Public Health and Tuberculosis Mortality During the Framingham Tuberculosis Demonstration

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Abstract:

Between 1900 and 1940, tuberculosis moved from being the second highest cause of death in the United States to no longer being a leading cause of death. The historical causes of the decline in tuberculosis thus remain unclear. This paper examines the role of public health demonstrations in the decline in tuberculosis by studying the Framingham Community Health and Tuberculosis Demonstration, a public health demonstration conducted in Framingham, Massachusetts from 1917-1924. We measure the decreases in tuberculosis and infant mortality during the Framingham Demonstration using a linear regression model and the synthetic control model first used by Abadie and Gardeazabal (2003). The linear regression model finds that tuberculosis mortality decreased by approximately 22 deaths per 100,000 population and infant mortality decreased by approximately 11 to 14 deaths per 1,000 live births over the period of 1917-1923. The synthetic control model confirms these findings.

Between 1900 and 1940, tuberculosis moved from being the second highest cause of death in the United States to no longer being a leading cause of death. This decline occurred before the invention of effective chemotherapy or vaccination against tuberculosis. While many theories explaining the decline in tuberculosis have been advanced, there has been very little quantitative research done on the subject. The historical causes of the decline in tuberculosis thus remain unclear. This paper considers the role of public health interventions in the decline of tuberculosis by examining one such public health demonstration, the Framingham Health and Tuberculosis Demonstration, and quantitatively measuring its effectiveness in reducing tuberculosis and infant mortality while the demonstration was occurring.

In 1916, the Metropolitan Life Insurance Company gave $100,000 to the National Tuberculosis Association to perform a public health demonstration in a small town in New York or Massachusetts. The demonstration was supposed to improve the general health of the community while paying specific attention to reducing the number of cases of, and deaths from, tuberculosis. The National Tuberculosis Association chose Framingham, Massachusetts, for the site of the demonstration and conducted the demonstration as an effort involving the entire community. Using newly-digitized data for 60 cities in Massachusetts, this paper tests whether Framingham's tuberculosis mortality and infant mortality rates declined during the Framingham Demonstration.

This paper is structured as follows. In section 1, we discuss tuberculosis as a disease, including its progression, diagnosis and treatment. In section 2, we discuss the history of the decline of tuberculosis and hypotheses previously advanced to explain the decline. In section 3, we discuss the Framingham Community Health and Tuberculosis Demonstration, including the funding and philosophies of the Demonstration and the public health measures implemented to

fight tuberculosis in the community. In section 5, we discuss the data used to analyze the trends of tuberculosis and infant mortality in Framingham. In section 6, we discuss a linear regression model used to determine the difference in tuberculosis and infant mortality between Framingham and the other cities in the sample. In section 7, we discuss a synthetic control model used to determine the difference in tuberculosis and infant mortality between Framingham and a synthetic version of Framingham representing a version of the town where the Demonstration never occurred. In section 8, we assess the causality of the declines in tuberculosis and infant mortality that correspond to the time of the Demonstration. Section 11 sums up our evaluation of the role of the Framingham Demonstration, and public health demonstrations in general, in the decline of tuberculosis.

Tuberculosis as a Disease

Tuberculosis is a disease caused by the tubercle bacillus. The disease causes lesions and later organ damage from multiplication of bacilli. The lesions may appear in many different parts of the body, although they most commonly form in the lungs. The bacilli are small and multiply slowly, have little ability to break down complex organic molecules, and are incapable of attacking many of the substances that form the structural component of human organs. Furthermore, a very large number of bacilli are needed to cause tuberculous lesions, but the bacilli cannot multiply extensively inside the human body. This causes the progression of the disease to be very slow. Tuberculous lesions sometimes calcify, becoming dormant; in this paper, cases of tuberculosis where lesions are calcified are referred to as “inactive” or “latent” cases. Inactive lesions cause little organ damage, and patients with inactive cases of tuberculosis are generally capable of living almost normal lives. Lesions that are dormant can become “active” again if they come in contact with more bacilli, and bacilli can live in dormant lesions

for years. Liquid in active lesions that do not calcify eventually soften and break open, leaving a cavity in the organ and allowing bacilli to enter the bloodstream.[1]

Several methods for diagnosis of tuberculosis were available during the period of the Demonstration. Following his 1882 discovery of the tubercle bacillus, in 1893 Koch announced the discovery of what he believed was a cure for tuberculosis: tuberculin. Koch believed tuberculin could be used to kill the tissue that formed lesions, removing the foundation of the disease from the body. While tuberculin was soon found to be ineffective as a cure for tuberculosis and, in fact, dangerous to patients treated with it in large doses, injecting a small amount of tuberculin under the skin was found to be an effective tool for diagnosis of tuberculosis. When it was injected under the skin of a patient carrying the tubercle bacillus, it caused a reaction in the skin even if there were no detectable lesions.[2] Another important development for diagnosis was the x-ray, which permits detection of lesions before there are any noticeable symptoms of the disease. However, it was not all-powerful: very early lesions were not visible on x-rays, active lesions sometimes appeared healed, and lesions could have been caused by diseases other than tuberculosis. Despite these limitations, the x-ray made clear that many humans were infected with tuberculosis without being aware of it, and infection often subsides spontaneously without causing significant damage.[3]

Vaccines and medical treatment for tuberculosis were not available in the United States until after the Second World War. The most effective vaccine for tuberculosis, BCG, was first developed in 1921 and was in widespread use in France by 1928. However, American doctors were generally wary of tuberculosis vaccines because of the previous experience with tuberculin,

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1 Rene Dubos and Jean Dubos, *The White Plague: Tuberculosis, Man and Society* (New Brunswick, NJ: Rutgers University Press, 1987), 111-117.
2 Michael Dormandy, *The White Death: A History of Tuberculosis*, (New York, NY: New York University Press, 2000), 139-142.
3 Dubos and Dubos, *The White Plague*, 120-121.

and in the 1920s BCG had not been subjected to a real controlled trial. Controversy over these and other early problems with credibility kept BCG out of the American and British markets until the late 1940s. While BCG helps increase natural resistance to tuberculosis, it does not give absolute immunity and is therefore not entirely effective in preventing the disease. Effective chemotherapy was developed around the same time. Streptomycin was the first chemotherapy effective in the treatment of tuberculosis, but it was not always completely effective.[4]

The Decline of Tuberculosis

Tuberculosis was the second greatest cause of death after pneumonia in the United States in 1900. The trend in tuberculosis mortality in the 20th century can be viewed in Figure 1. Its overall death rate was 194.4 per 100,000, accounting for 11.3 percent of all deaths.[5] Tuberculosis disproportionally affected the poor.[6] It also generally affected people in their prime of life, during the time when they would be working productively, rather than the very young and the very old. However, by 1940 tuberculosis was no longer a leading cause of death. Its overall death rate was 45.9 per 100,000, accounting for 4.5 percent of all deaths.[7] Because treatment with antibiotics began in the late 1940s, and vaccination was unavailable in the United States until around the same time, the decline occurred when there was no effective medical treatment for tuberculosis. The historical causes of the decline in tuberculosis are unclear.

Several hypotheses have been advanced to explain the decline of tuberculosis. One of the most commonly used explanations for the decline in tuberculosis is a reduction of overcrowding. Tuberculosis did not become a mass killer until the Industrial Revolution, when overcrowding became a major problem in industrialized cities. Tuberculosis disproportionately affected the

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[4] Dormandy, *The White Death*, 363-367.
[5] *Vital Statistics of the United States*, 1945: XXXI.
[6] Dormandy, *The White Death*, 73-84. While tuberculosis did affect the rich, death rates among the poor seem to have been higher, and when mortality declined the differential between the rich and poor remained nearly constant.
[7] *Vital Statistics of the United States*, 1945: XXXI.

poor, who were the people experiencing such poor living conditions. Dormandy (2000) suggests that the decline in tuberculosis may in fact have begun as a return to pre-Industrial Revolution levels. While the decline may have started with a reduction in overcrowding, its causes are likely multi-faceted.[8]

Many other possible causes have been proposed for the decline in tuberculosis, including the Spanish influenza pandemic, changes in nutrition, and changes in the water supply and sewer systems. Noymer (2011) found that there is some evidence for a link between the Spanish influenza pandemic in 1918 and the decline of tuberculosis, as many tuberculosis patients contracted the Spanish flu and died before they died from tuberculosis.[9] On the other hand, Almond (2006) found that the cohort that was in utero during the 1918 Spanish flu pandemic experienced many adverse health effects later in life, as well as lower educational attainment, income and socioeconomic status. Almond and Mazumder (2005) also found that these were lifelong effects – the susceptibility of the same cohort to tuberculosis may have been higher. Changes in overall nutrition may also have had some effect on tuberculosis mortality. Downes (1950) performed an experiment on African Americans, who were at highest risk for tuberculosis at the time due to a high level of poverty and poor living conditions, finding that there was a borderline significant decrease in tuberculosis mortality in a group given vitamins over a control group.[10] One of the standard treatments for tuberculosis at the time was also to consume more milk and eggs in order to build up the body's resistance to the disease.[11] Improvements to water supplies and sewer systems may also have affected tuberculosis mortality. Cutler and Miller

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[8] Amy L. Fairchild and Gerald M. Oppenheimer, "Public Health Nihilism vs Pragmatism: History, Politics, and the Control of Tuberculosis.," *American Journal of Public Health*, Vol. 88, no. 7 (July 1988): 1105-1117.
[9] Andrew Noymer, "The 1918 influenza pandemic hastened the decline of tuberculosis in the United States: An age, period, cohort analysis**,"** *Vaccine*, Vol. 29, Supplement 2, (22 July 2011**):** B38–B41.
[10] Jean Downes, "An Experiment in the Control of Tuberculosis Among Negroes," *The Millbank Memorial Fund Quarterly*, Vol. 28, no. 2 (Apr. 1950): 127-159.
[11] Barbara Bates, *Bargaining for Life: A Social History of Tuberculosis, 1878-1938*, (Philadelphia: University of Pennsylvania Press, 1992), 29.

