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Factors in the Drop in United States Infant Mortality: 1900-1940

Rose Goff
Carnegie Mellon University

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Rose Goff, College of Humanities and Social Sciences
Advised by Professor Karen Clay, Professor of Economics and Public Policy

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Abstract

This paper examines the causes of the steep drop in United States infant mortality, 1900-1940. I consider the country's national experience, as well as the local experience of Pittsburgh. In Section One, I present historical evidence on potential factors in the infant mortality drop. In Section Two, I estimate the effect of several of these factors on the United States infant mortality rate, as well as the Pittsburgh infant mortality rate. I find that the cleaning of market milk and the cleaning of drinking water are associated with significant decreases in infant mortality. My analysis suggests that the effect of the national cleaning of market milk was greater than the effect of the cleaning of water.

Introduction

At the close of the 19th century, infant mortality rates in regions of the United States and Western European countries were even higher than the rates in Africa today, ranging from about 100 to 350 deaths per 1000 live births. Over a roughly fifty year period the rates then dramatically dropped, down to below 50 deaths per 1000 live births by 1950.[1] It is clear that there are a number of factors that together caused this demographic change. However, the relative importance of these different factors is not well understood.[2]

Social scientists have broadly attributed the twentieth century infant mortality drop to improved nutrition, economic growth, advancing knowledge of infant care, and sanitary measures like the cleaning of drinking water and market milk.[3] The literature offers alternative views on which factor most significantly contributed to the drop in the United States. Lee (2007) presents a qualitative review of historical data on the decline and concludes that the cleaning of the market milk supply was the single most important contributor to the infant mortality drop. In

[1] See Lee (2007), 3

[2] Few quantitative studies have examined the factors that contributed to this drop. Cutler and Miller (2005) is the only multi-state econometric study that I know of that examines the early twentieth century infant mortality decline in the United States. There are many related studies. For instance, Cheney (1984) reviews data on seasonal infant mortality, and Currie and Neidel (2005) estimate the effect of air pollution on infant mortality in the 1990s.

[3] See Mckeown (1975), Preston and Haines (1991), Lee (2007), and Cutler and Miller (2005)

contrast, Cutler and Miller (2005) present regressions that indicate that clean water was responsible for 75% of the drop. That said, the authors' analysis focuses on the filtration and chlorination of water and does not take into account the cleaning of market milk. I am aware of no economic study that has examined the infant mortality drop and taken into account both the cleaning of water and the cleaning of market milk.

This paper moves beyond the existing literature by offering a more comprehensive picture of the causes of the drop in infant mortality. In the pages that follow, I will examine the causes of the steep drop in US infant mortality, 1900-1940, using Pittsburgh as a case study. The paper is divided in two parts. Part One is qualitative. It discusses five potential factors in the infant mortality drop. These include (1) the cleaning of water, (2) the cleaning of milk, (3) environmental change, (4) health related change, and (5) the effect of women's groups and the Children's Bureau. For each factor, I sketch important national happenings, as well as Pittsburgh events where relevant. Part Two is quantitative. In this section, I model the contribution of several factors to the infant mortality drop. I first use state level data to estimate regressions that shed light on the national story. I then use newly assembled city level data to estimate regressions that explain the situation in Pittsburgh. To quantify the milk and water effects on infant mortality, I use typhoid mortality as a proxy for the cleanliness of drinking water and tuberculosis mortality as a proxy for the cleanliness of market milk. As a check on the link between infant mortality and clean milk and water, I also test the direct relationship between the proxies for clean milk and water and the main cause of infant death, infantile diarrhea. I also control for health and environment related factors and test for their significance. Finally, I also use dummy variables to test for the effect of prohibition, the Children's Bureau and the Spanish influenza pandemic.

I find that the cleaning of drinking water and market milk are both associated with significant declines in the infant mortality rate. My estimates indicate that the cleaning of the drinking water supply (such that typhoid mortality drops by 1%) lowers infant mortality by .15-.21%. I also find that cleaning the market milk supply (such that the tuberculosis death rate drops by 1%) lowers infant mortality by .32-.50%. In all my specifications, the estimate for tuberculosis (milk proxy) is at least double that of the estimate for typhoid (water proxy). Thus, my results suggest that the cleaning of market milk played a larger role in impacting the infant mortality decline than did the cleaning of drinking water. I also find that my check on the link between the proxy variables and diarrhea confirms the relationship. My estimates suggest that the cleaning of the drinking water supply (such that typhoid mortality drops by 1%) lowers infant diarrhea by .28-.47%, and that the cleaning of the milk supply (such that tuberculosis mortality drops by 1%) lowers infant diarrhea by .34-.72% ($p < .01$).

In this way, my quantitative findings support Lee's assertion that market milk was an extremely important factor in the infant mortality drop, more important than family income, medical intervention or other sanitary measures like the cleaning of water. My findings indicate that Cutler and Miller's analysis omitted an important variable, the cleaning of market milk.

The Pittsburgh evidence provides support for the national analysis, suggesting that the national picture corresponds to a local story in at least one region. The historical evidence makes it clear that Pittsburgh had a really awful water supply. My estimates suggest that the cleaning of milk (such that tuberculosis mortality dropped by 1%) significantly decreased Pittsburgh's infant mortality rate ($p<.05$).

The rest of the paper is laid out as follows. Part 1 discusses the potential factors in the infant mortality drop, in five sections – Water, Milk, Environment, Health, and Women's

Groups. Part 2 begins the quantitative analysis. Section 1 describes my methodology and data. Section 2 presents descriptive statistics. Section 3 presents my estimates and I discuss my findings in a final section.

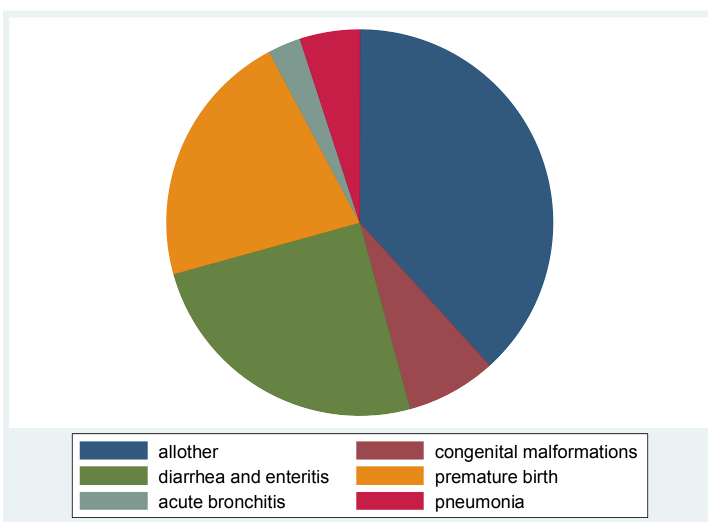
Part 1 begins with a first important factor, clean water.

Section 1: Water

In the late nineteenth and early twentieth centuries, public drinking water was largely contaminated by sewage, making it a major transmitter of disease. The unclean water put infants at risk for two main reasons. First, direct consumption of this water would make babies sick. Sometimes mothers would mix milk with this water and feed it to infants; other times mothers would feed the infants the water directly. This unclean water caused a variety of illnesses in infants, like diarrhea and typhoid, where diarrhea was the most common.

The graph below offers a picture of infant mortality by cause in the United States in the early twentieth century. Typhoid deaths are not recorded, likely because infant deaths due to typhoid at the turn of the century were relatively infrequent or because the disease was not correctly diagnosed.[4] As shown in the graph below, "diarrhea and enteritis" deaths (in green) account for a relatively large share of infant deaths due to disease, nearly one forth.

Graph 1: Infant Deaths due to Disease 1911-1920



Source: *Mortality Statistics 1920, Department of Commerce, Bureau of the Census*. Twenty-first Annual Report, 1922. Data available online at the Center for Disease Control website.
**allother* includes measles, whooping cough, scarlet fever, diphtheria and croup, influenza, erysipelas, tetanus, tblung, tbmeningitis, convlusions, organic diseases of the heart, acute bronchitis, dysentery, diseases of the stomach, congenital formations, injuries at birth, external causes, unknown or ill defined illnesses, and other illnesses

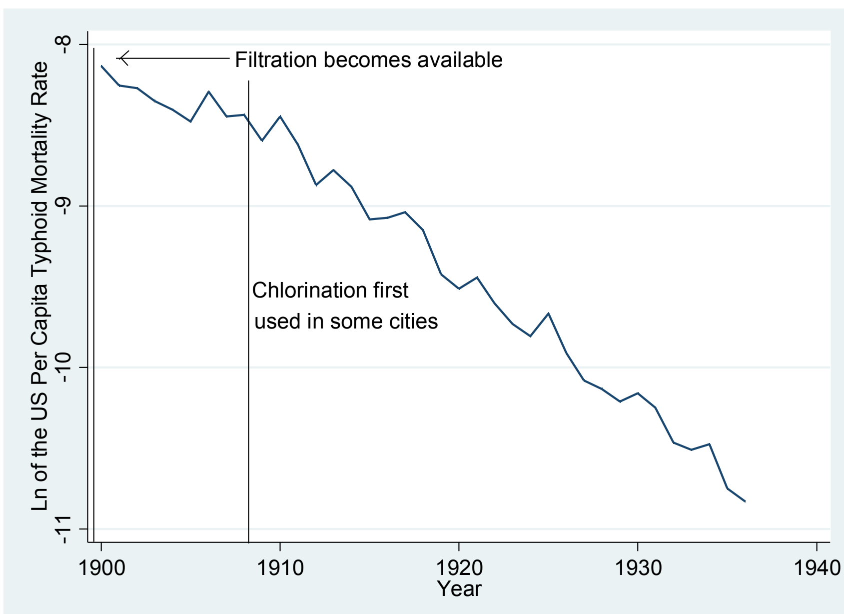
[4] Whipple (1908) notes that in many cases typhoid fever among the fever young were set aside as other diseases, p106

Infants were also affected by the water quality indirectly. For instance, mothers might get sick from the contaminated water and then become unable to provide proper care. An infant might also get exposure to the dirty water while bathing or by touching dirty dishes.

Typhoid Fever as a Marker for Water Quality

One way to measure the sanitary quality of water is to look at the death-rate due to typhoid fever. The relationship between the typhoid date rate and the quality of water is so close that it has long been used for this purpose.[5] Thus, the below graph of the US typhoid death rate offers a snapshot of the change in the quality of water in the US over time.

