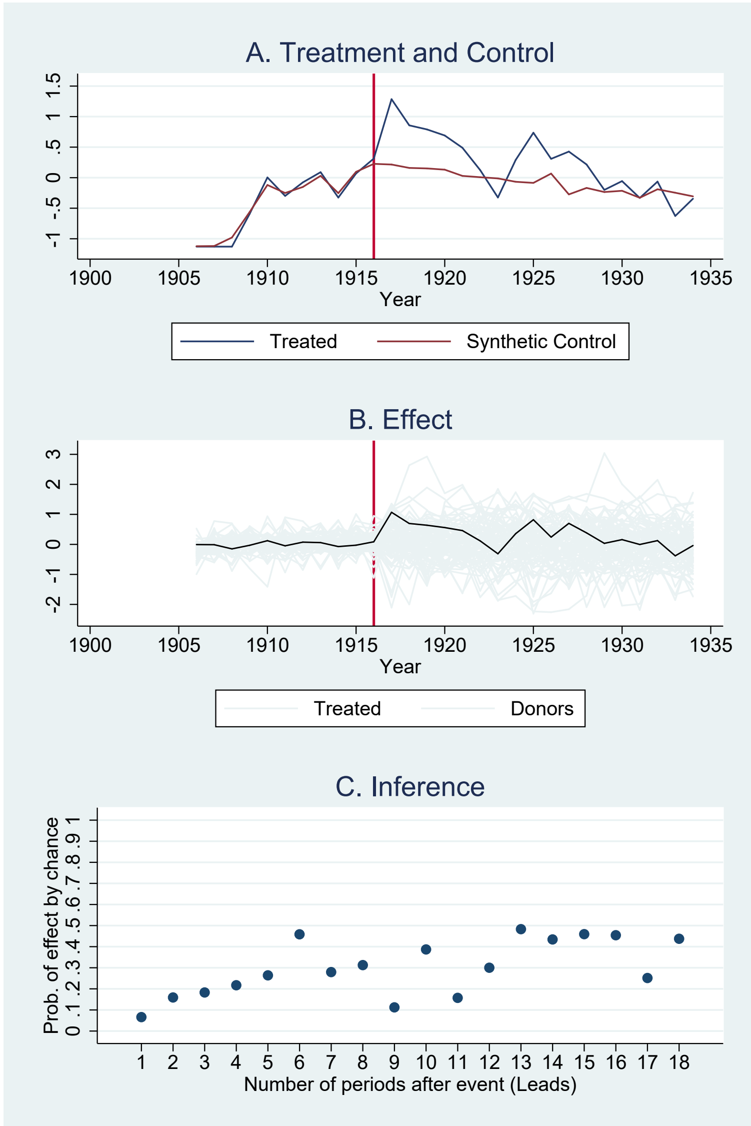
Note: This figure shows the results of the Elastic net estimation on log TB mortality per 1,000. The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log TB mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. The vertical red line indicates the start of the Demonstration in 1917. See Appendix Table A.4 for the weights assigned to the municipalities forming the synthetic control.

Figure 5: Synthetic control results on log TB cases per 1,000



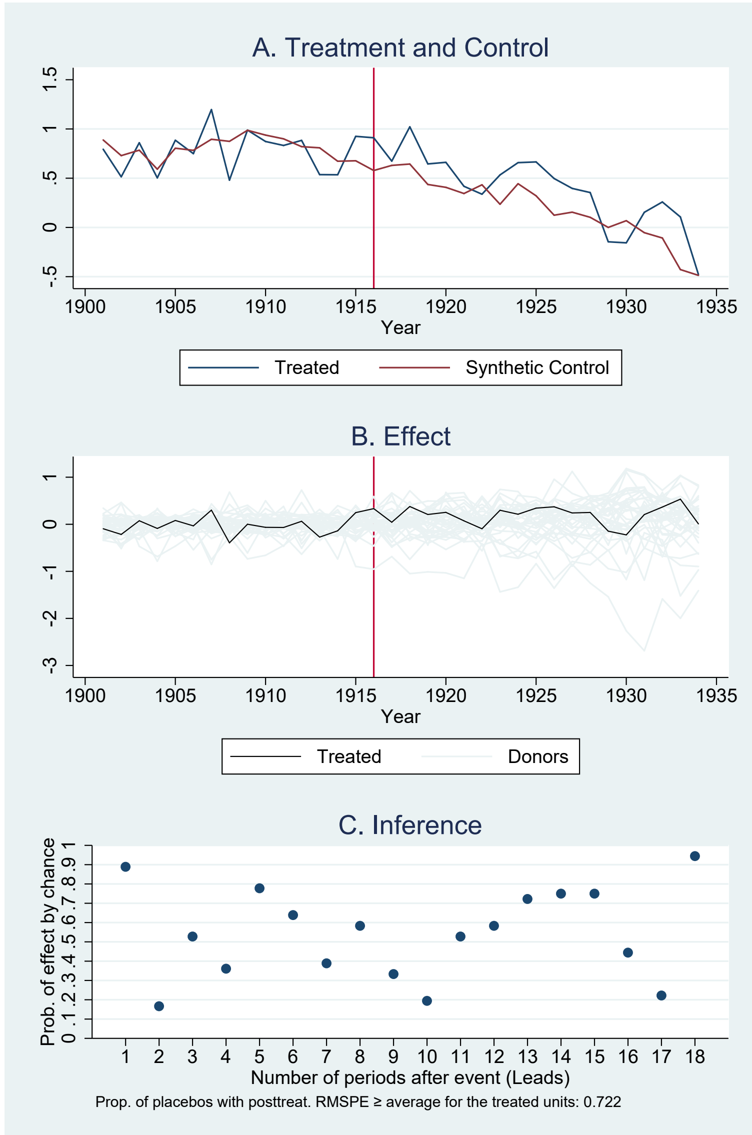
Note: This figure shows the estimation results of the SCM on log TB cases per 1,000, where the predictors of the log TB cases per 1,000 in the pre-Demonstration period (1906-1916) are: log TB case rate (1906-1916), log TB mortality rate (1906-1916), log infectious disease rate (1906-1916), log non-infectious disease rate (1906-1916), log population (1906-1916), share aged 0-14 (1910), share aged 45-59 (1910), share aged 60 and above (1910), share foreign born (1910), share literate (1910), and log occupational earnings score per worker (1910). The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log TB case rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. Placebo municipalities in the pool for inference are excluded if their pre-treatment RMSPE is greater than two times the pre-treatment RMSPE of the synthetic Framingham. The vertical red line indicate the start of the Demonstration in 1917. See Appendix Tables A.5 and A.6 for the weights assigned to the municipalities forming the synthetic control and the balance between the synthetic control and the treated unit before 1917, respectively.