(2005) found that clean water accounted for approximately half of the decrease in mortality and nearly three quarters of the decrease in infant mortality in the early twentieth century in major cities in the United States.[12] Ferrie and Troesken (2008) found that between 30 and 50 percent of the reduction in mortality in Chicago between 1850 and 1925 was due to improved water purification. Their findings are consistent with the Mills-Reincke phenomenon, which claims that for every death from typhoid fever prevented from purification of water, three or more deaths from other, generally non-waterborne, causes were prevented. Ferrie and Troesken argue that this was most likely due to the fact that typhoid fever had a low mortality rate but weakened the immune systems of its victims, leaving them susceptible to diseases like tuberculosis.[13] In general, it seems that improvements to water quality may have helped make the general population less susceptible to tuberculosis.

The isolation of tuberculosis patients most likely helped reduce the problem of tuberculosis. The sanatorium movement, which dominated tuberculosis treatment for almost a century, created a somewhat effective system of quarantine. Sanatoria aimed to increase the body's natural resistance to tuberculosis through various methods. These methods of treatment were probably not particularly effective; the Madras Experiment in 1956 found that home treatment with drugs was no less effective than the treatment of well-rested sanatorium patients with the same drugs.[14] Patients treated in a sanatorium were prevented from spreading the disease to their families, although many tuberculosis patients could not afford sanatoria or were driven away by the strict rules. Limits in scope of the sanatorium movement also prevented

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[12] David Cutler and Grant Miller, "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States," *Demography*, Vol. 42, No. 1 (2005): 13-14.
[13] Joseph P. Ferrie and Werner Troesken, "Water and Chicago's Mortality Transition, 1850-1925," *Explorations in Economic History*, Vol. 25 (2005): 1-16.
[14] Dormandy, *The White Death*, 373-375.

sanatoria from acting as a truly effective measure of quarantine.[15] By 1908, focus shifted to isolation in tuberculosis hospitals, where the tuberculous could die without infecting others. However, compulsory segregation was never instituted because there were never enough beds to make it a practical solution.[16]

Education was also a necessary step in the control of tuberculosis, as it would help encourage the public to cooperate with the necessary behavioral changes for the control of tuberculosis. Although most officials agreed on the need to strike a balance between being informative and not creating fear, propaganda was a commonly used tool in the educational campaign.[17] According to Tomes (1997), public health education focused heavily on "public health morality," or "the responsibilities that ordinary people assumed to guard themselves and others against infection." In their educational materials, public health officials used moral categorizations like "good" and "bad" to describe how well behaviors followed hygienic guidelines. The anti-tuberculosis crusade also targeted some commonplace behaviors like spitting that were only newly connected to the spread of disease.[18] Figure 2 is a typical poster used in educational campaigns against tuberculosis. The poster emphasizes individuals' responsibility for using personal hygiene and health habits such as covering coughs to prevent the spread of disease.

Visiting tuberculosis nurses helped to take care of the tuberculous poor in their own homes. Charged with educating the poor about how to save themselves from tuberculosis, their primary function was to impose the same kind of medical control and discipline that sanatoria

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[15] Bates, *Bargaining for Life*, 328-340.
[16] Michael E. Teller, *The Tuberculosis Movement: A Public Health Campaign in the Progressive Era*, (Westport, CT.: Greenwood Press, 1988), 93-94.
[17] Teller, *The Tuberculosis Movement*, 57.
[18] Nancy Tomes, "Moralizing the Microbe: The Germ Theory and the Moral Construction of Behavior in the Late-Nineteenth-Century Antituberculosis Movement," *Morality and Health*, ed. Allan M. Brandt and Paul Rozin (New York: Routledge, 1997), 272.

patients experienced. Visiting nurses often surveyed and corrected the hygienic conditions of the homes in which the tuberculous poor lived, and they sometimes partnered with social relief agencies to bring milk and eggs to their patients. However, as early as 1908 people began to be skeptical about the effectiveness of home visits.[19] The most important function of the tuberculosis nurse may have been that they reported all new cases they discovered. Nurses were, in fact, encouraged to take on more cases than they could treat in order to make sure that as many cases as possible were reported, which probably decreased their effectiveness in treating patients.[20]

Bovine strains of tuberculosis, transmitted to humans through the milk of infected cattle, was also a problem. In the United States, bovine tuberculosis was eliminated by the mass slaughter of all tuberculous cattle. Olmstead and Rhode (2004) demonstrate with a mathematical model that the slaughter of tuberculous cattle did help decrease overall tuberculosis mortality.

The overall effect of public health demonstrations on tuberculosis mortality is unclear and has not been heavily studied. While they focused more on individual health habits than on correcting some of the underlying conditions that predisposed populations to tuberculosis, like poverty and poor living conditions, they often did reduce tuberculosis mortality by a significant amount while they were going on, suggesting that the methods they employed were somewhat effective in the control of tuberculosis. [21] Combined with methods aimed at reducing poverty and other predisposing conditions for tuberculosis, the methods used in public health demonstrations are potentially effective in reducing the incidence of tuberculosis in the developing world today.

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[19] Bates, *Bargaining for Life*, 247-248.
[20] Ellen M. LaMotte, "Selections from *The Tuberculosis Nurse: Her Functions and Qualifications*," *From Consumption to Tuberculosis: A Documentary History*, ed. Barbara Gutmann Rosenkrantz (New York: Garland Pub, 1994), 447.
[21] Fairchild and Oppenheimer, "Public Health Nihilism vs. Pragmatism": 1109.

The Framingham Community Health and Tuberculosis Demonstration

In 1916, realizing that a large proportion of insurance claims they received were related to tuberculosis, the Metropolitan Life Insurance Company gave the National Tuberculosis Administration $100,000 to fund a public health demonstration in a town in New York or Massachusetts. Framingham was chosen as a site for the Demonstration because it was in many ways an average small town with above-average medical care. The Demonstration had two goals: to serve the general health needs of the community and, more specifically, to discover, control and prevent tuberculosis. The Demonstration was promoted as a community effort rather than an outside experiment on Framingham in an attempt to encourage widespread participation, using community machinery to convince the public to participate.[22] Although it was originally supposed to be only a three-year program, it was extended another three years when its success became apparent and thus ran from 1917 to 1923.

At the beginning of the Demonstration, Framingham had what were considered above average capabilities for medical care and the fight against tuberculosis. Approximately $0.40 per capita was spent on public health.[23] There was a tuberculosis dispensary with a full-time clinician and tuberculosis nurse. There was a community-wide Civic League that could be used to organize and engage the community in anti-tuberculosis efforts. The Board of Health had recently appointed an officer to oversee lab work, quarantine and other necessary processes.

The Framingham Demonstration followed, in many ways, the standard pattern of tuberculosis treatment of the time, attacking the disease from every known angle. Cases were identified as early as possible and treated through quarantine and rest, in sanatoria if possible. An

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[22] National Tuberculosis Association, *Framingham Monograph No. 1* (Framingham, Mass: Community Health Station, 1918), 6-8.

[23] Committee on appraisal for the Framingham community health and tuberculosis demonstration, *What Has the Demonstration Done? Should it be Continued?* (Framingham, Mass.: Community Health Station, 1919), 14.

educational campaign sought to encourage the public to safeguard their own health and that of those around them, drawing on their moral responsibility. Visiting nurses were responsible for much of the day-to-day care of tuberculosis patients. Figure 3 is a timeline of the Demonstration activities.