Graph 2: US Typhoid Mortality Rate



Source: The National Bureau of Economic Research's (NBER) *State Mortality Data, 1900-1936*. (Taken from *Mortality Statistics Volumes, Department of Commerce, Bureau of the Census*. Made available online by the Center for Disease Control and Prevention.)
Note: US per capita typhoid mortality rate calculated by averaging state rates

[5] Whipple (1908) notes the relationship, for instance

Unless otherwise noted, data for all national level graphs included in this paper come from the source mentioned above. As the graph shows, typhoid fever rates at the start of the twentieth century were high. In 1900, typhoid fever caused about 2.4 percent of deaths in major US cities.[6] In that year and during other early years of the twentieth century, many cities had "circular water systems," or a drinking water supply mixed with feces. In the worst cases, the backflow from sewer systems would directly contaminate drinking water.[7]

Science and Dirty Water

This abuse of water systems had its roots, in part, in the common conception of disease. Before 1890, the dominant understanding of disease was that infectious disease evolved *de nova* from putrefying organic matter. Scientists also believed that "running water purifies itself," an idea suggested by chemical analysis at the time.[8] For these reasons, leading sanitarians believed that moving a city's fecal waste to a remote waterway (via streams) would rid the city of the disease-prone matter and alleviate public health problems. Unfortunately, their well-intentioned efforts made the situation worse. Transporting fecal waste via streams contaminated the water and caused increased rates of infectious diseases (like typhoid fever) for communities downstream.[9]

In the 1890s, bacterial researchers built on scientists Pasteur and Koch's work on germ theory and identified the process involved in waterborne disease. The work of William T Sedgewich and others at the Massachusetts Board of Health Lawrence Experience Station was especially important. These bacterial researchers helped clarify the etiology of typhoid fever. From there, the relationship between typhoid and feces-contaminated water was confirmed. This

[6] Cutler and Miller (2005)
[7] Tarr (1996)
[8] The Pittsburgh Filtration Commission's 1899 report notes this (p73). Tarr (1996) also mentions the belief (343).
[9] Tarr (1996) describes the abuse of past water systems (343-4)

created the impetus for the cleaning of water, which led to the development of water purification technologies.[10]

The Cleaning of Water

The first major clean water technology, filtration, became available as early as the 1890s. Over the subsequent fifty years, clean water became a public health issue and major cities gradually began to adopt the technology. Cities like Philadelphia and Pittsburgh adopted the technology as early as 1908, while Memphis and Chicago did not filter public drinking water until after 1936. Though filtration was effective, it did not remove all bacteria from untreated water. Consequently, a number of complementary disinfection processes were investigated. Chlorination was the cheapest. It was first adopted at the Boontoon Reservoir in New Jersey in 1908, and cities in other states soon followed.[11]

As clean water technologies were adopted, the typhoid fever death rate dropped, as shown in Graph 2. By 1936, the percent of deaths caused by typhoid fever had dropped to .1, a 96% decline from typhoid's share of deaths in 1900.

Cutler and Miller (2005) estimate regressions that model this effect. The find that clean water technologies significantly reduced the typhoid mortality rate ($p<.1$), by 25% initially and by 65% after five years, leading to the near-eradication of typhoid fever in 1936.

Unclean Water in Pittsburgh

Pittsburgh is an example of a city where water quality at the start of the twentieth century was particularly poor. Pittsburgh drew its water supply from the Allegheny and Monongahela rivers, while sewage was discharged into these rivers by both Pittsburgh and communities

[10] See Safe Drinking Water Committee (1977), p3 and Tarr (1996), p344

[11] Cutler and Miller (2005) and Tarr (2003) list clean water intervention dates.

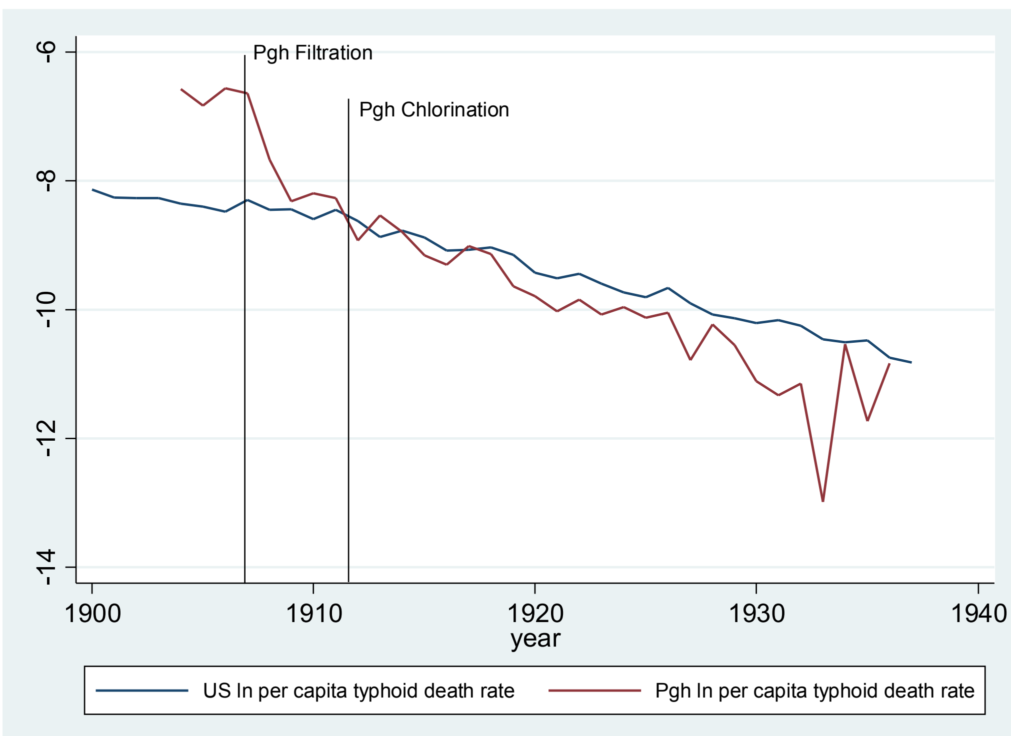
upstream.[12] The Report of the Filtration Commission in Pittsburgh (1899) comments on the situation:

> The sewers of the city of McKeesport, of the boroughs of Homestead, Braddock, Duquesne, and other lesser places, all empty into the river above the intake of the Monongahela Water Company, and as the growth of the population in these towns nad city is rapidly increasing, it is presumable that the amount of sewage emptied into the Monongahela River is destined likewise to increase (16).

This water pollution gave Pittsburgh the highest death rate from typhoid fever in large US cities, 1873-1907. Pittsburgh's rate was well over 100 deaths per 100,000 persons, while the 1905 average for northern cities was 35 per 100,000.[13] The typhoid fever death rate in Pittsburgh, as compared to the national rate, is graphed below.

[12] Described in Pittsburgh Filtration Commission (1899), p 16-17.
[13] See Tarr (2003), 70.

Graph 3: Typhoid Fever Death Rates in Pittsburgh and the US



Source: Newly hand-entered Pittsburgh data comes from *Mortality Statistics Volumes, Department of Commerce, Bureau of the Census*. Data available online at the Center for Disease Control website. National Data from NBER.

All Pittsburgh data for graphs included in this paper come from the hand-entered data set from the Mortality Statistics Volumes mentioned above. As shown on the graph, the typhoid death rate in Pittsburgh began to drop steeply in December of 1907, when the water department delivered the first filtered water to the city. In 1912, the city first chlorinated its water supply. From there, the death rate from typhoid fever dropped to the level of the national average for large cities, as shown on the graph.[14]

Pittsburgh's First Sewage Plant

Though the 1907 filtration and 1912 chlorination were steps in the right direction, Pittsburgh continued to dump sewage into the rivers. In 1923, a newly created Sanitary Water Board created a stream classification system that designated streams into three categories for users. These categories included:

> (1) relatively clean and pure
> (2) polluted but under control, and
> (3) so polluted that use for public water supplies (without treatment), for fishing, and for recreation were unadvisable. In this case, water could continue to be used as dumping ground for untreated waste.

Pittsburgh rivers were deemed category three – that is, they would continue to function as open sewers. It would take years of policy and value changes for the city to treat its sewage and come up with an alternative disposal system. This was finally realized in the 1959, when the Allegheny Country Sanitary Authority (formed in 1946) dedicated the first functioning sewage treatment plant.[15]

The Cleaning of Water and Infant Mortality

[14] This is also mentioned by Tarr, 2003, p73.
[15] Ibid 77-86.

Cutler and Miller (2005) have performed the only econometric study that I am aware of[16] on how the cleaning of water might have impacted the drop in infant mortality in the United States. They used a difference-in-difference approach to test the effects of chlorination and filtration on infant mortality, controlling for several demographic characteristics (population, age structure, sex, racial composition, and share of immigrants). Their regression results indicate that clean water was responsible for three quarters of the infant mortality reduction. That said, Cutler and Miller's model does not take into account other potentially relevant variables, the most important of which is market milk, the subject of my next section.

[16] Other authors have examined the impact of clean water interventions on total mortality (see Gaspari and Woolf's 1985 study, for instance), and other authors have examined the impact of clean water interventions on infant mortality in other countries (see Kinter's 1988 study on Temporal and Areal Variation in Infant Mortality in Germany, for instance) but I am aware of no other study that examples the impact of these interventions on infant mortality in the United States.

Section 2: Milk in the Early Twentieth Century

Drinking milk was another major disease vector in the early twentieth century. The raw (or unpasteurized) milk that was commonly available was often of poor quality, for a number of reasons. First, milk is an ideal environment for breeding bacteria. The older the milk is, the more time the bacteria have to grow. In the summer, the bacteria problem was particularly severe, because milk was often not refrigerated.[17] Second, milk was often transported over long distances and treated improperly while in transit. Milk delivered from far distances showed higher bacterial counts, particularly in cases of delivery delay or improper cooling.[18] Third, adulteration of milk and "swill" milk were also major problems. Swill milk is a term used to describe milk from cows that were fed on distillery waste, the hot alcoholic mash left over from making drinks. This milk was then adulterated with other ingredients like water, eggs, flour, molasses and plaster of Paris to give the "milk" the proper color and volume.[19]

The various types of unclean, high-bacteria milk were especially dangerous for pregnant women and children.[20] In the early twentieth century, there were two main causes of milk-related infant deaths – diarrhea and tuberculosis. As mentioned earlier, infantile diarrhea was a major cause of infant mortality, accounting for nearly ¼ of total infant mortality due to disease (see Graph 1 in previous section) and about half all infant deaths due to infectious disease.[21] Tuberculosis deaths accounted for a smaller but still important share of milk-related infant mortality. In the period from 1911-1920, non-lung tuberculosis deaths accounted for 1.03% of

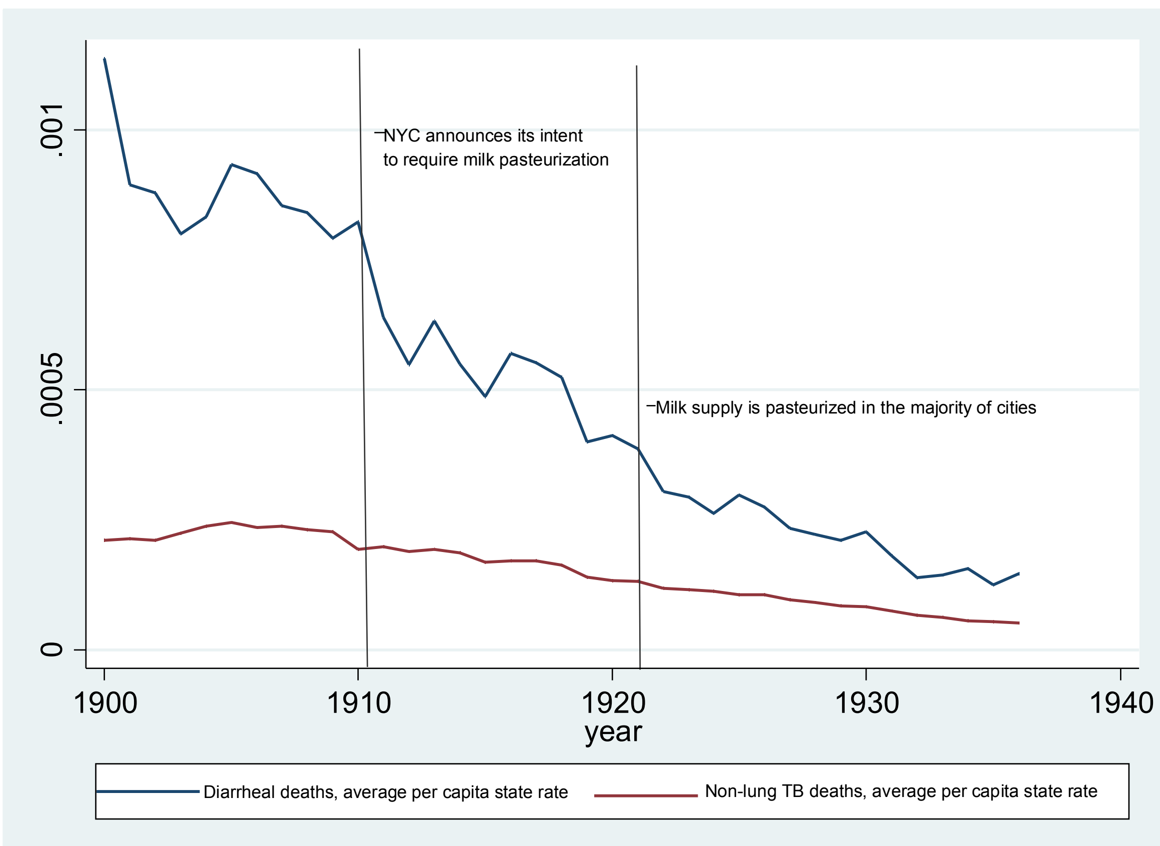
[17] Moring (1998)
[18] Lee (2007)
[19] See Wilson (2008) and "They Ought To Be Beaten: 'Swill Milk Tuomy'" (1878) from the New York Times.
[20] FDA (2009)
[21] *Mortality Statistics 1920* and Lee (2005)

total infant deaths due to disease, 1911-1920.[22] Because of the poor quality of milk, children who were breastfed or used dry milk were protected from these milk-related diseases.[23]

Non-lung Tuberculosis as a Marker for Milk Quality

One way to measure the sanitary quality of milk is to look at the (non-lung) tuberculosis death rate. When infants were fed milk from diseased cattle, they contracted bovine tuberculosis.[24] This relationship between tuberculosis and milk is close, so it is a reasonable proxy. Thus, the tuberculosis death rate offers a snapshot of the changes in the quality of milk in the United States over time, shown on the below graph in red.