Figure 6: Elastic net results on log TB cases per 1,000



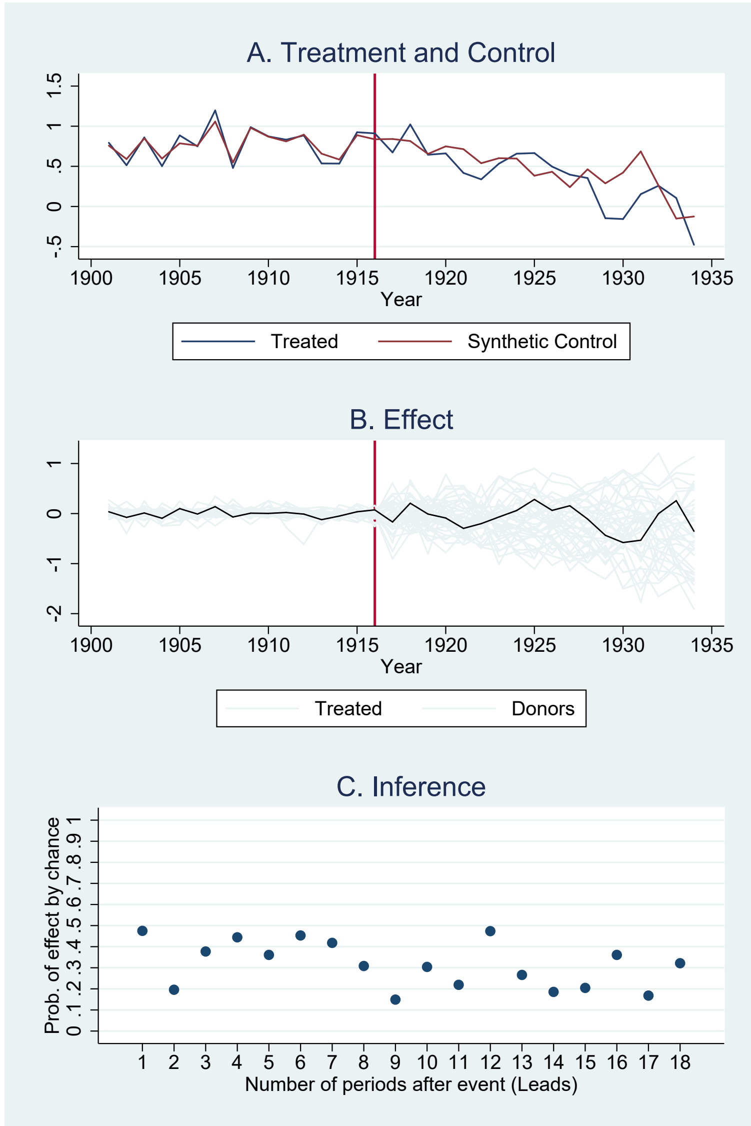
Note: This figure shows the results of the Elastic net estimation on log TB cases per 1,000. The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log TB case rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. The vertical red line indicate the start of the Demonstration in 1917. Three control municipalities are excluded from the analysis, as there is not enough varaition in their TB case rate to derive the tuning parameters from cross validation. See Appendix Table A.7 for the excluded municipalities and the weights assigned to the municipalities forming the synthetic control.

Figure 7: Synthetic control results on log infant mortality per 1,000



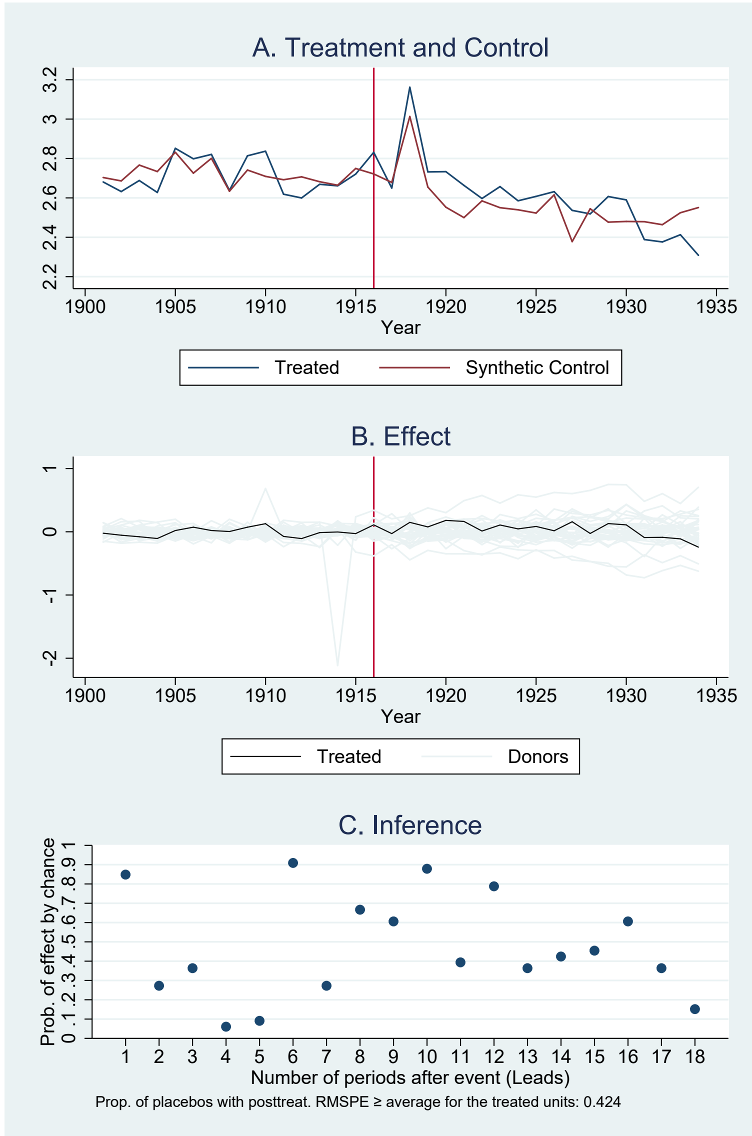
Note: This figure shows the estimation results of the SCM on log infant mortality per 1,000, where the predictors of the log infant mortality rate in the pre-Demonstration period (1901-1916) are: log infant mortality rate (1901-1916), log TB mortality rate (1901-1916), log TB case rate (1906-1916), log infectious disease rate (1901-1916), log non-infectious disease rate (1901-1916), log population (1901-1916), share aged 0-14 (1910), share aged 45-59 (1910), share aged 60 and above (1910), share foreign born (1910), share literate (1910), and log occupational earnings score per worker (1910). The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log infant mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect and the resulting (empirical) p-values are displayed in Panels B and C, respectively. Placebo municipalities in the pool for inference are excluded if their pre-treatment RMSPE is greater than two times the pre-treatment RMSPE of the synthetic Framingham. The vertical red line indicates the start of the Demonstration in 1917. See Appendix Tables A.8 and A.9 for the weights assigned to the municipalities forming the synthetic control and the balance between the synthetic control and the treated unit before 1917, respectively.