The first year of the Demonstration saw the beginning of many different strategies to fight tuberculosis. One of the first steps was to determine the extent of the tuberculosis problem in Framingham. A sickness census was taken in March and April of 1917 to determine the severity of all illness in Framingham, including minor illnesses. The sickness census found a sickness rate of 6.2% and 38 possible cases of tuberculosis, 16 of which were later confirmed.[24] The next step was a campaign providing free medical examinations, which had two phases in April and November of 1917. Between the two campaigns, 77% of those examined were found to have some form of illness, twelve times more than reported in the sickness census. The medical examinations also found 342 possible tuberculosis cases, 96 of which were confirmed. Many of the cases found were latent tuberculosis.[25] Von Pirquet tuberculin tests were administered to 500 children between the ages of one and seven, approximately 25% of the children of this age group in Framingham, between June and August 1917. Children were selected to be an "average" group. The survey found that 33% had a tuberculosis infection.[26] A sanitation survey of schools and factories was also carried out, with recommendations made for the improvement of sanitation in schools and workplaces. The Demonstration staff also studied the vital statistics of Framingham for the decade previous to the Demonstration, correcting death

[24] National Tuberculosis Association, *Framingham Monograph No. 2*, (Framingham, Mass: Community Health Station, 1918), 11-17.
[25] National Tuberculosis Association, *Framingham Monograph No. 4* (Framingham, Mass: Community Health Station, 1918), 22-23.
[26] National Tuberculosis Association, *Framingham Monograph No. 5* (Framingham, Mass: Community Health Station, 1919), 29-35.

certificates where they could confirm deaths from tuberculosis and determining the number deaths of "residents and transfers," that is, residents of Framingham who died both inside and outside of the city limits, for a more accurate assessment of the historical tuberculosis problem in Framingham. Through the vital statistics survey, the Demonstration staff found that attacking tuberculosis and infant mortality would be the easiest ways to reduce Framingham's mortality rate, as many of the highest causes of death over the past decade had been incurable degenerative diseases.[27]

Another important step that began in 1917 was an educational campaign, which was to be the main form of encouragement toward full community participation. The educational campaign was based on the distribution of literature about public health, hygiene and tuberculosis. Some of this literature came in the forms of publicly posted placards and pamphlets distributed in churches and other meeting areas, but the bulk of it came through the Sunday newspaper in the form of Health Letters. The Health Letters began with a series on tuberculosis, which provided methods for attacking tuberculosis infection, tuberculosis disease and tuberculosis mortality. In general, they focused on encouraging early disease detection and, to that end, emphasizing the need for an annual medical examination. The Health Letters also provided information on children's health, food safety, sanitation in the home and other relevant topics.[28] Further educational efforts came through the establishment of a medical club for continuing education of physicians, especially on topics related to tuberculosis, and the beginning of domestic science classes for local housewives.

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[27] National Tuberculosis Association, *Framingham Monograph No. 3* (Framingham, Mass: Community Health Station, 1918), 14.
[28] National Tuberculosis Association, *Framingham Monograph No. 8* (Framingham, Mass.: Community Health Station, 1920), 7-74.

The effort toward treatment began in 1917 as well, with the expansion of medical clinics into schools and large industries, the establishment of year-round infant welfare clinics, and the expansion of nursing and relief services. Quarantine of tuberculosis cases was highly encouraged by doctors and through the educational campaign, with visiting nurses checking in on confirmed tuberculosis cases. The Framingham Community Health Center was established as headquarters for the Demonstration. A summer camp for children at high risk of contracting tuberculosis held its first, during which children were fed nutritious diets and participated in health activities in hopes that they could be made more resistant to tuberculosis. The camp had the spillover benefit of allowing staff from the Community Health Center to examine and correct hygienic conditions in those children's homes during follow-up visits.[29] According to the National Tuberculosis Association, the most important effort was a medical consultation service that was established in 1917 as well.[30] The consultation service employed a doctor who was an expert in tuberculosis to help local physicians diagnose early and unclear cases of tuberculosis.

From 1918 on, most of the anti-tuberculosis efforts were a continuation or expansion of the services established in 1917. A few new efforts began each year. In 1918, a tuberculin study of cattle was made, and the results, showing that between 20 and 25% of Framingham's cattle were infected, helped motivate a push for pasteurization and other important methods of ensuring safe food and milk. [31] The Health Letters and other parts of the educational campaign especially emphasized making sure milk was pasteurized, providing instructions for how to pasteurize milk if it could not be bought pasteurized.[32] By the end of the Demonstration, the amount of milk pasteurized in Framingham moved from approximately 15% of the total supply to 80% of the

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[29] National Tuberculosis Association, *Framingham Monograph No. 7*, 29.
[30] National Tuberculosis Association, *Framingham Monograph No. 10* (Framingham, Mass.: Community Health Station, 1924), 41.
[31] National Tuberculosis Association, *Framingham Monograph No. 10*, 74-75.
[32] National Tuberculosis Association, *Framingham Monograph No. 8*, 30.

total supply.[33] More 1918 activities included the establishment of a tuberculosis clinic and the expansion of the Civic League's recreational activities. In 1919, a home hygiene study was performed, and medical services in schools expanded. From 1920 on, the sewer system was expanded and new schools were planned to meet the sanitation standards recommended by the Community Health Center. At the end of the Demonstration, almost all services established during the Demonstration were taken over by the community. The summer camp was discontinued because it could not be funded, and the consultation service was funded in part by Metropolitan Life for a short time after the end of the Demonstration. At the end of the Demonstration, approximately $2.40 per capita was being spent on public health, a more than 300% increase over the original figure of $0.40 per capita.[34]

It is unclear how long the activities of the Demonstration continued, but they seem to have diminished in effectiveness after the end of the Demonstration. In Framingham Monograph No. 10, it is claimed that "The presence of the Demonstration has built up a sentiment for health in the community, a popular sentiment which has on more than one occasion in town meeting and elsewhere, almost unanimously resisted and repudiated efforts to cut down expenditures for established health services."[35] From this, it seems that even before the end of the Demonstration, there were efforts made by some in the town government to cut back on health expenditures, although they met with opposition from the populace. It is possible that without the constant presence of the Demonstration, the town became less passionate about the need for proper health care and these initiatives began to pass. It is also possible that with a falling tuberculosis death rate, people began to see less need for efforts focusing on tuberculosis. Monograph No. 10 also makes frequent references to a lack of complete coordination between community health

[33] National Tuberculosis Association, *Framingham Monograph No. 10*, 74-75.
[34] National Tuberculosis Association, *Framingham Monograph No. 10*, 47.
[35] National Tuberculosis Association, *Framingham Monograph No. 10*, 34.

activities in Framingham throughout the Demonstration. It seems that problems with local politics may have prevented the effective consolidation of practical health services, including those established by the Demonstration. With the end of the Demonstration, the quality of central administration may have deteriorated, which could have led to deterioration in care and public health. It also seems likely that other neighboring towns began to "catch up" to Framingham rather than Framingham's tuberculosis mortality rates rising.

Data

In running the Demonstration, the National Tuberculosis Association designated seven cities as control cities for the experiment. Those cities were Chicopee, Clinton, Fitchburg, Gardner, Marlborough, Milford, and North Adams. The seven Demonstration control cities have been used in this paper to rule out some other possible explanations for declines of tuberculosis in Framingham specifically and are included in the sample for both the linear and synthetic models. In order to provide a more rigorous statistical analysis this paper expands the sample to include 58 cities other than Framingham. The sample of cities was made up of the cities with population greater than 10,000 in 1915.[36]

Newly digitized data was used to analyze the drop in tuberculosis death rate in Massachusetts over the period of 1900-1936. Data was collected for population or estimated population, total number of deaths, number of deaths in infancy[37], number of deaths from any form of tuberculosis, number of live births, population of foreign-born whites, total number of homes and total number of homes owned by their occupants. The total mortality rate per 100,000 people, tuberculosis mortality rate per 100,000 people, infant mortality rate per 1,000 live births,

[36] In 1915, there was a state census, making 1915 the most recent census year at the beginning of the Demonstration, which is why it was chosen as base year. The town of Danvers was excluded because of an anomalously high death rate each year, most likely due to its inclusion of the state asylum.

[37] Infant mortality was defined by the number of deaths occurring in children under one year of age.

percentage of foreign-born whites and percentage of home ownership were calculated from these data. Data for live births was unavailable for 1900-1913 and 1923, so infant mortality was not calculated for those years. Data was digitized from Mortality Statistics, Vital Statistics of Massachusetts, and the 1900-1930 Censuses of Population. A more detailed discussion of the sources and data construction is in Appendix A. Summary statistics for the data can be viewed in Table 1, displayed separately for the full dataset, Framingham alone, the seven Demonstration control cities, and the 58 control cities. $Population_{i,t}$ is the population of city *i* at time *t*. $MortRate_{i,t}$ is the mortality rate in city *i* at time *t*. $TBRate_{i,t}$ is the tuberculosis rate in city *i* at time *t*, while $InfantRate_{i,t}$ is the infant mortality rate for city *i* at time *t*. $ForeignPercent_{i,t}$ is the percentage of the population that was white and foreign-born for city *i* at time *t*. $HomesOwned_{i,t}$ is the percentage of families that owned their home for city *i* at time *t*.

Figure 4 shows tuberculosis mortality for Framingham and the average tuberculosis mortality for cities in the sample. Figure 5 shows the same for infant mortality. Framingham is noisy because it is one city being compared to the average of 58 cities. However, it is below the average tuberculosis mortality and average infant mortality for the remainder of the sample for the entirety of the Demonstration except for 1924, during which Demonstration activities were winding down. A rise in tuberculosis mortality occurred in 1918, at the same time as the Spanish influenza pandemic, and the mortality rate for tuberculosis fell overall from 1917 to 1923. Reductions in infant mortality toward the end of the Demonstration, between 1920 and 1922, are especially large.