Graph 4: Milk Related Diseases: US Death Rates



[22] *Mortality Statistics, 1920*
[23] Beaver; Vanderslic et al (1994)
[24] Atkins (2003)

The Cleaning of Milk

The problem of milk-related infant deaths was ultimately solved by pasteurization, but it was slow to be adopted. The national effort to clean the milk supply began as early as 1830, when reformers voiced concerns about the quality of urban market milk**.** From there, it took until 1921 for the majority of the market milk in large cities to be pasteurized.[25] In the decades depicted in the graph, industrymen, health scientists, politicians and activists all took part in a public drama over the quality of market milk.

Milk Stations

One highlight was the reformers' push for the establishment of milk stations what would provide mothers with free or subsidized milk. New York's first such station was opened on the Lower East side in 1893. Other cities followed, including Pittsburgh in 1898.[26] The milk offered at America's stations often was pasteurized and, initially at least, modified into infant formula. Though these milk stations only supplied a tiny fraction of the milk consumed by cities' babies, they were highly visible and served to bring together milk activists.[27]

The stations were also a focal point of a maternal reform movement. The movement began when activists pushed for a campaign that would educate poor mothers, instruct them on artificial feeding, and encourage them to nurse their infants, rather than feed them market milk). In response, in 1908, the New York Milk Committee incorporated maternal education and infant exams into the activities of the milk stations, and other cities soon followed. By 1915, the campaign was in full swing. That year, 205 agencies (operating 539 infant welfare stations in 142 cities) reported to the U.S. Children's Bureau that their primary concern was education and supervision. In fact, the stations of 95 agencies did not even dispense any milk.[28]

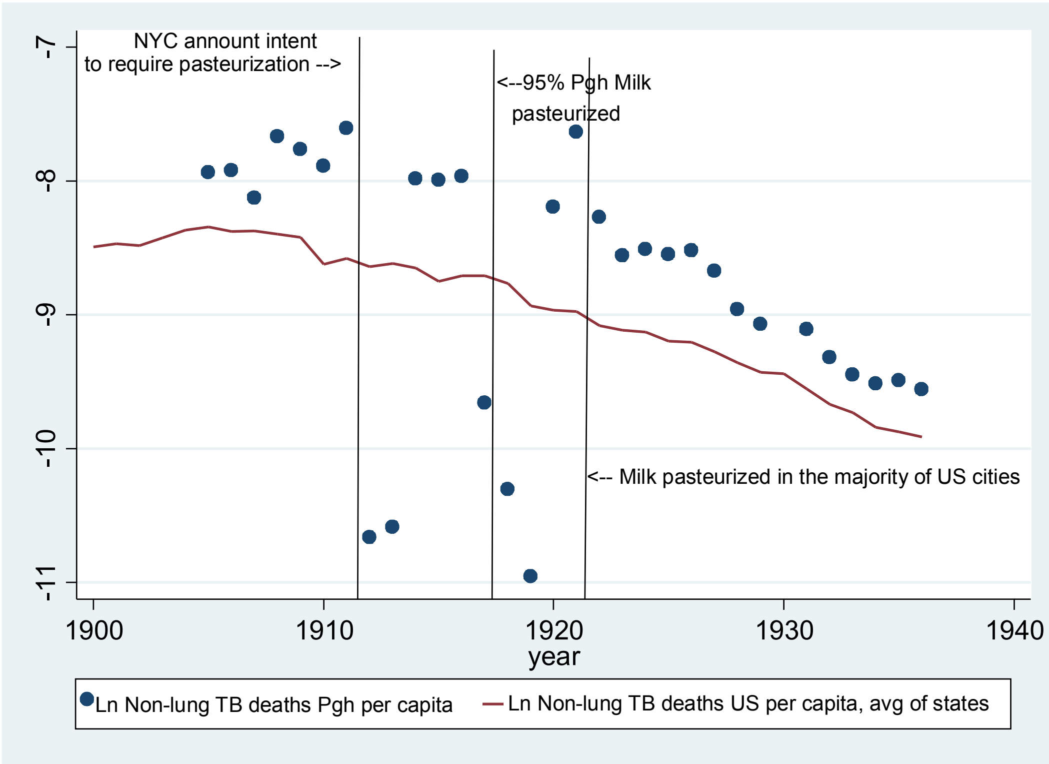
[25] See Meckel (1990), 63-89
[26] See Ravenel (1921), p306.
[27] See Skocpol (490) and Meckel (1990), p78-90
[28] Ibid, 124-125 and Lee (2007)

Development of Pasterization

Around the same time, the goal of clean public market milk supply was gradually being realized. In 1904 and 1906, Conn and then Roseneau removed two obstacles standing in the way of widespread pasteurization. Conn discovered a way to heat milk in a way that would kill pathogenic bacteria without harming the milk, and Roseneau found a way to inhibit the growth of bacteria from heat-resistant spores after the heading had happened.[29] In 1909, Chicago passed an ordinance to limit milk producers that had been voluntarily "pasteurizing" milk in a way that did not clean it, but solely of increased its shelf-life. And in 1910 the New York City health department passed a resolution that held that only *properly* pasteurized milk was safe for drinking. One year later, it announced its intent to require that all milk sold (except certified milk) be pasteurized. Other cities soon followed. A highly publicized discovery of tuberculin cows brought more cities on board, and by 1921 over 90 percent of American cities with populations over 100,000 had the majority of their public milk supplies pasteurized. In Pittsburgh, it was by 1916 that pasteurized milk accounted for 95 percent of the city's milk supply. The below graph depicts declining tuberculosis death rates and the cleaning of market milk in Pittsburgh, as compared to the US. [30]

[29] See Meckel (1990) 87 and Lee (2007)
[30] Ibid 89

Graph 5: Clean Milk and Tuberculosis Death Rates



Milk Stations in Pittsburgh

In the years following the adoption of pasteurization, Pittsburgh followed the national trend and also established milk stations to promote the distribution of affordable pasteurized milk. In the 1920s Pittsburgh's Public Health Nursing Association (PHNA) extended its services to include milk stations at settlement houses, along with related maternal and child health services, nutrition services and well baby clinics.[31] It ran milk stations at a number of locations, such as at the Hill Districts Irene Kaufman Settlement house. These stations were a part of a "Milk Well" program that aimed to offer affordable milk to families.[32] Below is a picture of a 1922 Irene Kaufman milk station.

[31] Visiting Nurse Association of Allegheny Country Records, 1918-1990
[32] See History Jewish Community Center; Power (1932); "Kaufman Settlement's Milk Well" from the Pittsburgh Press (1930).

Milk Station, Irene Kaufman Settlement, August 1922
From the Collections of the Pennsylvania Department, at The Carnegie Library of Pittsburgh

It is available online with the note "for another view of the 'Milk Well' campaign: girls enjoying milk and crackers."

The Cleaning of Milk and Infant Mortality

The effect of the cleaning of the market milk supply on infant mortality in the United States is well understood, though to my knowledge[33] the effect has not been analyzed quantitatively. Lee (2007) conducted a qualitative systematic review of historical data on the cleaning of market milk, in order to understand its effect on infant mortality. He finds that the evidence suggests that the cleaning of the market milk supply was the single most important

[33] Though I do not know of any quantitative studies on the effect of the cleaning of market milk, there are quantitative studies on related topics. For instance, Chen and Rogan (2003) find that breastfeeding is associated with a reduced risk of post natal death using data on US infants in 1988. Rosenberg (1989) examines infant mortality in Norway 1860-1930, and finds that the mortality of children not breast fed was three times that of children breastfed. VanDerslide etc al (1994) studies that interactive effect of drinking water, sanitation and breastfeeding in Filipino infants and finds that breastfeeding provides significant protection to children during the fist 6 months of life. Atkins (2003) offers a qualitative report on mothers milk and infant death in Britain (1900-1940) and finds that unclean milk is responsible for much disease morbidity and mortality.

contributor to the decline in overall infant mortality, far more important than other sanitary measures, or family income or medical intervention. Lee also finds the cleaning of market milk was the most important contributor to the decline in infantile diarrhea, which can be contracted in various manners. (Graph 4 above charts the drop in the diarrheal death rate.)

Section 3: Environment

Environmental conditions also influenced the health of infants. An infants' exposure to environmental hazards largely depended on whether he lived in an urban or rural region. In cities, infants and mothers were exposed to horse manure, garbage, sewage and airborne pollution, all which were likely to have averse health effects. In rural areas, the environment was not changing very quickly. Garbage and air pollution were generally less significant, though infants were still exposed to manure and sometimes human fecal material.

In both cities and rural areas, temperature and precipitation had implications for infant mortality. The effect was sometimes direct, in that babies might die of heat or cold. More often, the effect was indirect, in that temperature and rainfall would impact the cleanliness of market milk and drinking water.[34]

This section discusses each of these environmental factors in turn.

Horse Manure

Horse manure poses a significant health problem indirectly, because manure is a favorite breeding ground of house flies.[35] These flies transmit hundreds of diseases, including typhoid and infantile diarrhea. Bacteria and other pathogens are picked up on a fly's body and then they are spread as the fly travels between feces, humans and their food.[36]

The peak of the horse manure problem was at during the golden age of the urban horse, 1900-1905. At this time, America's cities relied heavily on horses for industrial and passenger transportation peaked. These horses produced a lot of manure. Heavy urban horses generated between thirty and fifty pounds of manure a day, probably averaging about 7 tons per year.[37] The

[34] Temperature and precipitation also mattered for food prices, which I discus in the nutrition section of Section 4
[35] Horse manure is not in and of itself a major health risk, even though it harbors tetanus spores.
[36] Morris (2007) p4-5.
[37] McShane and Tarr (2007) p 260

manure was an eyesore; it smelled; it attracted disease-carrying flies, and it took up precious city space.