Figure 8: Elastic net results on log infant mortality per 1,000



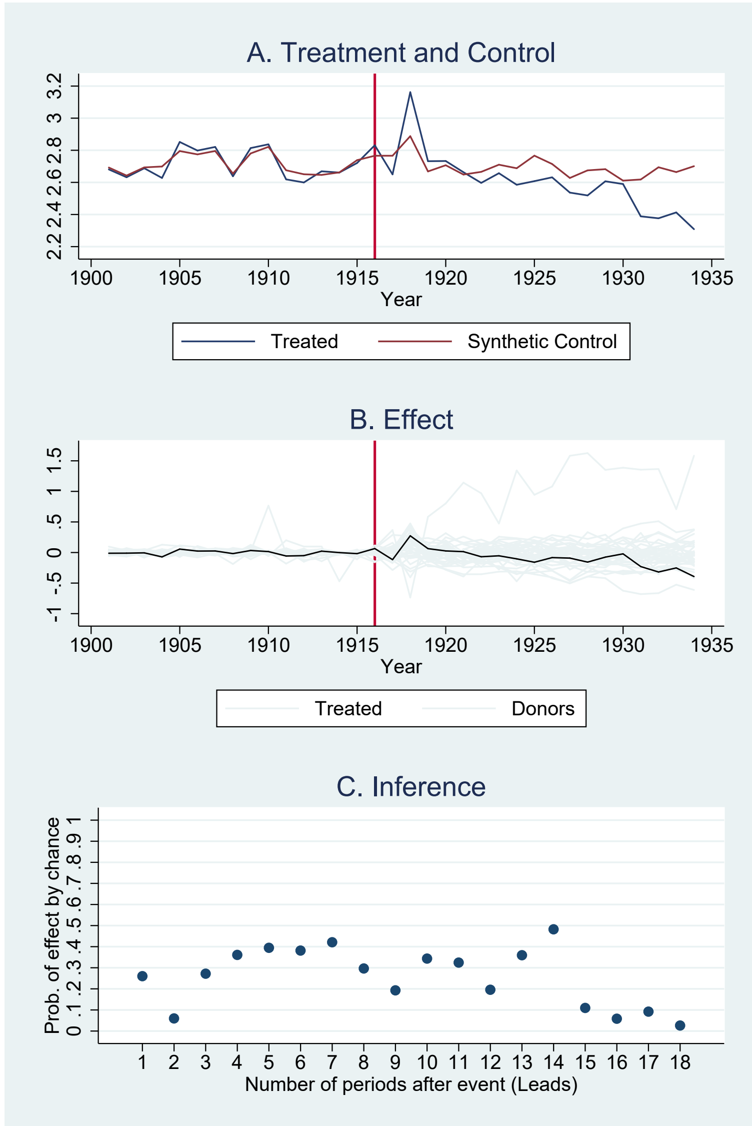
Note: This figure shows the results of the Elastic net estimation on log infant mortality per 1,000. The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log infant mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. The vertical red line indicates the start of the Demonstration in 1917. See Appendix Table A.10 for the weights assigned to the municipalities forming the synthetic control.

Figure 9: Synthetic control results on log total mortality per 1,000



Note: This figure shows the estimation results of the SCM on log total mortality per 1,000, where the predictors of the log total mortality rate in the pre-Demonstration period (1901-1916) are: log total mortality rate (1901-1916), log TB mortality rate (1901-1916), log TB case rate (1906-1916), log infectious disease rate (1901-1916), log non-infectious disease rate (1901-1916), log population (1901-1916), share aged 0-14 (1910), share aged 45-59 (1910), share aged 60 and above (1910), share foreign born (1910), share literate (1910), and log occupational earnings score per worker (1910). The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log TB mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. Placebo municipalities in the pool for inference are excluded if their pre-treatment RMSPE is greater than two times the pre-treatment RMSPE of the synthetic Framingham. The vertical red line indicate the start of the Demonstration in 1917. See Appendix Table A.11 and A.12 for the weights assigned to the municipalities forming the synthetic control, and the balance between the synthetic control and the treated unit before 1917, respectively.

Figure 10: Elastic net results on log total mortality per 1,000



Note: This figure shows the results of the Elastic net estimation on log total mortality per 1,000. The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants. Panel A shows the path of Framingham's log total mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. The vertical red line indicate the start of the Demonstration in 1917. See Appendix Table A.13 for the weights assigned to the municipalities forming the synthetic control.

A Appendix tables

Table A.1: Municipalities in the original control sample and the MA sample

MA municipality	Control municipality
Framingham	1
Chicopee	1
Clinton	1
Fitchburg	1
Gardner	1
Marlborough	1
Milford	1
North Adams	1
Abington	0
Adams	0
Amesbury	0
Amherst	0
Andover	0
Arlington	0
Athol	0
Attleboro	0
Belmont	0
Beverly	0
Blackstone	0
Braintree	0
Bridgewater	0
Brookline	0
Canton	0
Chelmsford	0
Chelsea	0
Concord	0
Danvers	0
Dartmouth	0
Dedham	0
Easthampton	0
Easton	0
Everett	0
Fairhaven	0
Franklin	0
Gloucester	0
Grafton	0
Great Barrington	0
Greenfield	0
Haverhill	0
Hingham	0
Hudson	0
Ipswich	0
Leominster	0
Lexington	0
Ludlow	0
Malden	0
Mansfield	0
Marblehead	0
Maynard	0
Medford	0
Melrose	0
Middleborough	0
Millbury	0
Milton	0
Monson	0
Montague	0
Natick	0
Needham	0
Newburyport	0
Newton	0
North Andover	0
North Attleborough	0
Northampton	0
Northbridge	0
Norwood	0
Orange	0
Palmer	0
Peabody	0
Pittsfield	0
Plymouth	0
Quincy	0
Reading	0
Revere	0
Rockland	0
Salem	0
Saugus	0
South Hadley	0
Southbridge	0
Spencer	0
Stoneham	0
Stoughton	0
Swampscott	0
Taunton	0
Tewksbury	0
Wakefield	0
Walpole	0
Waltham	0
Ware	0
Wareham	0
Watertown	0
Webster	0
Wellesley	0

Note: This table lists the original control municipalities, and the municipalities in Massachusetts with populations from 5,000 to 50,000 inhabitants.

Table A.2: Synthetic control weights for the synthetic control results on log TB mortality per 1,000

Municipality	Weight
Abington	0.000
Adams	0.000
Amesbury	0.000
Amherst	0.000
Andover	0.000
Arlington	0.000
Athol	0.000
Attleboro	0.000
Belmont	0.000
Beverly	0.000
Blackstone	0.000
Braintree	0.000
Bridgewater	0.000
Brookline	0.000
Canton	0.000
Chelmsford	0.000
Chelsea	0.000
Chicopee	0.000
Clinton	0.000
Concord	0.000
Danvers	0.000
Dartmouth	0.000
Dedham	0.000
Easthampton	0.000
Easton	0.000
Everett	0.000
Fairhaven	0.000
Fitchburg	0.000
Franklin	0.132
Gardner	0.000
Gloucester	0.000
Grafton	0.000
Great Barrington	0.000
Greenfield	0.000
Haverhill	0.000
Hingham	0.030
Hudson	0.000
Ipswich	0.063
Leominster	0.000
Lexington	0.000
Ludlow	0.000
Malden	0.000
Mansfield	0.000
Marblehead	0.000
Marlborough	0.000
Maynard	0.000
Medford	0.000
Melrose	0.000
Middleborough	0.000
Milford	0.000
Millbury	0.000
Milton	0.000
Monson	0.075
Montague	0.058
Natick	0.000
Needham	0.000
Newburyport	0.000
Newton	0.000
North Adams	0.000
North Andover	0.000
North Attleborough	0.000
Northampton	0.000
Northbridge	0.000
Norwood	0.000
Orange	0.213
Palmer	0.000
Peabody	0.000
Pittsfield	0.000
Plymouth	0.000
Quincy	0.000
Reading	0.000
Revere	0.000
Rockland	0.000
Salem	0.000
Saugus	0.000
South Hadley	0.000
Southbridge	0.000
Spencer	0.000
Stoneham	0.000
Stoughton	0.000
Swampscott	0.039
Taunton	0.000
Tewksbury	0.000
Wakefield	0.000
Walpole	0.000
Waltham	0.000
Ware	0.000
Wareham	0.223
Watertown	0.000
Webster	0.000
Wellesley	0.167

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the SCM estimation on log TB mortality per 1,000 shown in Figure 3 with balance of the predictor variables shown in Appendix Table A.3.