Demonstration officials studied vital statistics data for Framingham in order to assess the severity of Framingham's problems with tuberculosis. Mortality statistics generally record only the number of people who die within a town or city within a year, rather than the number of

residents of the city who die. The Demonstration officials re-computed the death rates for Framingham by examining death records, eliminating non-residents, and adding the residents of Framingham who had died outside the city limits. In this way, they were better able to analyze death rates of the residents of Framingham. For example, they were able to include tuberculosis patients from Framingham who were sent to sanatoria outside the city in Framingham's death rates.[38] While the "residents and transfers" mortality and tuberculosis data computed during the vital statistics survey in Framingham was digitized and analyzed, it was standardized to the age distribution of the population of Sweden[39], while the other data digitized for this paper was not. Data for other cities also did not include residents who had died outside the city limits, and the various cities thus could not be analyzed together. Therefore, while it could be valuable as a way to analyze the mortality situation in Framingham, it is not used in this model.

In the dataset, each city-year entry has a binary intervention variable. The variable is set to 1, or "on," for Framingham during the years of the Demonstration, 1917 to 1923, and 0 or "off" otherwise. The variable turns off for Framingham in 1923 rather than the official Demonstration end date of 1924 because most Demonstration tasks were completed by the end of 1923. 1924 was largely spent transferring programs to the control of Framingham and completing administrative tasks rather than in working on reducing tuberculosis.

Linear Regression Model

We use a difference-in-difference specification to examine the effect of the Framingham intervention on two outcome variables: tuberculosis mortality per 100,000 and infant mortality per 1,000 live births. As we noted earlier, there is only one 'treated' city, Framingham. The data

[38] National Tuberculosis Association, *Framingham Monograph No. 3*: 10-13. It was possible for Demonstration officials to calculate the number of residents who died outside Framingham because during this period the state of Massachusetts mailed copies of death certificates to the town of residence for the deceased.
[39] The population of Sweden seems to have been used as a standard for age distribution during this period.

span 1900-1937 for tuberculosis and 1915-1937 for infant mortality. The treatment turns on in 1917 and off in 1924. Later, we use synthetic control analysis[40] to check the robustness of the difference in difference results.

The regression model is:

$$y_{it} = \beta_0 + \beta_1 Intervention_{it} + \beta_{2i} City + \beta_{3t} Year_t + \beta_{4i}(City * Time)$$

y is the outcome variable in city i at time t. Intervention is a 0-1 indicator variable that is equal to 1 in Framingham for 1917-1923. City is city fixed effects; Year is year fixed effects; and City*Time are city linear time trends. Standard errors were clustered by city.
Regressions were run both with and without population weighting.

Table 2 reports the results of the model for tuberculosis mortality and infant mortality, both with and without population weighting. By these estimates, tuberculosis mortality decreased by approximately 22 deaths per 100,000 population and infant mortality decreased by 11 to 14 deaths per 1,000 live births. This represents a decrease of 18.8 percent in tuberculosis mortality and a decrease of 12.2 to 15.5 percent in infant mortality over the means for Framingham in the pre-Demonstration period.

Synthetic Control Method

The synthetic control method first described by Abadie and Gardeazabal (2003) was run as a robustness check for the difference in difference model. The synthetic control method uses a weighted average of data from other cities to construct a synthetic version of Framingham where the Demonstration never took place. The weights were decided using predictors of the composition of the city that determined similarity to Framingham. Tuberculosis mortality was then calculated for synthetic Framingham using the weighted average of other cities. Seven cities

[40] Alberto Abadie and Javier Gardeazabal, "The Economic Costs of Conflict: A Case Study of the Basque Country," *The American Economic Review*, Vol. 93, No. 1 (March 2003): 116-119. Abadie and Gardeazabal were the first to use the synthetic control analysis method.

with missing data were dropped entirely, leaving a pool of 53 cities including Framingham. Synthetic values for infant mortality were constructed using the same weights used for the synthetic values for tuberculosis mortality.

The synthetic version of Framingham measuring the effects of the Demonstration's beginning was created from three cities using population, the percentage of the population that was foreign-born and white, and percentage of home ownership as predictors. The foreign-born population and home-owning population were used as indicators of poverty. The two cities used to create synthetic Framingham were Brookline, with a weight of .467, and Lowell, with a weight of .533. The rest of the optimal weights were zero. While using only three cities to construct synthetic Framingham seems low, Abadie and Gardeazabal's original paper uses only two cities to construct their synthetic model, and removing predictors leads to more cities being used in the weighted average.

Table 3 reports the tuberculosis mortality rates for the real and synthetic versions of Framingham and the difference between them. Figure 6 displays the values for tuberculosis mortality in real Framingham and synthetic Framingham for 1900-1936. While Framingham's tuberculosis mortality rate is noisy because it is one town with relatively small population, the real rate is relatively similar to the synthetic rate from 1900-1916. The real rate is less than the synthetic rate for the entire period of the Demonstration by a larger amount than the reduction of 22 deaths per 100,000 population indicated by the linear model. From 1924 on, the synthetic rate is very similar to the real rate. These differences indicate that the findings of the linear model for tuberculosis mortality are robust.

Table 4 reports the infant mortality rates for the real and synthetic versions of Framingham and the difference between them. Figure 7 displays the values for infant mortality

in real Framingham and synthetic Framingham for 1900-1937. The lack of data before 1914 and the noise caused by Framingham's small population make it hard to tell how close the synthetic model is to the real values before the Demonstration. However, they do seem to be relatively similar over the three years before the Demonstration, with only small differences for 1915 and 1916. The real rate is less than the synthetic rate for the entire period of the Demonstration by a larger amount than the reduction of 11 to 14 deaths per 1,000 live births indicated by the linear model. In 1924, the real and synthetic values are similar. However, from 1925 to 1931, there is a similarly large gap between the real and synthetic values, indicating that the Demonstration may have had a more lasting effect for infant mortality.

Causality

Crowding Reductions

Based on the US Census data for 1910, 1920 and 1930 on number of households and population of Framingham and the cities used by the National Tuberculosis Association as control cities[41], Table 5 reports the average number of people per household in Framingham and the control cities. It seems that Framingham experienced no more of a reduction in housing density than other similar cities between 1910 and 1930, with the average number of people per household dropping by only 0.27 people as compared to as many as two people in other cities.

After the 1919 children's summer camp in Framingham, a survey was conducted of the families and households of the children who had participated in the camp – a sample of the children considered most at-risk of contracting tuberculosis. The average family size among that sample was 6.3 people with 2.5 adults and 3.8 children. Households had an average of 0.3 lodgers. There is no record of how many families were surveyed, but based on the total number of lodgers, which was 24, it seems that approximately 80 families were included in the sample.

[41] Those cities were Chicopee, Clinton, Fitchburg, Gardner, Marlborough, Milford and North Adams.

Of the households surveyed, 88% had children sharing beds with either their parents or other children.[42] While the housing survey is hardly a representative sample, it does find that there may have been more crowding in the households considered most at-risk than in the general population. However, based on the data it seems that Framingham did not experience a greater reduction in crowding than other areas, and thus extra reductions in crowding cannot explain changes in Framingham's tuberculosis and infant mortality rates during the Demonstration.

Nutritional Improvements

Much of the educational material distributed in Framingham was in the form of the Health Letters. The Health Letters especially emphasized the consumption of milk, recommending a quart per day per child, and a pint per day for adults. The letters also emphasized making sure that milk was pasteurized or came from tuberculin-tested cattle. It seems that most of the food-related letters concerned proper food safety rather than the type of food that should be consumed. There are only one or two letters in the material that mention types of food people should be eating. They advised avoiding food that was too cold or too hot, including ice water, and consuming bread and raw vegetables at the beginning of each meal to encourage digestion. The letters also advised avoiding over-consumption of meat, eggs and other proteins, although in moderation those were encouraged as well.[43] The actual effect of the encouragements in the Health Letters is unclear, but they do provide some insight into what the Community Health Station was trying to promote.

The children's summer camp focused both on making sure children got enough calories and making sure that they were fed a healthy diet. Children were fed two meals and a snack, an average of 1324 calories per person - the camp meals nearly met a child's daily nutritional value

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[42] National Tuberculosis Association, *Framingham Monograph No. 7* (Framingham, Mass.: Community Health Station, 1920): 23.

[43] National Tuberculosis Association, *Framingham Monograph No. 8*, 13, 34, 69.

as determined at the time. There was a dietician who directed all food preparation. 40.76 percent of the food consumed by the children was milk or cheese, and 13.22 was fruits and vegetables. This distribution of types of food was different from that which the children ate at home. Children were, however, taught their dietary needs and follow-up home visits found that children were, at least, drinking more milk after the camp.[44]

There is no significant evidence from the Framingham Monographs or other primary documents that the availability of food in Framingham changed or that people significantly changed their nutritional habits on their own beyond what appeared in the Health Letters.