After 1905, America's horse population began its decline, where the magnitude and speed of the change varied by sector and by city. Eventually the use of urban horses for anything besides entertainment purposes disappeared entirely. With fewer horses, there was less manure and fewer disease-carrying flies. Thus, the decline of urban horses likely also played a role in the drop in infant mortality in city areas.[38]

In Pittsburgh, horse population peaked at about fourteen thousand in about 1900, though exact figures are lacking.[39] Historian and horse expert Joel Tarr also guesses that the number had shrunk to about three to four thousand by 1930 though again exact figures are not available. Like in cities around the country, horses in posed a major environmental and public health problem. The manure created offensive conditions in many Pittsburgh neighborhoods.

I do not directly test for the affect of horse manure in my analysis. Incorporating data on horse population or city manure into this analysis would be a interesting direction for future research.

Garbage

Exposure to landfills and garbage also poses a health risk to infants, both directly and indirectly. First, it is well understood that mothers that live in proximity of a landfill are more likely to have low birth weight babies than mothers that do not. The low-birth weight babies are more likely to die during the first year of life.[40] Secondly, municipal and industrial landfills would sometimes contaminate groundwater supply, and garbage and sewage were commonly

[38] See Graham-Smith (1939)
[39] Tarr, 2008, 1 and Tarr personal correspondence
[40] Low birth weight is a leading cause of neonatal mortality. See Vrijheid (2000) and Child Health USA 2003

disposed of in waterways.[41] As mentioned in the *Water* section, contaminated water was a health threat, especially before water was properly treated.

In the early twentieth century, the lack of effective garbage systems made city environments filthy.[42] For most cities, there were no specific regulations about trash. Instead, the issue would just be treated under nuisance provisions of the law. Solid-waste disposal was largely treated as an engineering issue and an inconvenience, rather than a public health problem. Thus, it wasn't until much later that the hazards of land disposal were tackled. The issue was opened in the 1960s and the 1965 Solid Waste Disposal Act finally brought it to national attention.[43] Prior to 1968, there are over 1,000 unregulated landfills in Pennsylvania and the garbage situation in many of Pittsburgh's neighborhoods was atrocious. Activist Anna B. Heldman Heldman (1873-1940) describes the living conditions in Pittsburgh's twentieth century Hill District as follows:

> "Mire flowed in from the rear alley... all the families in the row burned coal and dumped the ashes and garbage in the rear alley against the fence. In places the alley was filled with garbage three or four feet deep … the large rats scampered into rear yards… the odor from the alley could never be described; it had to be experienced…"[44]

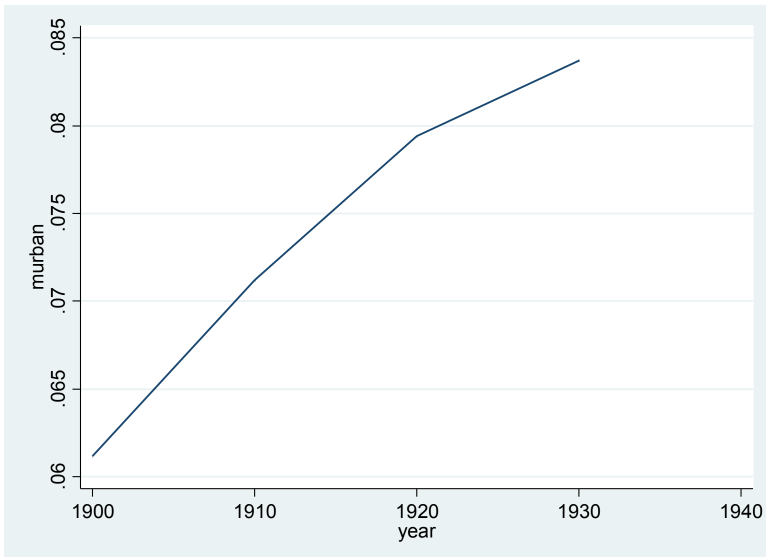
It wasn't until 1968, after Congress's (1965) Waste disposal act, that Pennsylvania passed its first law regulating solid waste.[45]

Though the garbage situation undoubtedly had implications for public health, it likely did not play a very large role in the early twentieth century infant mortality drop. This is because the garbage situation didn't change very much from 1900-1936. In cities, the situation remained bad, and in rural areas, the situation remained less of a problem. That said, in my analysis I do include a variable *nurban*, which accounts somewhat for the urbanization of the country. This

[41] Tarr 1996
[42] Melosi (2005)
[43] Tarr (1996) p 343-345.
[44] Quoted in Selaven (1980) p 3
[45] Pennsylvania Waste Industrial Association (2005)

variable tracks the share of people living in towns of 2,500 of greater. As the below graph shows, she share of people living in relatively high-density environments in the US was growing in the early twentieth century.

Graph 6: The Growing Number of Regions with High Population Density in the US



Source: IPUMS statistics, samples of the US Census. Available online.
Murban is the average share of people living in towns of 2,500 or greater

Even if the garbage situation wasn't changing too much over time within cities, we'd expect that the impact of city environmental issues (like garbage) on infant mortality to go up as the number of high-density environments increased and the country became more urbanized. In this way, the *nurban* variable accounts in part for the increasing relevance of city environmental problems like garbage and also pollution.

Air Pollution

Air pollution posed different health threats, and it was again a bigger problem in cities than in rural areas. Pollution is a risk factor for respiratory-related postneonatal mortality, and numerous studies have found that increased air pollution is significantly linked to increased infant mortality.[46] Recently, Currie and Neidell (2005) find that carbon monoxide has a significant effect on fetal health even at low pollution levels.[47]

In the early twentieth century, urban populations increased with the rise of American industry, and so did city pollution. In Pittsburgh, air quality was poor. As noted by an old newspaper article, “practically everyone” had heard of someone who had refused to accept a position in Pittsburgh because of its reputation as a ‘dirty city.’[48]

Though air pollution is certainly important for mortality, it was probably not significant in impacting the early twentieth century infant mortality drop. Nationally, and in Pittsburgh, air pollution was increasing at a time that infant mortality was dropping, so it doesn’t make sense that it would be a cause of the drop. That said, my *nurban* variable should capture some of the effect of pollution on mortality, because cities experienced more pollution than urban areas. [49]

Temperature and Precipitation

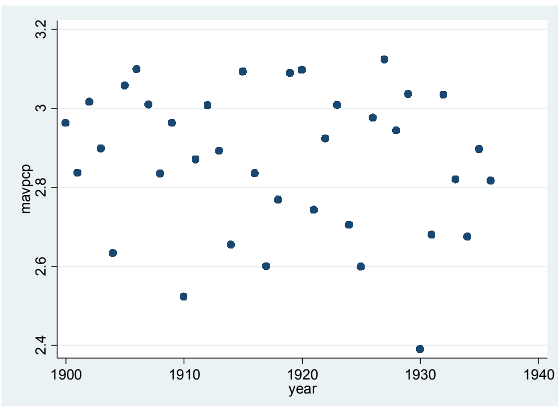
Weather conditions also have implications for health outcomes. Unusually hot or cold years may directly impact infant mortality, in that babies may die of heat or cold. More frequently, these fluctuations impact infant mortality indirectly, in that they have implications for the quality of air, and the cleanliness of water and market milk. For instance, the seasonal affect of infantile diarrhea is well documented. In the early twentieth century, infant mortality often rose sharply in summer months, especially in cities. Milk was more likely to spoil in hot summer months, and thus infants were more likely to contract fatal diarrhea.[50] In contrast, the seasonal affect of the flu is the opposite, as infants more frequently die of influenza during winter months. As to precipitation, high rainfall may also lead to higher rates of diarrhea, because human

[46] See Woodruff et all (2008), Chay and Greenstone (2004), for instance.
[47] Authors’ estimates indicate that a one unit change in mean CO during the last trimester of pregnancy increases the risk of low birth weight by 8 percent, and a one unit change in mean CO during the first two weeks after birth increases the risk of infant mortality by 2.5 percent relative to baseline levels.
[48] Lubove (1996)
[49] I do not collect data on pollution levels by state; this would offer an even better control in future research.
[50] Cheney (1984) and Lee (2007)

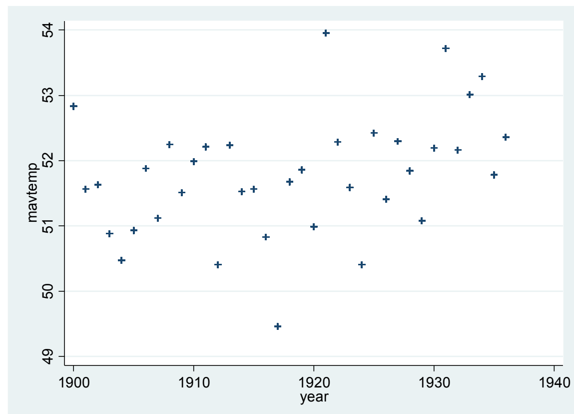
environments are ideal places for bacteria to grow and increased amounts of rain may mean a higher fly population.[51]

To control for these effects, I have included data on rainfall and temperature in my analysis of the infant mortality decline. The graphs below depict the trends in rainfall and average temperature over time.

Graph 7: Average US Precipitation



Graph 8: Average US Temperature



As the graphs indicate, there was not a strong trend in either direction. Data for both graphs come from the National Climactic Data Center at the National Oceanic and Atmospheric Administration

<u>Section 4: Health Factors</u>

Nutrition, the seasonal flu, immunizations, alcohol consumption and changes in the national health environment also had implications for the infant mortality drop. This section discusses each briefly.

Nutrition

McKeown (1976) emphasized that nutrition was a major factor in Britain's twentieth century steep mortality drop, which set off a decades of debate among social scientists about the

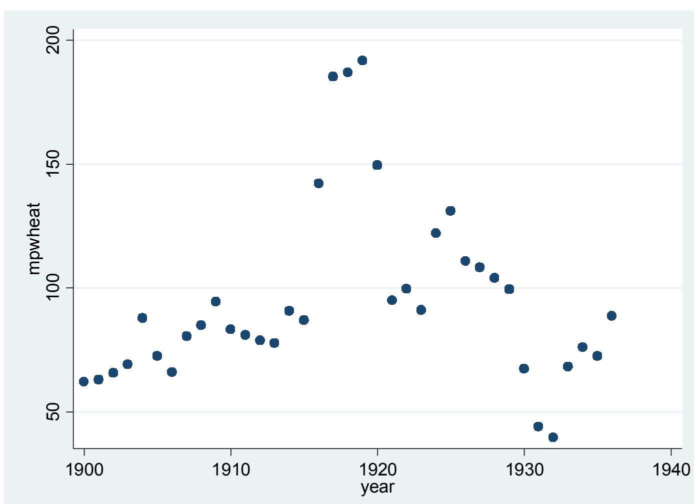
[51] Woodward et al (1974)

role of nutrition in mortality fluctuations.[52] Since twentieth century infants and mothers may or may not have gotten a health mix of food, nutrition is also relevant to the drop in infant mortality. Past studies indicate that nutrition will be particularly relevant to the drop in diarrheal deaths. Cheney (1984) examines the seasonal aspects of diarrheal death and notes that the analysis is sensitive to changes in nutrition and Lee (2007) also notes that nutrition may have contributed to the decline in deaths due to diarrhea.

To measure the impact of nutrition on the infant mortality drop, I control for food prices. To do this, I include variables for the price of wheat and the value of milk cows[53]. Food prices are a reasonable proxy representation for the nutrition of Americans in the earlier twentieth century, with higher food prices indicating a lesser availability of food and more American with poor nutrition.[54]

The below graph depicts changes in the price of wheat.

Graph 9: Average US Price of Wheat



[52] For instance, Harris (2004) presents a qualified defence of the McKeown thesis, while Grundy (2004) argues that much of the action needed to protect society's wellbeing is outside the realm of things seen as health related. She emphasizes that factors such as income, workplace safety and stress and the environment were important.