Table A.3: Balance of treated versus the synthetic control for the synthetic control results on log TB mortality per 1,000

	Treated	Synthetic
log TB rate	−0.258	−0.254
log TB case rate	−0.382	−0.668
log infectious disease rate	0.768	0.639
log non-infectious disease rate	0.118	0.118
log population	9.467	8.554
Share aged 0-14	0.182	0.242
Share aged 45-59	0.169	0.156
Share aged 60-	0.084	0.119
Share foreign born	0.300	0.300
Share literate	0.857	0.903
log income rate	6.531	6.567

Note: This table lists the average value of the predictors of the log TB mortality rate in the pre-Demonstration period (1901-1916) for the treated unit (Framingham), and the sythetic control from the SCM estimation shown in Figure 3, using the weights assigned in Appendix Table A.2.

Table A.4: Synthetic control weights for the Elastic net results on log TB mortality per 1,000

Municipality	Weight
Abington	−0.050
Adams	0.000
Amesbury	0.000
Amherst	0.000
Andover	−0.012
Arlington	0.032
Athol	−0.055
Attleboro	0.000
Belmont	0.006
Beverly	0.000
Blackstone	0.022
Braintree	−0.055
Bridgewater	0.016
Brookline	0.000
Canton	−0.009
Chelmsford	0.004
Chelsea	0.000
Chicopee	0.000
Clinton	−0.013
Concord	−0.051
Danvers	0.000
Dartmouth	0.048
Dedham	−0.037
Easthampton	0.050
Easton	0.045
Everett	0.000
Fairhaven	0.000
Fitchburg	0.000
Franklin	0.046
Gardner	0.024
Gloucester	0.000
Grafton	−0.008
Great Barrington	−0.055
Greenfield	0.035
Haverhill	0.000
Hingham	0.032
Hudson	0.065
Ipswich	0.000
Leominster	0.000
Lexington	0.023
Ludlow	0.043
Malden	0.002
Mansfield	−0.030
Marblehead	0.000
Marlborough	0.000
Maynard	0.000
Medford	0.002
Melrose	0.000
Middleborough	0.000
Milford	0.000
Millbury	0.000
Milton	0.000
Monson	0.010
Montague	0.000
Natick	0.000
Needham	0.000
Newburyport	0.068
Newton	0.000
North Adams	0.000
North Andover	0.033
North Attleborough	0.000
Northampton	0.000
Northbridge	0.000
Norwood	0.000
Orange	0.028
Palmer	0.000
Peabody	0.000
Pittsfield	0.002
Plymouth	−0.007
Quincy	0.006
Reading	0.000
Revere	0.012
Rockland	0.122
Salem	0.000
Saugus	0.000
South Hadley	0.000
Southbridge	0.000
Spencer	0.000
Stoneham	0.000
Stoughton	0.015
Swampscott	0.000
Taunton	0.000
Tewksbury	0.024
Wakefield	0.054
Walpole	0.094
Waltham	0.000
Ware	0.000
Wareham	0.044
Watertown	0.014
Webster	0.000
Wellesley	0.038

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the Elastic net regression on log TB mortality per 1,000 shown in Figure 4.

Table A.5: Synthetic control weights for the synthetic control results on log TB cases per 1,000

Municipality	Weight	Municipality	Weight	Municipality	Weight
Abington	0.000	Grafton	0.000	Northbridge	0.000
Adams	0.000	Great Barrington	0.000	Norwood	0.000
Amesbury	0.000	Greenfield	0.000	Orange	0.000
Amherst	0.000	Haverhill	0.000	Palmer	0.000
Andover	0.000	Hingham	0.000	Peabody	0.000
Arlington	0.000	Hudson	0.156	Pittsfield	0.000
Athol	0.000	Ipswich	0.000	Plymouth	0.000
Attleboro	0.000	Leominster	0.609	Quincy	0.000
Belmont	0.000	Lexington	0.000	Reading	0.000
Beverly	0.000	Ludlow	0.000	Revere	0.000
Blackstone	0.000	Malden	0.000	Rockland	0.000
Braintree	0.000	Mansfield	0.000	Salem	0.000
Bridgewater	0.000	Marblehead	0.044	Saugus	0.000
Brookline	0.000	Marlborough	0.000	South Hadley	0.000
Canton	0.000	Maynard	0.000	Southbridge	0.190
Chelmsford	0.000	Medford	0.000	Spencer	0.000
Chelsea	0.000	Melrose	0.000	Stoneham	0.000
Chicopee	0.000	Middleborough	0.000	Stoughton	0.000
Clinton	0.000	Milford	0.000	Swampscott	0.000
Concord	0.000	Millbury	0.000	Taunton	0.000
Danvers	0.000	Milton	0.000	Tewksbury	0.000
Dartmouth	0.000	Monson	0.000	Wakefield	0.000
Dedham	0.000	Montague	0.000	Walpole	0.000
Easthampton	0.000	Natick	0.000	Waltham	0.000
Easton	0.000	Needham	0.000	Ware	0.000
Everett	0.000	Newburyport	0.000	Wareham	0.000
Fairhaven	0.000	Newton	0.000	Watertown	0.000
Fitchburg	0.000	North Adams	0.000	Webster	0.000
Franklin	0.000	North Andover	0.000	Wellesley	0.000
Gardner	0.000	North Attleborough	0.000		
Gloucester	0.000	Northampton	0.000		

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the SCM estimation on log TB cases per 1,000 shown in Figure 5 with balance of the predictor variables shown in Appendix Table A.6.

Table A.6: Balance of treated versus the synthetic control for the synthetic control results on log TB cases per 1,000

	Treated	Synthetic
log TB case rate	−0.382	−0.381
log TB rate	−0.352	−0.343
log infectious disease rate	0.773	0.699
log non-infectious disease rate	−0.011	−0.268
log population	9.523	9.495
Share aged 0-14	0.182	0.238
Share aged 45-59	0.169	0.160
Share aged 60-	0.084	0.077
Share foreign born	0.300	0.299
Share literate	0.857	0.875
log income rate	6.531	6.551

Note: This table lists the average value of the predictors of the log TB case rate in the pre-Demonstration period (1906-1916) for the treated unit (Framingham), and the sythetic control from the SCM estimation shown in Figure 5, using the weights assigned in Appendix Table A.5.