Water and Sewers

Framingham's water and sewer system was not joined with that of Boston until 1951.[45] During the period studied Framingham seems to have been on a system of wells and, probably mostly in the rural areas, privies. While a survey of the sanitation of those wells and privies is mentioned several times throughout the Framingham Monographs and other available literature, they do not report the results of that survey. No matter the results of the survey, it does not seem that there was any significant change in the Framingham water supply during the Demonstration. Expansion of the sewer system was planned, but it is unclear whether the expansion was implemented.[46]

During the Demonstration, a survey of schools and workplaces was performed, including of toilet facilities. The facilities were found to generally be dimly lit and dirty, often with out-of-date trough equipment. It seems that during the Demonstration, new schools were contracted for,

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[44] National Tuberculosis Association, *Framingham Monograph No. 7*, 14-19.
[45] *An Act to include the town of Framingham within the south metropolitan sewerage district.* Massachusetts Chap. 0527 (1951). http://archives.lib.state.ma.us/bitstream/handle/2452/115182/1951acts0527.txt?sequence=1 (accessed 29 March 2014).
[46] National Tuberculosis Association, *Framingham Monograph No. 10*, 31.

and construction begun on some of them, with plans for more modern toilet facilities.[47] A similar study performed on factories also called for the improvement of toilet facilities, but there is no mention of improvements made based on such recommendations.[48]

Drinking facilities in schools and factories were examined in the same survey. It was found that many schools and workplaces were using common cups or unsanitary drinking fountains that risked spreading disease. Plans for the new schools involved more sanitary drinking fountains, and factory owners were given the recommendation to update their facilities. What was accomplished was the banning of common cups in many schools and factories, which likely helped prevent some transmission of disease in general.[49] Although tuberculosis does not spread through saliva,[50] it is possible that tuberculosis-infected sputum or airborne bacteria could have been spread through the use of the common cup, and other diseases could have been spread the same way. Therefore, the banning of the common cup may have had at least an indirect effect on the reduction of tuberculosis mortality.

Spanish Influenza

Framingham Monograph No. 9 describes the flu epidemic in Framingham. Framingham experienced two waves of the flu, in October and December 1918. Between September 1918 and June 1919, there were 118 deaths. 12% of the population total contracted influenza. However, only 4% of those with tuberculosis, either active or inactive, were affected, and only 2% of those with inactive cases of tuberculosis were affected. There was a follow-up program developed in Framingham to reach out to all flu patients, especially those who also suffered from tuberculosis.

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[47] National Tuberculosis Association, *Framingham Monograph No. 10*: 31, 76; National Tuberculosis Assocation, *Framingham Monograph No. 6*: 14-15.
[48] National Tuberculosis Association, *Framingham Monograph No. 10*, p. 78; National Tuberculosis Association, *Framingham Monograph No. 6*: 40.
[49] National Tuberculosis Association, *Framingham Monograph No. 6*, 1919.
[50] Center for Disease Control and Prevention, "Basic TB Facts," http://www.cdc.gov/tb/topic/basics/default.htm (accessed 30 March 2014).

Starting about three months after the end of the second wave of influenza cases, there were three follow-ups of flu victims: the first covered 700 people, the second 644 of the 700 from the previous follow-up and the third 600 of the cases from the previous follow-up. The follow-ups especially focused on patients who also had tuberculosis. During the second follow-up, it was found that 10 patients had inactive tuberculosis, all of which were already known. None of those cases had become permanently active, and the cases that had been activated soon became inactive again. There were 13 new active cases of tuberculosis. During the third follow-up, it was found that all cases of tuberculosis were inactive, but two of the original 700 cases chosen for follow-up had died of tuberculosis.[51]

Based on this evidence it seems that the Spanish flu pandemic did not significantly raise or lower tuberculosis mortality in Framingham during the Demonstration.

Conclusion

The Framingham Community Health and Tuberculosis Demonstration used a variety of public health methods to decrease tuberculosis and infant mortality. Most of these public health methods were based on encouraging the populace to adopt better personal health and hygiene habits. The main thrust of the Demonstration's activities was an educational campaign, which emphasized the necessity of yearly medical examinations and good hygienic practices. While other methods, such as inspections and improvements of schools and workplaces and free examination of most of the town's residents, were used in the course of the Demonstration, they usually were tied in with the educational campaign and were focused on ways to make better hygiene and health habits easier for Framingham's residents to adopt. The emphasis on personal habits seems to have been effective in helping reduce both tuberculosis and infant mortality

[51] National Tuberculosis Association, *Framingham Monograph No. 9* (Framingham, Mass.: Community Health Station, 1922), 12-15.

during the Demonstration. Based on both of our models, there was a significant decrease in tuberculosis and infant mortality during the period the Demonstration took place. Tuberculosis mortality decreased by 18.8 percent of the mean tuberculosis mortality rate in Framingham between 1900 and 1916. Infant mortality decreased by between 12.2 and 15.5 percent of the mean infant mortality rate in Framingham between 1914 and 1916. Factors such as reductions in crowding, improvements in nutrition, improvements in water quality and interaction with the Spanish influenza pandemic are often correlated with decreases in tuberculosis. However, based on our analysis of circumstances in Framingham, it seems that these played a minimal role in the reductions in tuberculosis mortality during the Demonstration.

The intense focus on changing personal habits rather than on changing circumstances that might lead to higher tuberculosis mortality could explain why the gains in tuberculosis mortality in Framingham were not sustained past the end of the Demonstration. After the Demonstration, there were no longer weekly health letters and advertisements for methods to fight tuberculosis. It is possible that once there was no longer a constant reminder of how to take proper care of themselves and, in the process, prevent tuberculosis, Framingham's citizens returned to their old habits. The Demonstration also made it easier to practice good habits by offering services such as free medical examinations in an early campaign. With the end of some of these services, practicing good health habits may have become harder. With tuberculosis mortality rates falling, it also may have begun to seem less important to practice habits that would prevent tuberculosis. Other towns may also have begun to catch up to Framingham after the Demonstration ended. Based on the synthetic control model, gains in infant mortality may have been sustained until 1930. This may be because services specifically geared toward promoting infant health were transferred to the jurisdiction of the town rather than ending.

Tables and Figures

Figure 1: Trends in tuberculosis over the 20th century. Source: George W. Comstock, *Advances Toward the Conquest of Tuberculosis*, Public Health Reports, September-October 1980, Vol. 95 No. 5 447, "Landmarks in American Epidemiology"

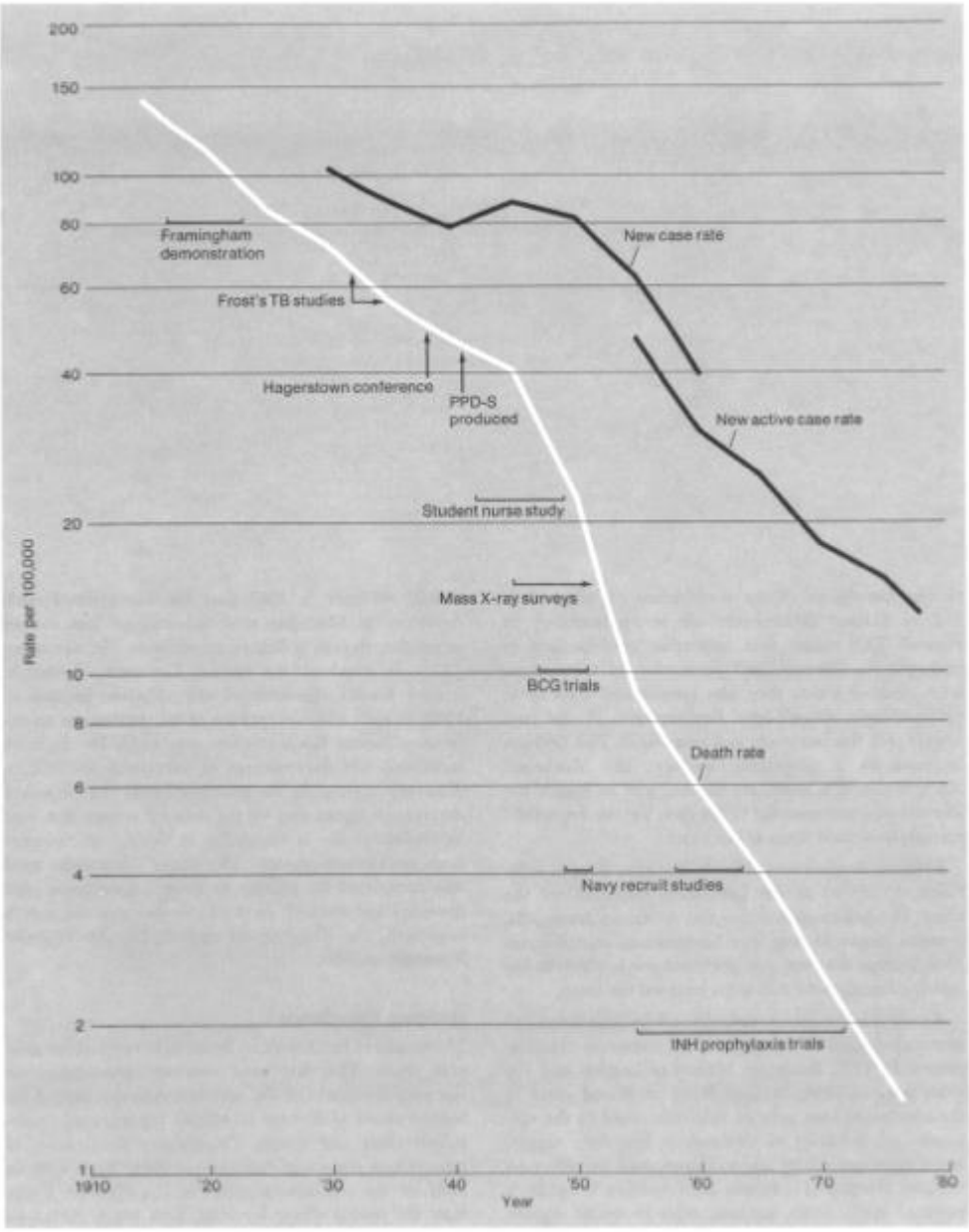

Figure 2: Poster from an educational campaign about tuberculosis. Source: Rensselaer County Tuberculosis Association, *Prevent Disease: Careless Spitting, Coughing, Sneezing, Spread Influenza and Tuberculosis*, ca. 1925, National Library of Medicine.