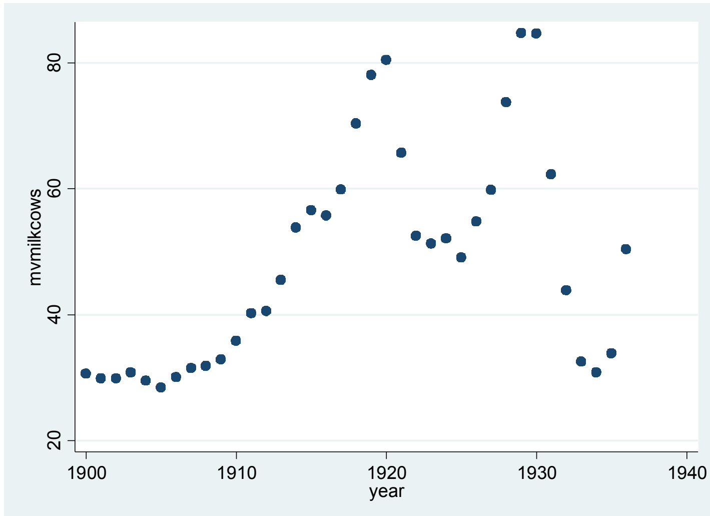
[53]

[54] In a recent study, Scott et al (1995) used the wheat price index for this purpose and found that infant mortality in historical (16th – 19th century) England is sensitive to changes in food quality.

Source: Annual crop and livestock statistics collected by the United States Department of Agriculture

The below graph depicts changes in the value of milk cows. This may proxy the price of milk, or potentially the price of meat.

Graph 10: Average US Value of Milk Cows

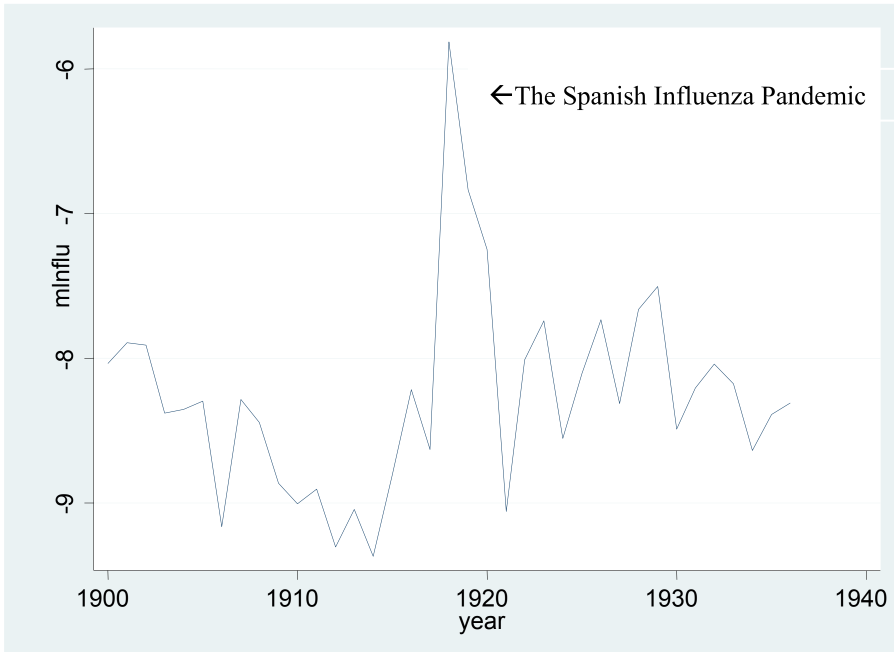


Source: Annual crop and livestock statistics collected by the United States Department of Agriculture

The Seasonal Flu

The seasonal flu is observed around the world with substantial mortality impact, and major changes in the virus sometimes result in pandemic outbreaks. Thus, fluctuations in seasonal flu deaths may have also impacted the early twentieth century infant mortality drop. The following graph depicts flu deaths in the US.

Graph 11: Flu Deaths in the US



**Mlnflu* is the natural log of the per capita flu rate, averaged across states

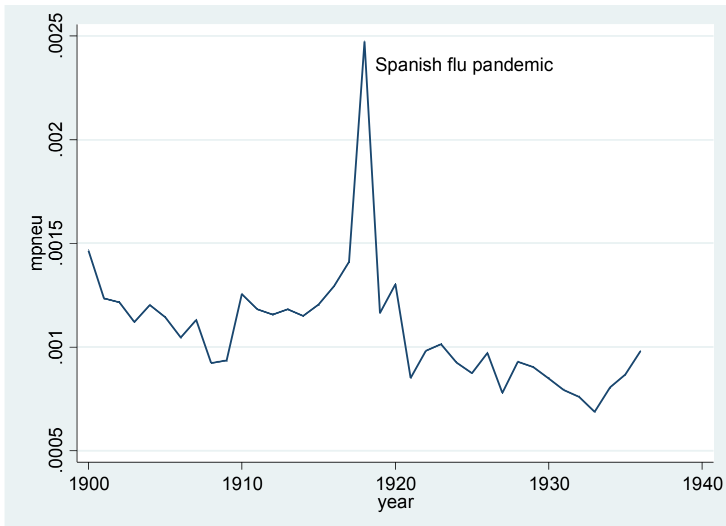
The spike in flu deaths on the graph corresponds to the 1918-1919 pandemic Spanish influenza virus. The devastating virus killed an estimated 20 to 50 million people worldwide and an estimated 675,000 Americans (DHHS). The World Health Organization called it "the most deadly disease event in the history of humanity," killing more than even the Bubonic Plague of 1347-1351.[55]

Early symptoms of the disease included a 102-104 degree temperature, a sore throat, exhaustion, headache, aching limbs, bloodshot eyes, a cough and occasionally a violent nosebleed. Some patients also suffered from digestive symptoms such as vomiting or diarrhea. Most patients who experienced these symptoms would fully recover, but many patients would then suffer a relapse. Their temperatures would rise again, they'd experience serious respiratory

[55] Delavero (2004)

problems, and some patients experienced massive pulmonary hemorrhages. Many died, and victims were found with swollen lungs and oversized spleens. Others, who did not die of the flu directly, died of pneumonia. Thus pneumonia deaths also spiked at the time, as shown in the graph below.[56]

Graph 12: Pneumonia Deaths in the US (per capita)



In addition, Graph 1 (at the beginning of this paper) also makes it clear that pneumonia accounted for about seven percent of infant death in particular from 1911-1920, which is likely in large part due to the Spanish influenza pandemic.

The Spanish influenza pandemic and the seasonal flu likely impacted the health of infants directly (when they died of flu) and indirectly (when infants' sick mothers would not give them proper care). Thus, in my analysis, I control for the effects of the seasonal flu on infant mortality with a regressor (flu) and I control for the effects of Spanish influenza with a year dummy.

Immunizations

There were also a number of immunizations that became available early in the twentieth century, which possibly played a role in the infant mortality drop. It is likely this effect was not

[56] See DHHS; Delavero (2004), Reid et al 2001.

very large, as it was mostly older children who were being vaccinated. Moreover, not all early twentieth century vaccines were initially effective. That said, there were possibly indirect effects of these immunizations; infants may have died less frequently of diseases they would have contracted from siblings or parents were it not for the vaccines. Vaccines that became available during the period include typhoid, pertussis, cholera, diphtheria, tuberculosis, tetanus, and yellow fever.[57]

These vaccines became available at different times in different states. In my analysis the effect of these vaccines on the infant mortality decline are controlled for by state and time fixed effects.

Alcohol Consumption and Prohibition

When mothers use alcohol during pregnancy, it threatens the health of their babies. Pregnant women who drink alcohol are more likely to have low birth weight babies, and low birth weight is a leading cause of neonatal mortality.[58] For this reason, doctors recommend that pregnant women abstain from drinking[59].

Studies have found that regular and relatively heavy drinking increases the risk of infant mortality. [60] In December of 1919, United States government ratified the 18th amendment, which went into effect in 1920. This amendment imposed a prohibition on alcohol which lasted until its repeal in 1933. In addition, thirty-two states adopted prohibition laws prior to 1920 (see Appendix Table 1). During national and state prohibitions, alcohol consumption declined.[61]

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[57] See Children's Hospital (2010) and Link (1937)

[58] See Brandt Jr (1984), Child Health USA (2003)

[59] That said, the question of whether there is a "safe" level of moderate drinking during pregnancy remains controversial (Kesmodel et al 2002)

[60] See Strandberg-Larsen et al 2009, for instance

[61] It's clear that alcohol consumption did decline during prohibition, but the extent to which it declined remains a subject of debate. Dills and Miron (2003) examine the impact of prohibition on the cirrhosis death rate, a proxy for alcohol consumption. They find that national prohibition did reduce cirrhosis by about 10-20 percent, which suggests that it did reduce alcohol consumption, though they find that state prohibitions were weak, with only a minimal impact on cirrhosis.

Thus, prohibition is another factor that potentially impacted early twentieth century infant mortality fluctuations. I control for the effect of prohibition in my analysis with a dummy variable for national prohibition, as well as dummies for individual state prohibitions.

Maternal Health

The progressive era also brought changes in health practices, which may have also had implications for infant mortality. Prior to the 1920s and 30s, most deliveries happened in a woman's home and obstetrics was practiced largely by midwives. For instance, in Pittsburgh, only 3.6 percent of 1907 births happened in hospitals.[62] During the first third of the twentieth century, practices across the country shifted. Hospital births became more and more common, until childbirth ultimately occurred predominantly in institutions. That said, these early obstetrics units were not necessarily safer than women's bedrooms. Maternal mortality remained high in the hospitals in the 1920s and 1930s.[63]

A less common alternative to risky hospital birth or independent at-home delivery was birth with nurses at bedside. In Pittsburgh, the progressive era Public Health Nursing Association (PHNA) offered an enormous amount of bedside care, and thus had a great impact on infant health. In the 1930s, PHNA nurses visited 42% of all resident live births in Pittsburgh during the first month of life. In 1935, the PHNA nurses made 6054 maternity home visits per 1,000 resident births in the county. The sheer scope of this service offered by the PHNA is impressive, and the value of these one-to-one visits is immeasurable for maternal and infant health.[64]

In the years that followed, hospitals became safer, and by the 1940s and 1950s, maternal mortality in hospitals had fallen significantly with advances in medicine.[65]

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[62] See Carson (1994) p 78 and Carson (1997) p 31

[63] Leavitt (1986) discusses the shifting of birth practices, p 194.

[64] Unfortunately, changes in funding and politics led to the discontinuation of services to mothers and babies by 1963. That said, the PHNA (now called the Visiting Nurse Association) did continue to offer home care services to high-risk mothers and infants. See Carson (2007), p 149-151.

[65] Leavitt (1986), p194

Section 5: Women's Groups

In the early twentieth century, there were also women and women's groups that undertook a variety of activities related to hygiene, infant care, health politics, and clean milk. I do not know of a way to measure their effect, except for indirectly through time fixed effects and through milk and water. That said, it's clear that the efforts of these women mattered. To illustrate the part that women played, I highlight several examples. I first introduce the Children's Bureau, and I then discuss how it impacted the grassroots initiatives, using the Johnstown field investigations and National Baby week as examples. I also touch on local women's groups in Pittsburgh and Well Baby Clinics.