Table A.7: Synthetic control weights for the Elastic net results on log TB cases per 1,000

Municipality	Weight
Abington	0.000
Adams	0.036
Amesbury	0.010
Amherst	0.000
Andover	0.000
Arlington	0.000
Athol	0.023
Attleboro	0.000
Belmont	0.000
Beverly	0.000
Blackstone	0.006
Braintree	0.000
Bridgewater	0.000
Brookline	0.000
Canton	0.000
Chelmsford	NA
Chelsea	0.000
Chicopee	0.000
Clinton	0.028
Concord	0.000
Danvers	0.000
Dartmouth	0.008
Dedham	0.000
Easthampton	0.022
Easton	−0.051
Everett	0.000
Fairhaven	0.000
Fitchburg	0.061
Franklin	0.000
Gardner	0.000
Gloucester	0.000
Grafton	0.000
Great Barrington	0.000
Greenfield	0.057
Haverhill	0.000
Hingham	0.008
Hudson	0.000
Ipswich	0.014
Leominster	0.000
Lexington	0.000
Ludlow	0.026
Malden	0.000
Mansfield	0.000
Marblehead	0.049
Marlborough	0.000
Maynard	0.000
Medford	0.000
Melrose	0.059
Middleborough	0.000
Milford	0.000
Millbury	0.000
Milton	0.000
Monson	0.000
Montague	0.000
Natick	0.000
Needham	0.043
Newburyport	0.000
Newton	0.000
North Adams	0.000
North Andover	0.019
North Attleborough	0.000
Northampton	0.000
Northbridge	0.044
Norwood	0.000
Orange	NA
Palmer	0.000
Peabody	0.000
Pittsfield	0.000
Plymouth	0.000
Quincy	0.000
Reading	0.000
Revere	0.000
Rockland	0.000
Salem	0.000
Saugus	0.010
South Hadley	0.000
Southbridge	0.006
Spencer	NA
Stoneham	0.000
Stoughton	0.040
Swampscott	−0.015
Taunton	0.020
Tewksbury	−0.035
Wakefield	0.000
Walpole	0.000
Waltham	0.000
Ware	0.000
Wareham	0.000
Watertown	0.020
Webster	0.048
Wellesley	0.000

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the Elastic net regression on log TB cases per 1,000 shown in Figure 6. If weight equals "NA" the municipality is excluded from the analysis, see the Note of Figure 6.

Table A.8: Synthetic control weights for the synthetic control results on log infant mortality per 1,000

Municipality	Weight	Municipality	Weight
Adams	0.000	Milford	0.000
Arlington	0.000	Natick	0.129
Attleboro	0.000	Newburyport	0.000
Beverly	0.000	Newton	0.103
Brookline	0.000	North Adams	0.000
Chelsea	0.000	Northampton	0.000
Chicopee	0.000	Peabody	0.000
Clinton	0.000	Pittsfield	0.000
Danvers	0.000	Plymouth	0.000
Everett	0.000	Quincy	0.000
Fitchburg	0.000	Revere	0.000
Gardner	0.000	Salem	0.000
Gloucester	0.000	Southbridge	0.000
Haverhill	0.000	Taunton	0.115
Leominster	0.266	Wakefield	0.000
Malden	0.000	Waltham	0.000
Marlborough	0.386	Watertown	0.000
Medford	0.000	Webster	0.000
Melrose	0.000		

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the SCM estimation on log infant mortality per 1,000 shown in Figure 7 with balance of the predictor variables shown in Appendix Table A.9.

Table A.9: Balance of treated versus the synthetic control for the synthetic control results on log infant mortality per 1,000

	Treated	Synthetic
log IMR	0.779	0.807
log TB rate	−0.258	−0.001
log TB case rate	−0.382	−0.312
log infectious disease rate	0.768	0.675
log non-infectious disease rate	0.118	0.118
log population	9.467	9.742
Share aged 0-14	0.182	0.252
Share aged 45-59	0.169	0.159
Share aged 60-	0.084	0.100
Share foreign born	0.300	0.270
Share literate	0.857	0.914
log income rate	6.531	6.465

Note: This table lists the average value of the predictors of the log infant mortality rate in the pre-Demonstration period (1901-1916) for the treated unit (Framingham), and the sythetic control from the SCM estimation shown in Figure 7, using the weights assigned in Appendix Table A.8.

Table A.10: Synthetic control weights for the Elastic net results on log infant mortality per 1,000

Municipality	Weight
Adams	0.000
Arlington	−0.029
Attleboro	0.000
Beverly	0.000
Brookline	−0.189
Chelsea	0.093
Chicopee	0.029
Clinton	0.239
Danvers	0.224
Everett	−0.104
Fitchburg	0.000
Gardner	0.000
Gloucester	−0.180
Haverhill	−0.099
Leominster	0.187
Malden	0.000
Marlborough	0.000
Medford	0.127
Melrose	0.034
Milford	0.000
Natick	0.000
Newburyport	−0.032
Newton	0.082
North Adams	−0.015
Northampton	−0.135
Peabody	0.000
Pittsfield	0.000
Plymouth	0.159
Quincy	−0.015
Revere	0.000
Salem	0.000
Southbridge	0.019
Taunton	0.124
Wakefield	0.000
Waltham	0.000
Watertown	0.000
Webster	0.000

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the Elastic net regression on log infant mortality per 1,000 shown in Figure 8.

Table A.11: Synthetic control weights for the synthetic control results on log total mortality per 1,000

Municipality	Weight
Adams	0.000
Arlington	0.000
Attleboro	0.000
Beverly	0.000
Brookline	0.000
Chelsea	0.000
Chicopee	0.000
Clinton	0.000
Danvers	0.000
Everett	0.000
Fitchburg	0.000
Gardner	0.000
Gloucester	0.000
Haverhill	0.000
Leominster	0.459
Malden	0.000
Marlborough	0.000
Medford	0.000
Melrose	0.000
Milford	0.000
Natick	0.097
Newburyport	0.000
Newton	0.000
North Adams	0.000
Northampton	0.000
Peabody	0.000
Pittsfield	0.000
Plymouth	0.000
Quincy	0.000
Revere	0.000
Salem	0.000
Southbridge	0.007
Taunton	0.360
Wakefield	0.077
Waltham	0.000
Watertown	0.000
Webster	0.000

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the SCM estimation on log total mortality per 1,000 shown in Figure 9 with balance of the predictor variables shown in Appendix Table A.12.

Table A.12: Balance of treated versus the synthetic control for the synthetic control results on log total mortality per 1,000

	Treated	Synthetic
log CDR	2.718	2.720
log TB rate	−0.258	0.130
log TB case rate	−0.382	−0.201
log infectious disease rate	0.768	0.843
log non-infectious disease rate	0.118	0.081
log population	9.467	9.860
Share aged 0-14	0.182	0.263
Share aged 45-59	0.169	0.146
Share aged 60-	0.084	0.093
Share foreign born	0.300	0.299
Share literate	0.857	0.884
log income rate	6.531	6.525

Note: This table lists the average value of the predictors of the log total mortality rate in the pre-Demonstration period (1901-1916) for the treated unit (Framingham), and the sythetic control from the SCM estimation shown in Figure 9, using the weights assigned in Appendix Table A.11.