Figure 3: Timeline of the Demonstration

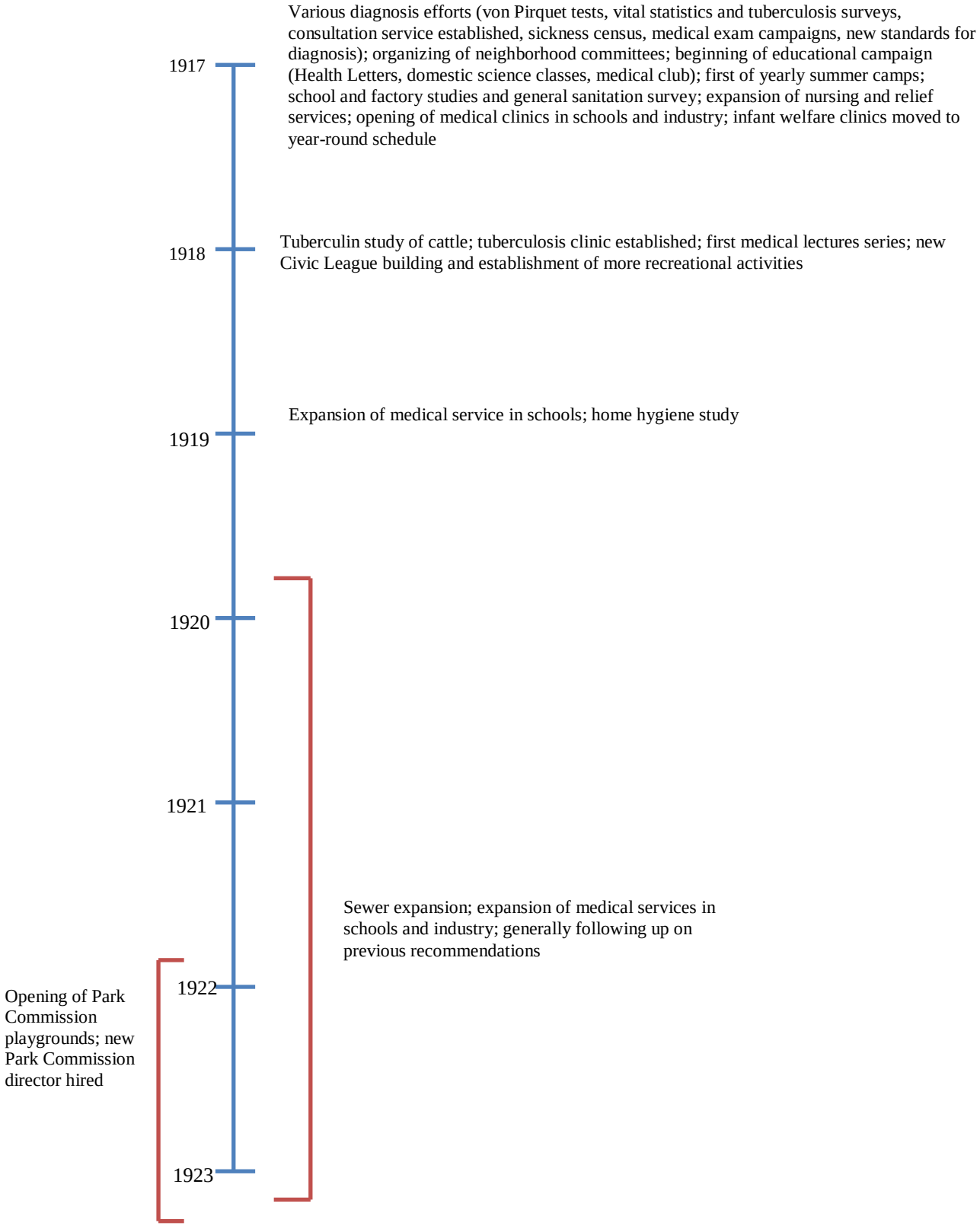

Figure 4: Tuberculosis mortality over time

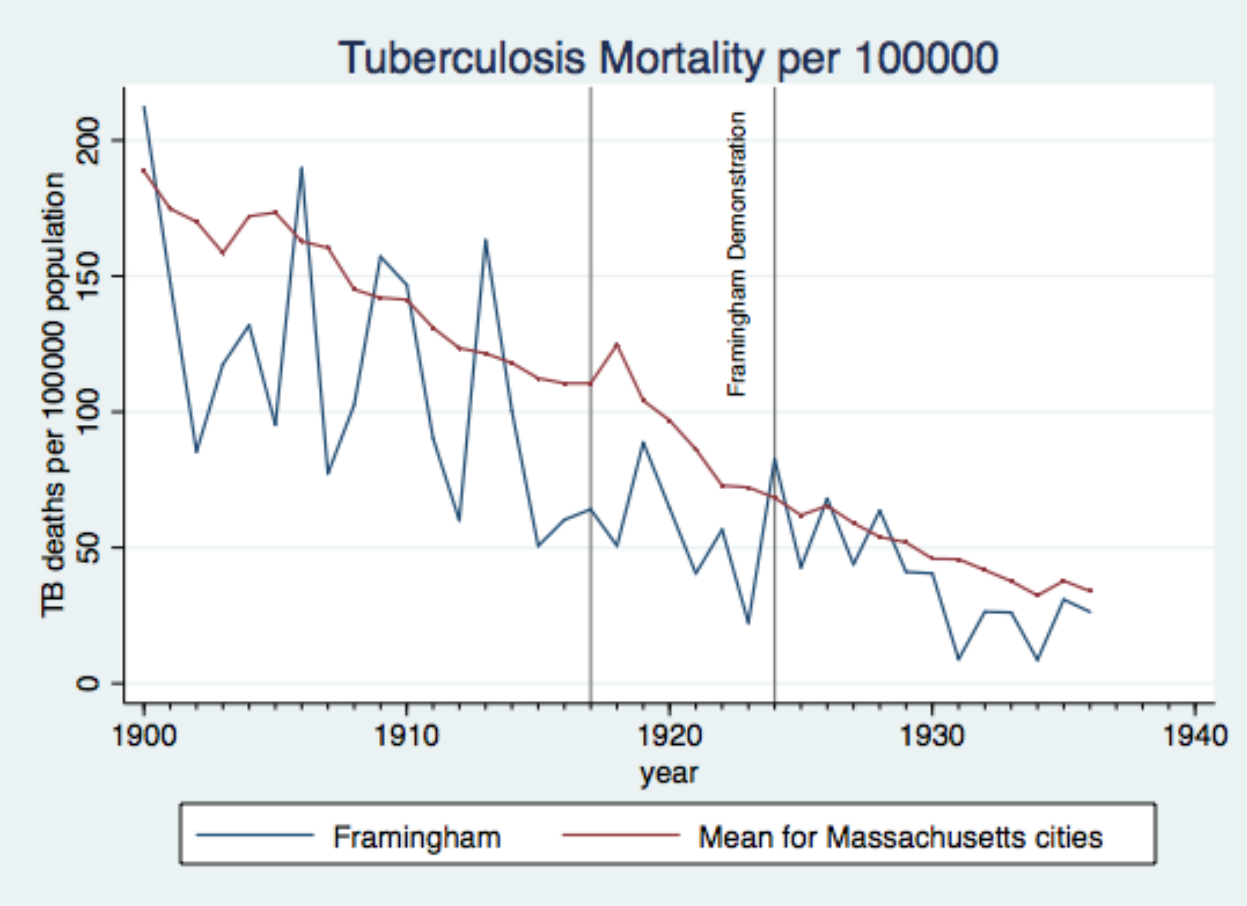

Figure 5: Infant Mortality Over Time

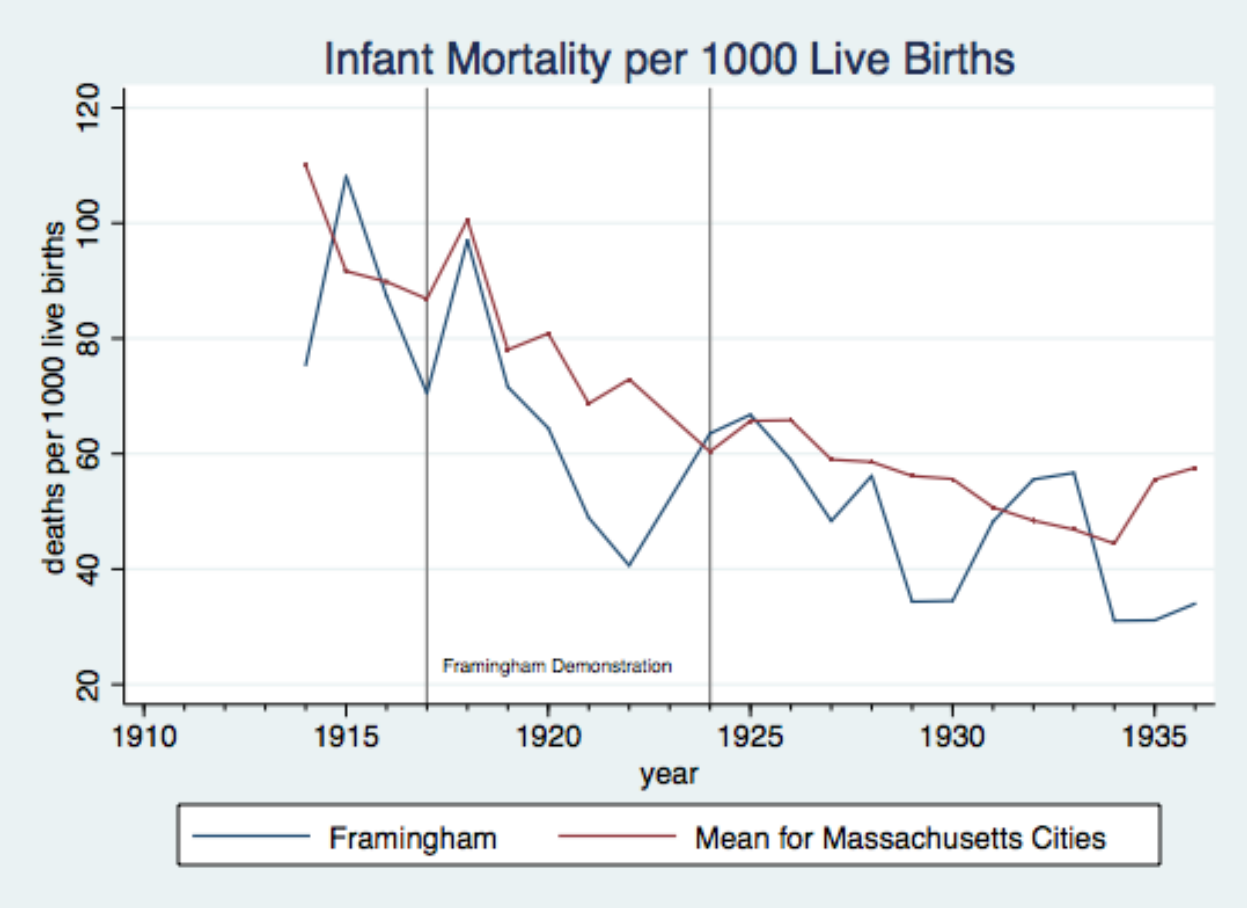

Table 1: Descriptive Statistics

VARIABLES	Observations	Mean	Std. Dev.	Min	Max
All Cities					
$Population_{i,t}$	2126	50666.99	96223.11	8047	829251
$MortRate_{i,t}$	2126	1327.091	393.5205	122.3374	3778.422
$TBRate_{i,t}$	2126	100.1905	66.97582	0	527.2824
$InfantRate_{i,t}$	1296	67.75045	34.92449	3.47354	661.017
$ForeignPercent_{i,t}$	1702	.2790185	.0662122	.1352903	.4810576
$HomesOwned_{i,t}$	1742	.3898412	.1486006	.1272161	2.520352
Framingham					
$Population_{i,t}$	37	16997	4575.397	11302	24342
$MortRate_{i,t}$	37	1432.738	250.8407	979.6306	2200.214
$TBRate_{i,t}$	37	77.99148	50.7276	8.631106	212.3518
$InfantRate_{i,t}$	22	58.32409	21.16426	31.04213	108.1081
$ForeignPercent_{i,t}$	31	.2304301	.008385	.2115555	.2437442
$HomesOwned_{i,t}$	31	.4167921	.0422083	.377397	.5174178
Demonstration Control Cities					
$Population_{i,t}$	259	21916.65	10511.6	10813	46472
$MortRate_{i,t}$	259	1339.258	270.6705	569.0872	2275.91
$TBRate_{i,t}$	259	100.0308	53.17562	0	264.5308
$InfantRate_{i,t}$	154	72.8485	29.11745	11.23596	180.9524
$ForeignPercent_{i,t}$	217	.2988724	.064867	.1784821	.4426625
$HomesOwned_{i,t}$	217	.3913504	.0764937	.2520124	.6835393
All Control Cities					
$Population_{i,t}$	2089	51263.34	96964.69	8047	829251
$MortRate_{i,t}$	2089	1325.22	395.3687	122.3374	3778.422
$TBRate_{i,t}$	2089	100.5837	67.17139	0	527.2824
$InfantRate_{i,t}$	1274	67.91323	35.09769	3.47354	661.017
$ForeignPercent_{i,t}$	1671	.2799199	.0664796	.1352903	.4810576
$HomesOwned_{i,t}$	1711	.3893529	.1497925	.1272161	2.520352

Table 2: Results of the linear model