Women and the Children's Bureau

Legend has it that the idea of the Children's Bureau was born at a 1903 breakfast discussion between two activists, Florence Kelley and Lillian Wald. As Robyn Muncy tells the story, Kelley opened

> a letter that asked why nothing was done about the high summertime death rate among children … As Wald mused that she knew no source of information on variable death rates among children, Kelley read aloud an article from the morning paper, which announced that the federal government was sending the Secretary of Agriculture to investigate damage inflicted by the boll weevil in southern cotton fields. Wald is purposed to have retorted: "If the Government can have a department to take such an interest in what is happening to the cotton crop, why can't it have a bureau to look after the nation's child crop?"[66]

Eventually, this breakfast table idea made its way into the national agenda. In 1912, Congress passed an act creating the Children's Bureau, and charged it to investigate and report on issues of child life and welfare of children.[67] Once it was established, the relationship between the Bureau and associated American women strengthened and deepened. A woman activist, Julia Lathrop, was its first chief. She chose to stress infant and maternal mortality as the organizations first

[66] Quoted by Skocpol (1992) p43
[67] See Bradbury, Publication of the United States Department of Health, Education and Welfare

focus. Thus, even from the start, the organization was to have an impact on the health of babies. As chief, Lathrop extended the Bureau's reach into local communities, inspiring rank-and-file members of small women's organizations.

The Children's Bureau and Johnstown Field Investigations

For instance, the Children's Bureau pursued field investigations of infant mortality in local communities, starting with Johnstown Pennsylvania, about 67 miles from Pittsburgh. These investigations called for both local mobilization and statistical analysis. Women's clubs were asked to compile lists of babies born in a given year. Then, female agents from the Bureau came out to interview the mothers of the babies and the results of these surveys were ultimately used to drive local improvements.[68] After the results of the Johnstown study were published, Lathrop reported proudly on the success. She wrote that:

> [The] files of the Johnstown press, the reports of the city health officer, the statements of clubs and individuals show a remarkable and sustained interested expressed in many forms, among which may be mentioned the securing of infant-welfare nurses, an improved milk supply, a baby-welfare station, and renewed effort for a complete sewerage system… The understanding shown by the people and press of Johnstown indicates that there is a clear view of the ceaseless work required to secure permanent reduction of infant mortality.[69]

After the study, the Bureau in Washington compiled the locally gathered statistics. It used them to argue that infant mortality was directly related to low incomes of working-class fathers, as well as to the necessity of poor mothers to take out tiring and ill-paid jobs outside the home.[70]

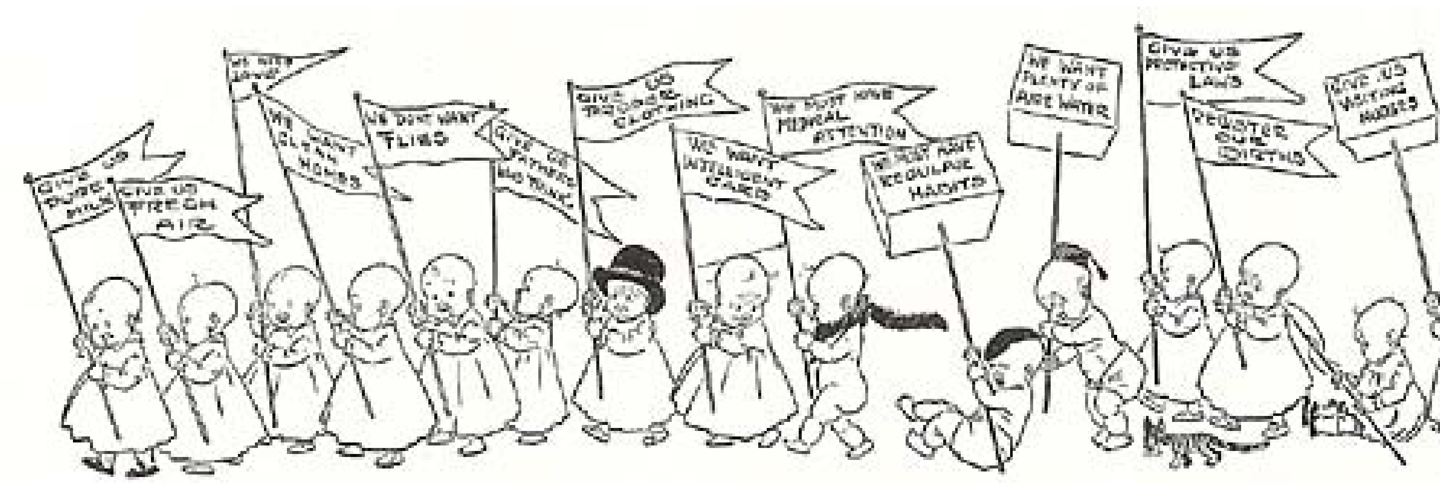
The Children's Bureau and Baby Week

In addition to initiating field studies, the Children's Bureau found creative ways to keep local communities invested in prevention of infant mortality and protection of maternal health. For instance, in March 1916, after its work on infant mortality, the Bureau sponsored a "Baby

[68] See Lindenmeyer (1997) and Skocpol (1992) p 487
[69] Quoted by Skocpol (1992) p 490.
[70] Ibid 491

Week" jointly with the General Federation of Women's clubs.[71] For this extravaganza, the Bureau worked with local groups to sponsor events that addressed the "constructive side of infant care" – meetings, exhibits, processions, plays, kids essays, conferences with parents, distributions of flags, and even examinations of well babies. After the week had ended, the Bureau claimed that it had communicated with over 4,000 communities and that 2083 communities had sent reports of local Baby Weeks The following May another Baby Week was held, though this time on a slightly smaller scale.[72]

Cartoons for baby week appeared in many newspapers. This one depicted babies asking for love, intelligent care, protective laws, birth registration, and "fathers who think," among other things.[73]



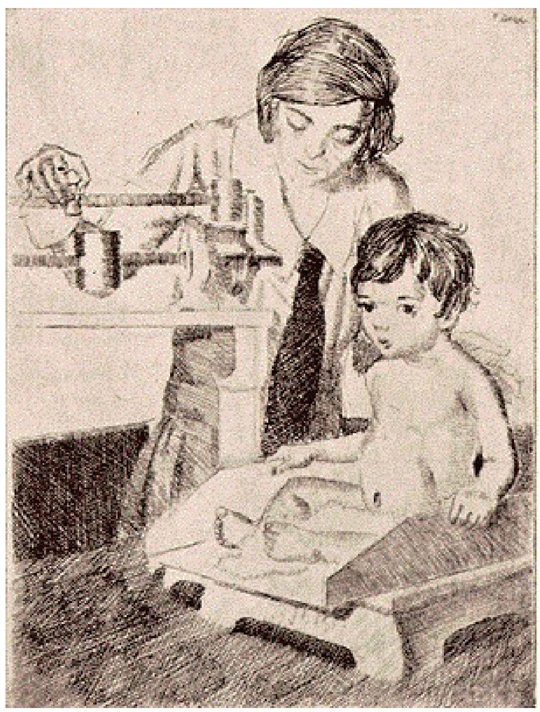
Pittsburgh Women's Groups

Local communities also had their own grassroots infant health efforts, independent of national initiatives. In Pittsburgh, there were numerous small women's groups that were active. Examples include the Womens Auxililary, the Columbian Council (later, the Irene Kaufman house), the Women's Club of Pittsburgh, the Twentieth Century Club of Pittsburgh (later, the

[71] Bureau Publication, Issues 11-20, 1915, p9
[72] Skocpol (1992), p494
[73] Displayed on Adoption History Project Website (2007)

Civic Club of Pittsburgh), Kingsley and other settlement houses. These groups offered classes on feeding children, basic baby care for children, milk stations and “Better Baby” clinics, among other things.

For instance, in 1924, a first well baby clinic was opened in the Harrisburg public library building. At clinics like this one, medical advice was given for free and babies were weighed and examined.[74] These were extremely successful, so much so that after no more than a few years over four hundred of these clinics were in operation.[75] An undated postcard depicts a baby clinic at the Irene Kaufman settlement in the hill district:



Better Baby Clinic, Irene Kaufman Settlement
From the Collections of the Pennsylvania Department, at The Carnegie Library of Pittsburgh .
From an etching by Samuel Filner (No. 273)

Another undated photograph depicts a line a line for a Weekly Better Baby Clinic:

[74] Described in “Kaufman Settlement’s Milk Well” in the Pittsburgh Press, 1930.
[75] Kunkle, (196-?), p84

Weekly Baby Clinic, Irene Kaufman Settlement
From the Collections of the Pennsylvania Department, at The Carnegie Library of Pittsburgh, photographer Bill Lewis

Though I do not know how to measure the effect of local women's groups on the national infant mortality drop, I do account for the effect of the Children's Bureau in my analysis with a year dummy variable.

Part 2: Quantitative Section

Thus far, I have presented a picture of five categories of factors that were important for early twentieth century infant mortality – water, milk, environmental change, health related change, and women's groups. In this section, I'll estimate the effect of some of these factors on infant mortality rates, in an attempt to understand which factors contributed most greatly. The literature has suggested that it is water, milk and some health factors that are likely have played the greatest role in the infant mortality drop[76], and my analysis I quantify the effects of each of these factors, as well as others. I look first at national data, and then at newly assembled data for the city of Pittsburgh.

Section 1: Methodology and Data

a) Methodology

In order to understand the significant factors in the national drop in infant mortality, I estimate models of the form:

(A) $lninfant_{it} = B_0 + B_1 \text{lntboth} + B_2 \text{lntyph} + \text{state}_i + \text{year}_t + u_{it}$

where i indexes states and t indexes years,
lninfant is the ln of the national per capita infant mortality rate,
lntboth is the ln of national per capita rate of tuberculosis mortality (excluding tuberculosis of the lungs),
lntyph is the ln of the national per capita rate of typhoid mortality
state is a vector of state fixed effects,
year is a vector of year fixed effects

State effects control for any fixed state characteristics that might be correlated with the tuberculosis rate, the typhoid rate or other variables of interest. The year effects control for any characteristics of any one year that might be correlated with any variables of interest. In this

[76] See Cutler and Miller (2005), Lee (2007) and McKeown (1795)

way, this model relates infant mortality to the national tuberculosis and typhoid death rates. Regression estimates of this form are shown in Table One.

b) Dependent Variable

Infant mortality is defined as the number of infants who die within the first year of life. I use the data for infant deaths by state and population by state to generate the variable *lninfant*, the natural log of the national per capita infant mortality rate. Data for the full sample of infant (or under one) deaths by state comes from the National Bureau of Economic Research's *State Mortality Data, 1900-1936*. Unless mentioned otherwise, data for other variables also comes from this source.

b) Typhoid and Clean Water

I use data for typhoid mortality by state and population by state to generate my first key regressor, the variable *lntyph,* the national log of the national per capita tuberculosis mortality rate. I use it as a proxy for the cleanliness of public drinking water.[77]

c) Tuberculosis and Clean Milk

My second key regressor, *lntboth,* is the natural log of the national per capita rate of deaths due to (non-lung) tuberculosis. I use it as a proxy for the cleanliness of market milk.[78]

d) Diarrheal Deaths – A Check for Causality

Though bad milk or unclean water can cause a variety of diseases, it is by and large diarrhea that would kill babies who drank bad milk or unclean water. As I've noted earlier,

[77] As mentioned earlier, the relationship between the typhoid death rate and the quality of water is close (Whipple 1908, 228).