Table A.13: Synthetic control weights for the Elastic net results on log total mortality per 1,000

Municipality	Weight
Adams	−0.062
Arlington	−0.065
Attleboro	0.127
Beverly	0.201
Brookline	0.013
Chelsea	0.000
Chicopee	−0.019
Clinton	0.000
Danvers	0.026
Everett	0.012
Fitchburg	0.080
Gardner	0.000
Gloucester	−0.130
Haverhill	0.088
Leominster	0.116
Malden	0.001
Marlborough	0.000
Medford	0.034
Melrose	0.127
Milford	0.030
Natick	0.000
Newburyport	−0.099
Newton	0.000
North Adams	−0.067
Northampton	0.028
Peabody	0.024
Pittsfield	−0.066
Plymouth	0.014
Quincy	0.000
Revere	−0.064
Salem	0.000
Southbridge	0.063
Taunton	0.124
Wakefield	0.000
Waltham	0.142
Watertown	0.083
Webster	−0.103

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the Elastic net regression on log total mortality per 1,000 shown in Figure 10.

Table A.14: Synthetic control weights for the synthetic control results on log TB mortality per 1,000 excluding municipalities within 50 kilometers of Framingham

Municipality	Weight	Municipality	Weight
Adams	0.000	Middleborough	0.000
Amesbury	0.000	Monson	0.000
Amherst	0.000	Montague	0.000
Athol	0.000	Newburyport	0.000
Beverly	0.000	North Adams	0.000
Chicopee	0.000	North Andover	0.000
Danvers	0.000	Northampton	0.000
Dartmouth	0.086	Orange	0.163
Easthampton	0.176	Palmer	0.000
Fairhaven	0.000	Pittsfield	0.213
Gardner	0.118	Plymouth	0.000
Gloucester	0.000	Salem	0.000
Great Barrington	0.000	South Hadley	0.000
Greenfield	0.000	Southbridge	0.000
Haverhill	0.000	Taunton	0.000
Ipswich	0.071	Ware	0.000
Ludlow	0.000	Wareham	0.101
Marblehead	0.073		

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the SCM estimation on log TB mortality per 1,000 shown in Figure A.8 with balance of the predictor variables shown in Appendix Table A.15.

Table A.15: Balance of treated versus the synthetic control for the synthetic control results on log TB mortality per 1,000 excluding municipalities within 50 kilometers of Framingham

	Treated	Synthetic
log TB rate	−0.258	−0.224
log TB case rate	−0.382	−0.525
log infectious disease rate	0.768	0.711
log non-infectious disease rate	0.118	0.057
log population	9.467	9.117
Share aged 0-14	0.182	0.242
Share aged 45-59	0.169	0.147
Share aged 60-	0.084	0.089
Share foreign born	0.300	0.275
Share literate	0.857	0.939
log income rate	6.531	6.539

Note: This table lists the average value of the predictors of the log TB mortality rate in the pre-Demonstration period (1901-1916) for the treated unit (Framingham), and the sythetic control from the SCM estimation shown in Figure A.8, using the weights assigned in Appendix Table A.14.

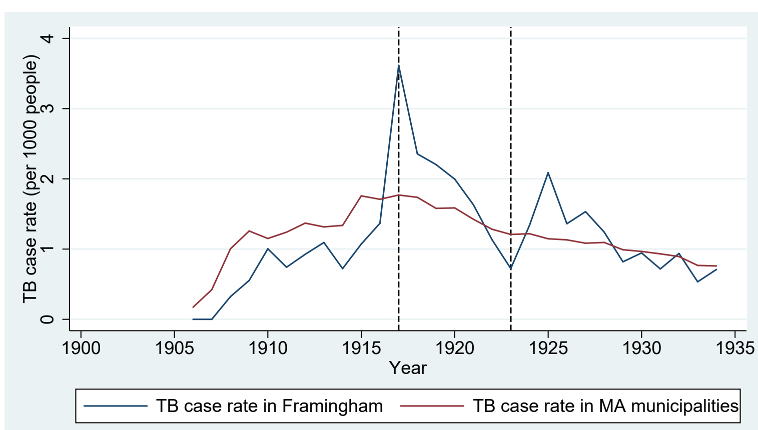
Table A.16: Synthetic control weights for the Elastic net results on log TB mortality per 1,000 excluding municipalities within 50 kilometers of Framingham

Municipality	Weight
Adams	0.000
Amesbury	0.000
Amherst	0.000
Athol	0.000
Beverly	0.000
Chicopee	0.000
Danvers	0.000
Dartmouth	0.088
Easthampton	0.129
Fairhaven	0.000
Gardner	0.000
Gloucester	0.000
Great Barrington	0.000
Greenfield	0.020
Haverhill	0.000
Ipswich	0.000
Ludlow	0.000
Marblehead	0.000
Middleborough	0.000
Monson	0.000
Montague	0.000
Newburyport	0.155
North Adams	0.000
North Andover	0.000
Northampton	0.000
Orange	0.000
Palmer	0.000
Pittsfield	0.000
Plymouth	0.000
Salem	0.000
South Hadley	0.000
Southbridge	0.000
Taunton	0.000
Ware	0.000
Wareham	0.000

Note: This table lists the weights assigned to municipalities in the donor pool of municipalities in the extended Massachusetts panel from the Elastic net regression on log TB mortality per 1,000 shown in Figure A.9.

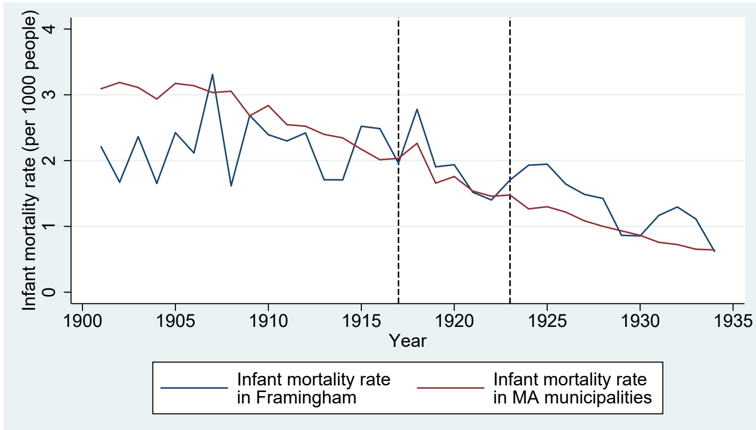
A Appendix figures

Figure A.1: TB cases per 1,000 in Framingham and in MA



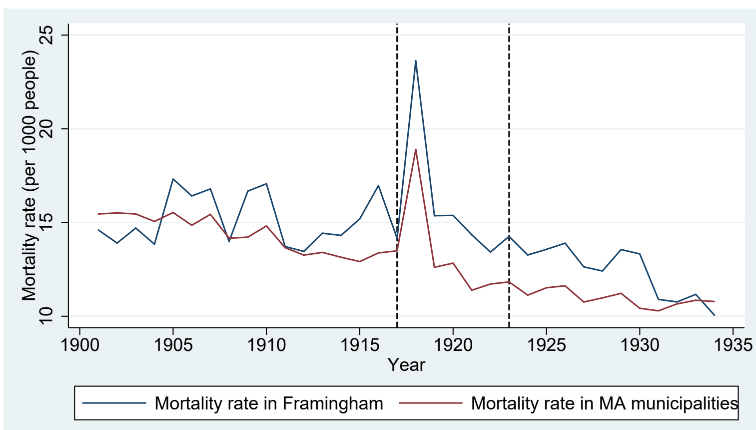
Note: The graph plots the development of the aggregate TB cases per 1,000 in Framingham and the MA municipalities. The vertical dotted lines enclose the Demonstration period from 1917 to 1923.