VARIABLES	**(1)** ***tbrate***	**(2)** ***infantrate***	**(3)** ***tbrate***	**(4)** ***infantrate***
intervention	-22.584***	-11.649***	-22.543***	-14.341***
	(3.038)	(2.838)	(2.597)	(1.077)
Constant	181.181***	236.296***	187.399***	220.798***
	(4.995)	(16.542)	(4.848)	(6.740)
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
City time trend fixed effects	Yes	Yes	Yes	Yes
Population weighting	No	No	Yes	Yes
Years measured	1900-1937	1915-1937	1900-1937	1915-1937
Observations	2,126	1,296	2,126	1,296
R-squared	0.795	0.556	0.901	0.742

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Results of the synthetic control model for tuberculosis

Year	Real Value	Synthetic Value	Difference
1900	212.3518	169.0311	-43.3207
1901	147.7233	136.5836	-11.1397
1902	85.36794	150.7056	65.33766
1903	117.4497	135.3822	17.9325
1904	131.9479	111.9841	-19.9638
1905	95.25459	136.4138	41.15921
1906	189.7042	139.7076	-49.9966
1907	77.27975	144.2705	66.99075
1908	102.6079	114.2661	11.6582
1909	157.1833	118.9285	-38.2548
1910	146.7408	102.4268	-44.314
1911	90.30704	107.559	17.25196
1912	60.08261	105.2736	45.19099
1913	163.1926	89.70608	-73.48652
1914	100.4016	99.44475	-0.95685
1915	50.63291	94.12029	43.48738
1916	60.26274	114.2694	54.00666
1917	64.11751	117.8644	53.74689
1918	50.64431	136.4047	85.76039
1919	88.70491	103.471	14.76609
1920	64.58052	83.94008	19.35956
1921	40.49754	73.77918	33.28164
1922	56.61552	79.82867	23.21315
1923	22.32766	64.57108	42.24342
1924	82.56729	74.6027	-7.96459
1925	42.69855	74.96746	32.26891
1926	68.06425	72.72034	4.65609
1927	43.84811	48.17057	4.32246
1928	63.62942	61.1297	-2.49972
1929	41.08126	56.46729	15.38603
1930	40.52229	48.46225	7.93996
1931	8.890864	43.52912	34.638256
1932	26.40496	32.10836	5.7034
1933	26.14265	41.13277	14.99012
1934	8.631106	26.32911	17.698004
1935	30.90371	34.30326	3.39955
1936	26.32156	33.45478	7.13322