[78] Again, tuberculosis is one of two main causes of milk-related infant deaths, along with diarrhea. Tuberculosis is a better proxy for the cleanliness of market milk than diarrhea, even though diarrhea was a more frequent cause of infant death, because the relationship between cow's milk and tuberculosis is more direct. Infantile diarrhea may be caused by many other factors.

infant diarrhea accounted for a large proportion of all infant deaths in the early twentieth century.[79] Thus, as a check on the link between unclean milk/water and infant deaths, I also estimate the effect of the proxy variables (lntyph and lnboth) on diarrheal deaths with specifications of the form:

(B) $lndiar_{it}$=B_0+B_1lntboth+B_2lntyph+ +$state_i$+$year_t$+u_{it}

Lndiar is the ln of national per capita diarrheal mortality
all other variables are the same as in (A)

Regression estimates of this form are shown in Table Two.

e) Health Factors

i. Prohibition

To test the effect of the 1920-1933 national prohibition and the pre-1920 state prohibitions, I add two time dummy variables to regressions of form (A): *natprohib* (for national prohibition) and *Iprohib* (for state prohibitions). *Natprohib* is 1 if the year is ≥ 1920 and ≤ 1933 and zero otherwise. *Iprohib* is 1 for an individual state if it is enforcing a state prohibition in a particular year (See Appendix A for a list of state prohibitions).

ii. Nutrition

I also control for nutrition-related changes by including regressors for the dollar price of wheat (*pwheat*) and the dollar value of milk cows (*vmilkcows*). As mentioned earlier, food prices are a reasonable proxy representation of the nutrition of Americans in the early twentieth century, with higher food prices indicating a lesser availability of food and more Americans with poor nutrition.[80] Data comes from annual crop and livestock statistics collected by the United States Department of Agriculture.

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[79] From 1911-1920, it caused just under a fourth of all infant deaths (*Mortality Statistics 1920).*
[80] Scott et al (1995) used the wheat price index for this purpose and found that infant mortality in historical (16th – 19th century) England is sensitive to changes in food quality.

iii. The Seasonal Flu and Spanish Influenza

I control for the role of the seasonal flu by adding a flu variable (*lnflu*), the natural log of per capita flu related deaths in the US. I control also for the Spanish influenza pandemic by including a time dummy variable (*i.spanish*) that is coded 1 during the years of the outbreak (1917-1918) and 0 otherwise.

f) Environmental Factors

I also include regressors to control for precipitation, temperature, and urbanization. I use yearly state-level data to generate *avgpcp* (average yearly precipitation in inches), *avtemp* (average yearly temperature in Fahrenheit), and *nurban*[81] (the share of people who are living in towns of population 2,500 of greater). Data on average annual temperature and average precipitation are from the National Climactic Data Center at the National Oceanic and Atmospheric Administration.[82] Data on urbanization come from IPUMS statistics, samples of the US Census.

g) Women's Groups

I do not know of a way to test the effects of these groups directly. That said, the analysis that I have described thus far tests for the effects of these groups indirectly, through time and state fixed effects and the effect of clean milk and water. I include one other dummy variable to indirectly capture the effect of these groups. This is a time dummy for the creation of the 1912 Children's Bureau, which is 1 if the year is ≥ 1912 and 0 otherwise.

[81] As mentioned earlier, health risks associated with exposure to air pollution, garbage, sewage and fecal material were experienced more frequently by those living in crowded cities.

[82] They describe the data as follows: "The statewide values are available for the 48 contiguous States and are computed from the divisional values weighted by area. The Monthly averages within a climatic division have been calculated by giving equal weight to stations reporting both temperature and precipitation within a division." The observations were corrected for time of observation bias as described in Karl, et al. (1986). The annual state values for 1895-2000 were averaged to generate the initial condition.

Finally, I also test the relationship between the creation of the Children's Bureau and the United States' use of clean milk directly, with:

(C) $lntboth = B_0 + B_1 cldbur + state_i + year_t + u_{it}$
all other variables are the same as in (A) and (B)

and

(D) $lntboth = B_0 + B_1 cldbur + u$
*without fixed effects

Results are shown in Table Three.

h) Demographic Variables

I also control for some demographic factors. I add variables to control for the number of mothers (*nmom)*, the number of foreign born citizens (*nfborn*), and the number of whites (*nwhite*). Data comes from IPUMS statistics, samples of the US Census.

h) Pittsburgh Analysis

Sometimes what is important for a demographic change on a large national scale is not what matters most on a local level. I also include analysis of a Pittsburgh data set, to serve as an example of one local region's experience during the early twentieth century infant mortality drop. I assemble my own dataset by hand entering data points from the Historical Mortality Statistics Volumes, available online at the Center for Disease Control and Prevention's website. This dataset includes yearly data (1905-1936) for infant mortality rates, (non-lung) tuberculosis death rates, and typhoid death rates. Using this data, I estimate regressions of the similar form the national analysis:

(E) $lnpinfant_{it} = B_0 + B_1 lnptboth + B_2 lnptyph + year + u_{it}$

Lnpinfant is the ln of the per capita infant mortality rate in Pittsburgh
Lnptboth is the ln of the per capita non-lung tuberculosis death rate in Pittsburgh
Lnptyph is the ln of the per capita typhoid death rate in Pittsburgh
Year captures time effects

My data set is not panel data and for this reason the state and year fixed effects I used for the national analysis are not possible. Instead, I include a time variable to control for the fact that infant mortality and disease rates all trend downward.

Analysis for this data is limited because of the size of the dataset. There are only 31 observations. Additionally, there are 5 strong outliers in the data on tuberculosis (see the graph of Pittsburgh's non-lung TB rate in the next section). These values seem unusual[83] enough that my best guess is that they are a result of some sort of mistake, perhaps a transcription error. For this reason, I remove them from the regression analysis. This makes the sample even smaller; my analysis includes just 26 observations. Again, what can be done with a dataset of this size is limited.

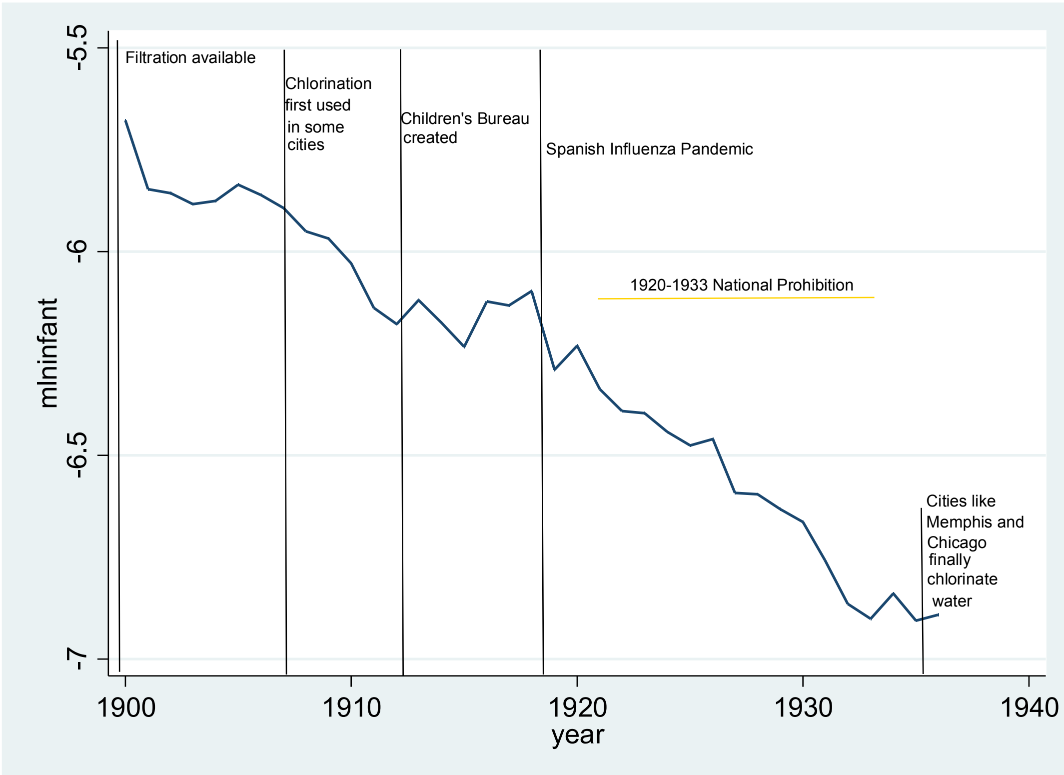
That said, I do use Pennsylvania state data from the national dataset to control for two additional factors. I control for nutrition related changes by add a regressors for the value of Pennsylvania's milk cows, denoted in the same way as in the national analysis. I also control for changes in the seasonal flu by adding *lnflu,* or the natural log of the per capita flu deaths in Pennsylvania.

Section 2: Descriptive Statistics

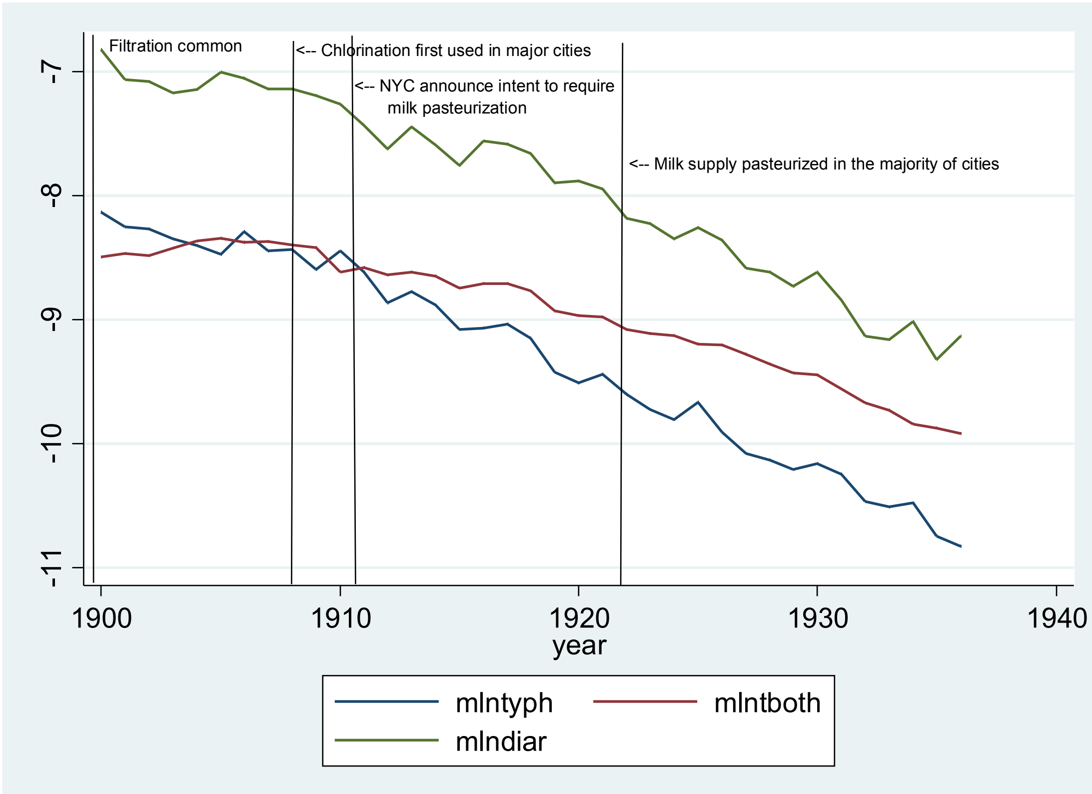
The following three graphs summarize some of the important trends and dates relevant to the infant mortality drop in the United States.

[83] For instance, the 1912 Mortality volume records 9 (non-lung) tuberculosis deaths for Pittsburgh, as compared to 187 in 1911, 137 in 1910, and 139 in 1914. During these years, the market milk supply in Pittsburgh was not fully pasteurized.