Figure A.2: Infant mortality per 1,000 in Framingham and in MA



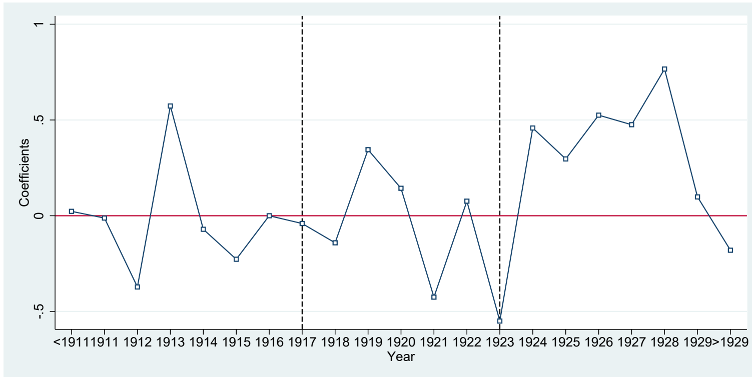
Note: The graph plots the development of the aggregate infant mortality per 1,000 in Framingham and the MA municipalities. The vertical dotted lines enclose the Demonstration period from 1917 to 1923.

Figure A.3: Mortality per 1,000 in Framingham and in MA



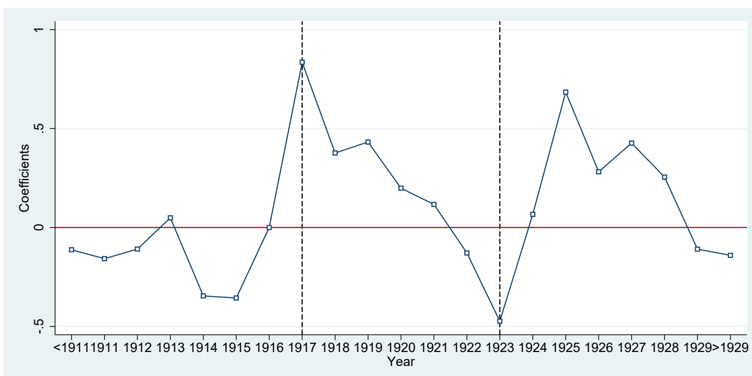
Note: The graph plots the development of the aggregate mortality per 1,000 in Framingham and the MA municipalities. The vertical dotted lines enclose the Demonstration period from 1917 to 1923.

Figure A.4: Event-study TB mortality per 1,000



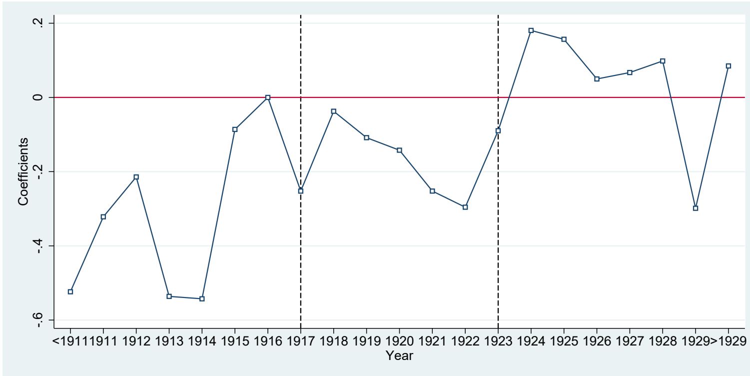
Note: This graph shows the coefficients from estimating the following event-study of the Framingham demonstration with 1916 as the base year on log TB mortality per 1,000: $\log COD_{ct} = \sum_{j \in T} \beta_j Demo_{ct}^{\tau+j} + \phi_c + \phi_t + \varepsilon_{ct}$, where COD_{ct} is the dependent variable, $\sum_{j \in T} \beta_j Demo_{ct}^{\tau+j}$ is a set of intervention indicators, one for each year between 1911 and 1928, excluding 1916, and two intervention indicators for the years prior to 1911 and for the years after 1928. ϕ_c and ϕ_t are municipality and year fixed effects respectively.

Figure A.5: Event-study TB cases per 1,000



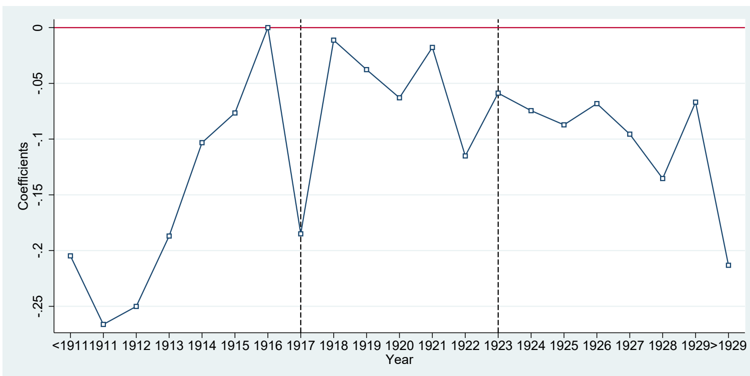
Note: This graph shows the coefficients from estimating the following event-study of the Framingham demonstration with 1916 as the base year on log TB cases per 1,000: $\log COD_{ct} = \sum_{j \in T} \beta_j Demo_{ct}^{\tau+j} + \phi_c + \phi_t + \varepsilon_{ct}$, where COD_{ct} is the dependent variable, $\sum_{j \in T} \beta_j Demo_{ct}^{\tau+j}$ is a set of intervention indicators, one for each year between 1911 and 1928, excluding 1916, and two intervention indicators for the years prior to 1911 and for the years after 1928. ϕ_c and ϕ_t are municipality and year fixed effects respectively.