Figure 6: Tuberculosis Mortality in Real and Synthetic Framingham

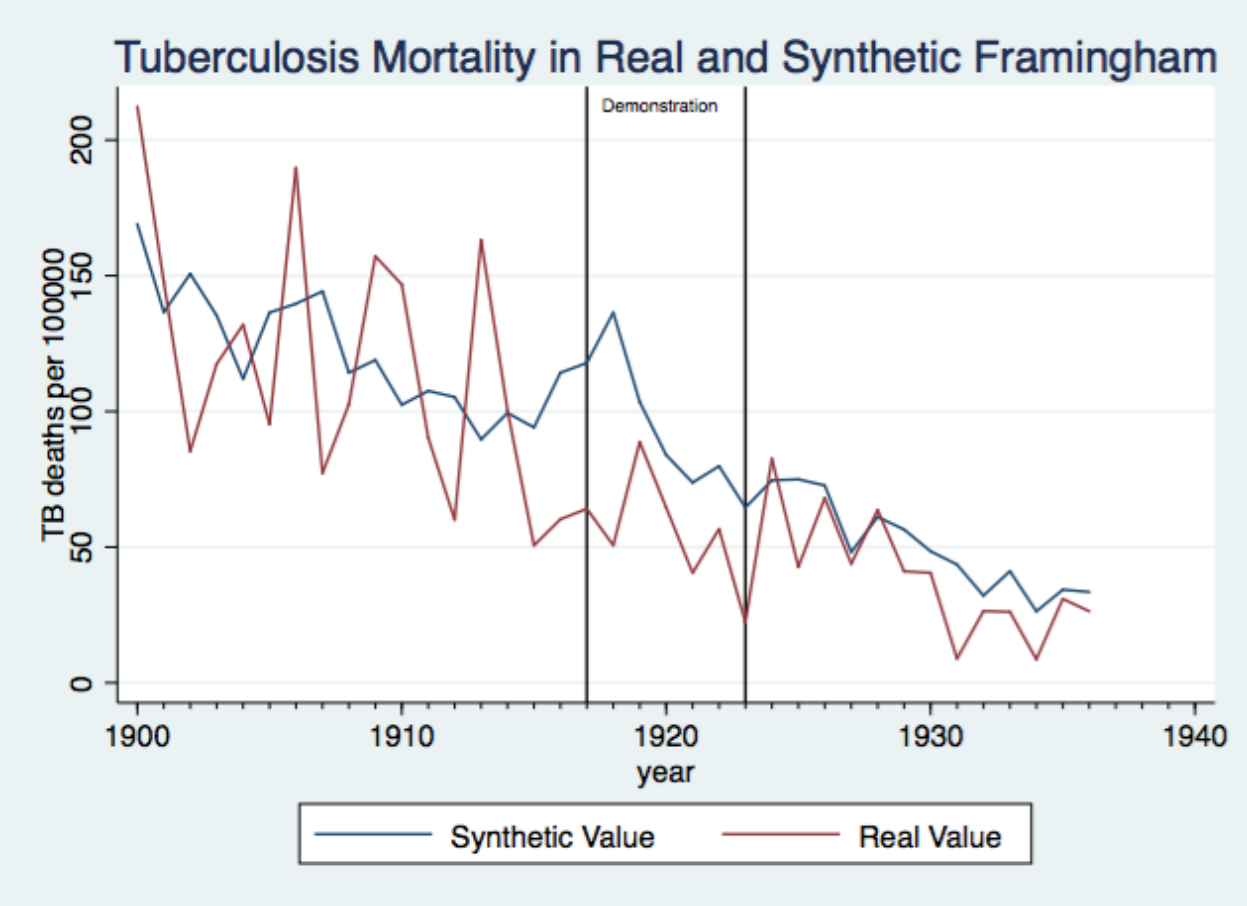

Table 4: Results of the synthetic control model for infant mortality

Year	Real Value	Synthetic Value	Difference
1914	75.36232	116.5134251	41.15110507
1915	108.1081	107.3770724	-0.73102765
1916	87.33624	96.0554996	8.7192596
1917	70.48458	103.3446398	32.8600598
1918	97.04642	113.5650145	16.51859449
1919	71.58836	92.04327643	20.45491643
1920	64.45313	103.0638703	38.61074029
1921	48.91304	67.40266978	18.48962978
1922	40.625	87.50287655	46.87787655
1923	--	--	--
1924	63.51791	64.38932245	0.87141245
1925	66.77525	91.87767161	25.10242161
1926	58.92256	71.7653772	12.8428172
1927	48.33837	86.87244669	38.53407669
1928	56.15942	80.59662154	24.43720154
1929	34.35805	71.65022618	37.29217618
1930	34.48276	59.42893964	24.94617964
1931	48.23748	47.8051339	-0.4323461
1932	55.55556	62.65947442	7.10391442
1933	56.68934	48.56099467	-8.12834533
1934	31.04213	54.80274645	23.76061645
1935	31.12033	47.47484287	16.35451287
1936	34.01361	60.33094953	26.31733953

Figure 7: Infant Mortality for Real and Synthetic Framingham

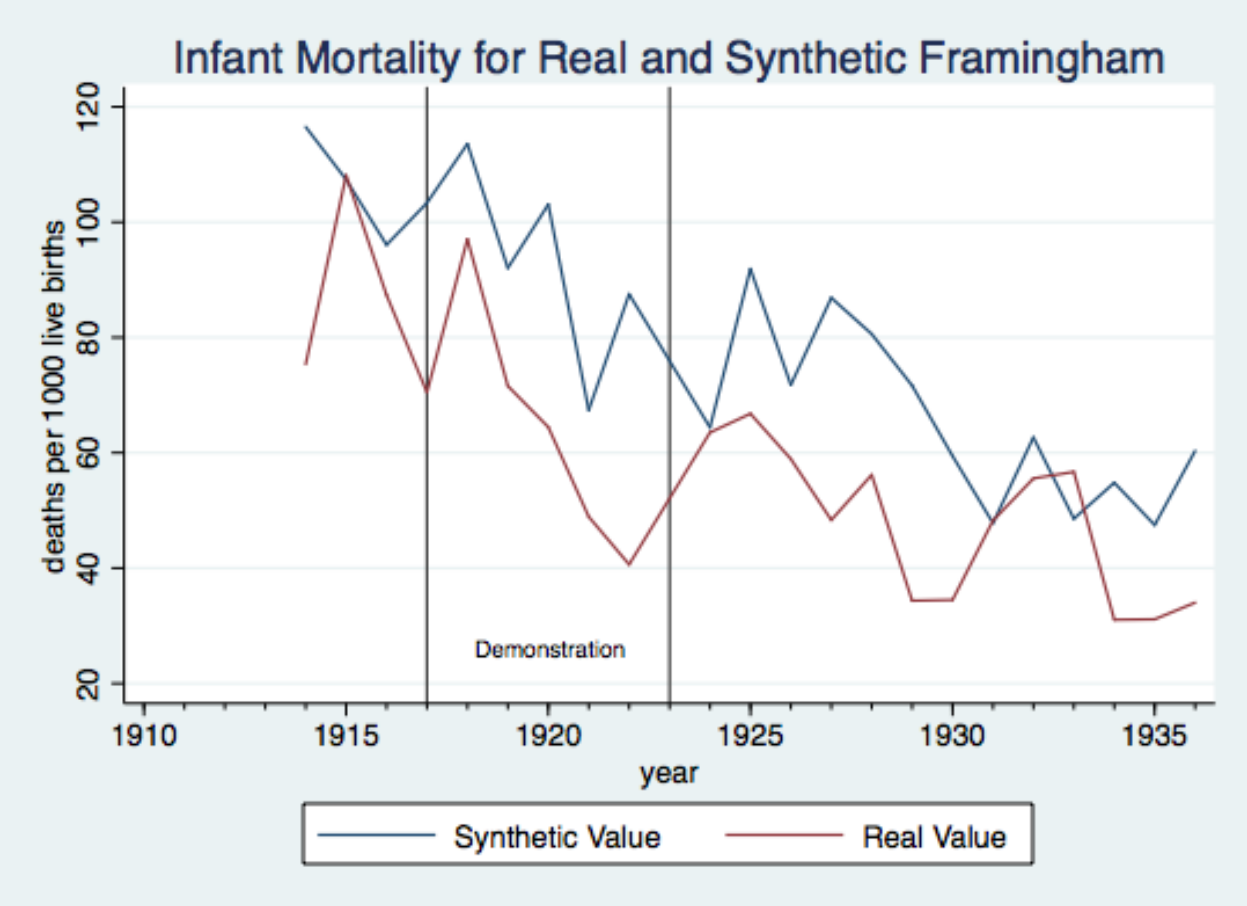

Table 5: Average number of people per household

City	1910	1920	1930	Total Reduction, 1910-1930
Framingham	4.64	4.39	4.37	.27
Chicopee	5.72	5.17	4.71	1.01
Clinton	4.97	4.60	4.31	.66
Fitchburg	4.77	4.42	4.23	.54
Gardner	4.80	4.71	2.62	2.18
Marlborough	4.40	4.26	4.28	.12
Milford	4.51	4.55	2.37	2.14
North Adams	4.65	4.44	4.10	.55

Appendix A: Data Construction

For 1900-1913, all data was collected from the Census Bureau's *Mortality Statistics*. For 1914, most of the data for population, total number of deaths and number of deaths in infancy were collected from the *Vital Statistics of Massachusetts*, and the data for deaths from tuberculosis and some of the remaining data from the other categories were collected from the US mortality statistics, as the Massachusetts volumes only listed deaths from pulmonary tuberculosis and was missing population and infant mortality data for some cities. For 1915-1920, all data possible was collected from the Massachusetts vital statistics volumes with some of the missing data filled in from the US mortality statistics. For 1921-1936, all data was collected from the Massachusetts vital statistics volumes, with no missing data.

Data for number of foreign-born whites, number of families, total number of homes and number of homes owned were collected from the US Census reports for 1900, 1910, 1920 and 1930 and was calculated by linear interpolation for years the census was not taken and for the 33 cities with population under 25,000 in 1920, as data was not available for those cities in that year.

From 1900-1913, there is no data for cities in the sample that were not registration cities during various years; those cities were excluded for any years where there is no data. Registration cities were those of population greater than 8,000 which were determined to have accurate enough death registration to be used by the Bureau of the Census. From 1914-1920, some data is missing for population and infant mortality for the cities not in the registration area where that data was unreported in the Massachusetts volumes. Population for those cities was imputed using linear interpolation.

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