Figure A.6: Event-study infant mortality per 1,000



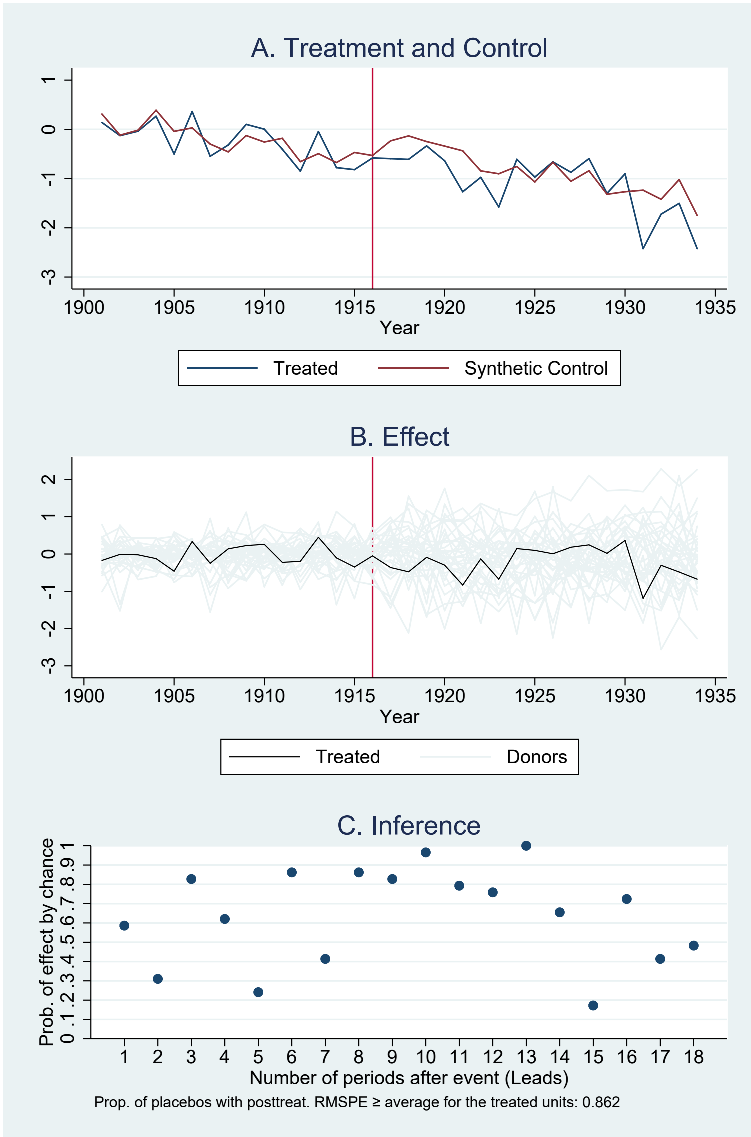
Note: This graph shows the coefficients from estimating the following event-study of the Framingham demonstration with 1916 as the base year on log infant mortality per 1,000: $\log COD_{ct} = \sum_{j \in T} \beta_j Demo_{ct}^{\tau+j} + \phi_c + \phi_t + \varepsilon_{ct}$, where COD_{ct} is the dependent variable, $\sum_{j \in T} \beta_j Demo_{ct}^{\tau+j}$ is a set of intervention indicators, one for each year between 1911 and 1928, excluding 1916, and two intervention indicators for the years prior to 1911 and for the years after 1928. ϕ_c and ϕ_t are municipality and year fixed effects respectively.

Figure A.7: Event-study total mortality per 1,000



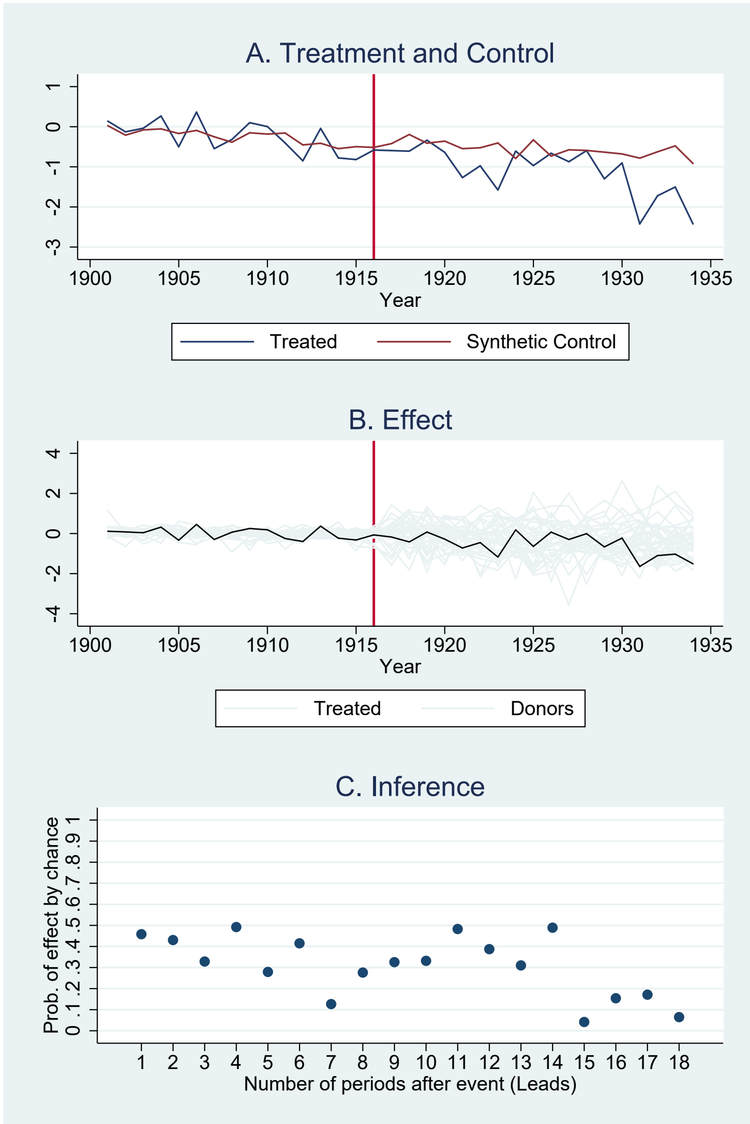
Note: This graph shows the coefficients from estimating the following event-study of the Framingham demonstration with 1916 as the base year on log total mortality per 1,000: $\log COD_{ct} = \sum_{j \in T} \beta_j Demo_{ct}^{\tau+j} + \phi_c + \phi_t + \varepsilon_{ct}$, where COD_{ct} is the dependent variable, $\sum_{j \in T} \beta_j Demo_{ct}^{\tau+j}$ is a set of intervention indicators, one for each year between 1911 and 1928, excluding 1916, and two intervention indicators for the years prior to 1911 and for the years after 1928. ϕ_c and ϕ_t are municipality and year fixed effects respectively.

Figure A.8: Synthetic control results on log TB mortality per 1,000 excluding control municipalities within 50 kilometers of Framingham



Note: This figure shows the estimation results of the SCM on log TB mortality per 1,000, where the predictors of the log TB rate in the pre-Demonstration period (1901-1916) are: log TB mortality rate (1901-1916), log TB case rate (1906-1916), log infectious disease rate (1901-1916), log non-infectious disease rate (1901-1916), log population (1901-1916), share aged 0-14 (1910), share aged 45-59 (1910), share aged 60 and above (1910), share foreign born (1910), share literate (1910), and log occupational earnings score per worker (1910). The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants, excluding municipalities within a radius of 50 kilometers of Framingham. Panel A shows the path of Framingham's log TB mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. Placebo municipalities in the pool for inference are excluded if their post-treatment RMSPE is greater than two times the pre-treatment RMSPE of the synthetic Framingham. The vertical red line indicate the start of the Demonstration in 1917. See Appendix Table A.14 and A.15 for the weights assigned to the municipalities forming the synthetic control, and the balance between the synthetic control and the treated unit before 1917, respectively.

Figure A.9: Elastic net results on log TB mortality per 1,000 excluding control municipalities within 50 kilometers of Framingham



Note: This figure shows the results of the Elastic net estimation on log TB mortality per 1,000. The synthetic control is constructed from the municipalities in Massachusetts with populations from 5,000 and up to 50,000 inhabitants, excluding municipalities within a radius of 50 kilometers of Framingham. Panel A shows the path of Framingham's log TB mortality rate, along with the (counterfactual) synthetic path. The in-place placebo effects, along with the "true" Demonstration effect, and the resulting (empirical) p-values are displayed in Panels B and C, respectively. The vertical red line indicate the start of the Demonstration in 1917. See Appendix Table A.16 for the weights assigned to the municipalities forming the synthetic control.