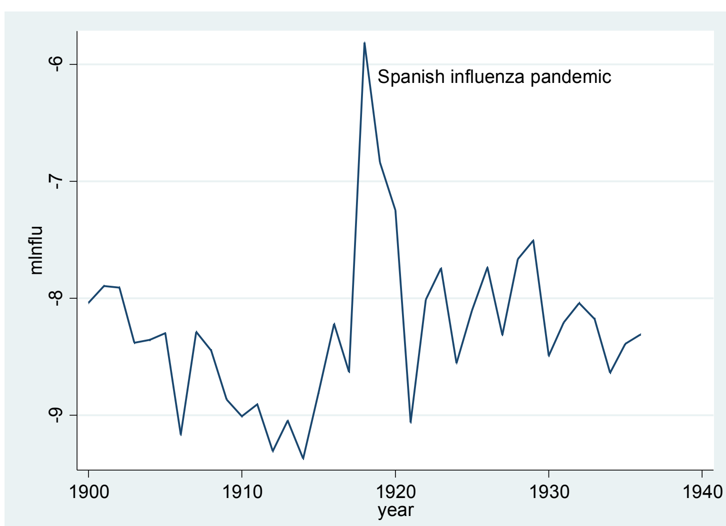
Graph 14: The Early Twentieth Century Infant Mortality Drop



Graph 15: Milk and Water Related Disease Rates in the US
Diarrhea, Typhoid and Non-lung TB

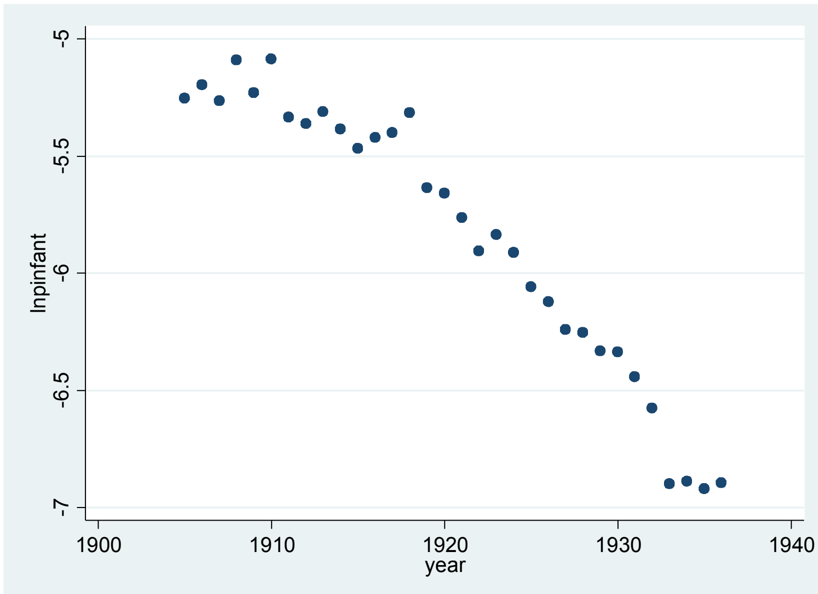


Graph 16: Flu death Rates and Spanish Influenza

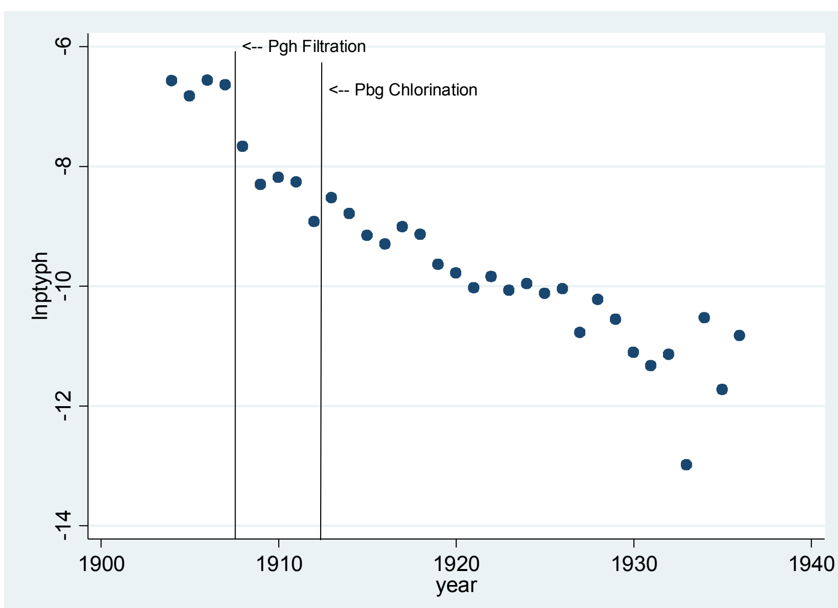


The next three graphs offer a look at the situation in Pittsburgh.

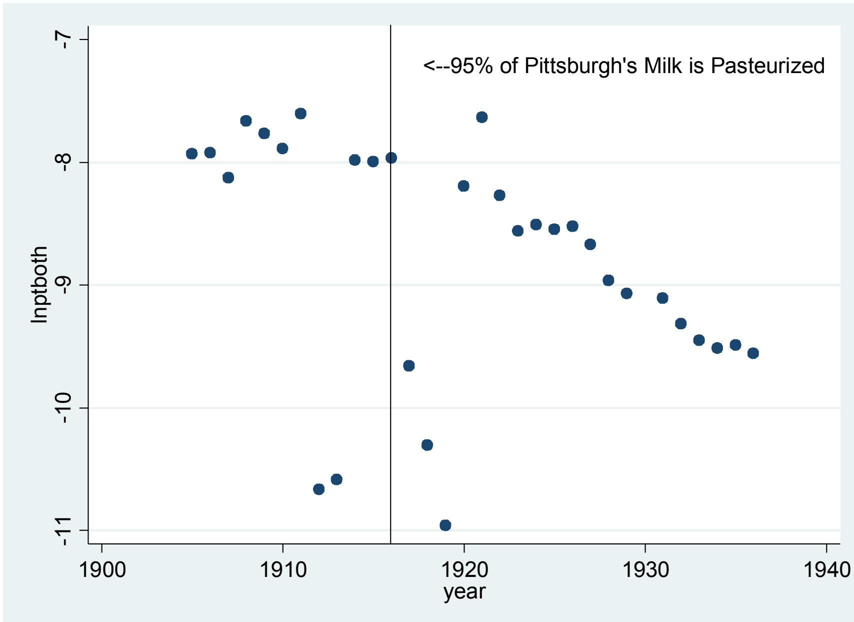
Graph 17: The Infant Mortality Decline in Pittsburgh



Graph 18: The Typhoid Death Rate Decline and the Cleaning of Water in Pittsburgh



Graph 19: The Non-lung TB Date Rate Decline and the Cleaning of Milk in Pittsburgh



Note the five outliers 1910-1920.

Section 3: National Results

a) Milk and Water Effects

Estimates from models of the form (A) are shown in Table One. As column (1) shows, the general mortality rate for (non-lung) tuberculosis has a positive and statistically significant relationship with infant mortality ($p<.01$). The point estimate implies that (as market milk is cleaned) for every 1% decrease in the national per capita occurrence of tuberculosis, there is a .496% decrease in the national infant mortality rate.

Column (1) also provides evidence about the typhoid effect. It shows that general typhoid mortality has a positive and statistically significant relationship with infant mortality ($p<.01$). The point estimate implies that (as drinking water is cleaned) for every 1% decrease in the national per capita occurrence of typhoid, there is a .212% decrease in the national infant mortality rate. In each specification in Table One, the contribution of *lntboth* to the drop in infant mortality is at least double that of *lntyph*.

b) Diarrheal Deaths – Table Two

Estimates of the form (B) are shown in Table Two. Specifications in this table confirm the link between clean milk/water and infant mortality, by relating clean milk/water to diarrheal death. *Lntyph* and *lntboth* are significant in all three specifications ($p < .01$). The estimates suggest that the cleaning of milk (such that tuberculosis mortality decreases by 1%) decreases diarrheal mortality by .39-.50% and that the cleaning of water (such that typhoid mortality decreases by 1%) decreases diarrheal mortality by .15-.21%.

c) Health Factors

i. Prohibition

My analysis suggests that a prohibition effect exists. In specification (3) of Table One, the dummy for state-level prohibition is significant ($p<.1$), and the point estimate implies that infant mortality was 5.58 percent lower while state prohibitions were occurring, as compared to when they were not.[84]

ii. Nutrition

My analysis suggests that a nutrition effect exists, though exactly what the estimates indicate is unclear. In specifications (2) and (3) of Table One, *vmilkcows* is significant ($p<.05$) and negative, suggesting that a 1 dollar increase in the price of milk cows is associated with a .26-.29 percent decrease in infant mortality. Thus, as milk (or meat) became more expensive, infant mortality decreased. This might indicate that more expensive meat meant better quality and better nutrition. It might also or instead indicate that as milk became more expensive, more mothers breastfed or used milk alternatives. This could mean that less bad milk was consumed, which would decrease infant mortality. Table Two links this nutrition effect to diarrheal deaths in particular, the *vmilkcows* effect on diarrheal mortality is again negative and significant ($p>.1$).

iii. Seasonal Flu and Spanish Influenza

My analysis suggests that the seasonal flu and the Spanish Influenza outbreak both impacted infant mortality fluctuations. Estimates indicate increases in the occurrence of the flu would increase infant mortality rates ($p>.01$). Specification (8) of Table Three suggests that a 1% increase in the national per capita flu mortality rate corresponds to a .173% increase in infant mortality. Specification (3) of Table One suggests that the outbreak of Spanish influenza increased infant mortality by 29%, as compared to what it would have been otherwise.

d) Environmental Factors

[84] I tested the effect of national prohibition, but the dummy did not have the correct sign. It may have captured some other time effect besides prohibition. For this reason it is not included in the tables.

The analysis suggests that rainfall had an effect on infant mortality. Specification (2) of Table One suggests that a once inch increase in average yearly precipitation is associated with a .26% decrease in infant mortality ($p<.1$). (Though specification (3) is not significant, the estimate is of the same sign and of a very similar magnitude.) This may suggest that more water meant better food supply outcomes, lower food prices, and better nutrition. Table Two indicates that increases in rainfall corresponded to decreases in diarrheal disease ($p<.01$). The reason for this is unclear. More water may have meant better nutrition, which may have meant fewer diarrheal deaths. Whatever the cause, this diarrhea effect explains at least in part the rainfall effect on infant mortality. The data do not provide evidence that *avtemp* or *nurban* had significant impacts on the infant mortality decline.

e) The Children's Bureau – Table Three

Table Three shows the results for the analysis of the effect of the Children's Bureau. Estimates suggest that a Children's Bureau effect may exist. That said, the analysis is limited in that the regressors are just before/after year dummies. Though fixed year effects should control for year-specific change, the dummies still may pick up other non-Children's Bureau related effects that correspond to the same before/after time period. The point estimate in specification (7) suggests that the infant mortality rate was lower after the Creation of the Bureau, as compared to otherwise ($p<.01$). The point estimates in specifications (7) and (8) imply that prior to the creation of the Children's Bureau, the relationship between tuberculosis and infant mortality is stronger than after the bureau was created; the effect of lntboth on infant mortality is.14-.18% lower after the Bureau was created ($p<.05$). This may capture the fact that the Children's Bureau helped promote the use of clean milk, which would lower tuberculosis death rates and thus weaken the link between tuberculosis and infant mortality.

Specifications (9) and (10) check the direct effect of the Children's Bureau on lntboth. The effect is significant in specification (10), which leaves out fixed effects, and insignificant in specification (9), which includes fixed effects.

f) Pittsburgh Results

Estimates for Pittsburgh results are shown in Table Four. Estimates for *lnptboth* indicate that the cleaning of milk (such that tuberculosis mortality drops by 1%) lowers infant mortality by .27-.40% ($p<.01$). The data do not provide evidence that lowering of the typhoid death rate lowered infant mortality. That said, the historical evidence does make it clear that Pittsburgh's water supply was filthy. Data do not provide evidence that *lnflu* or *vmilkcows* were significant.

Section 6: Discussion and Conclusion:

The qualitative and quantitative sections of this paper have presented a broad picture of the decline in infant mortality in the twentieth century United States. Part One presented historical evidence on five main categories of factors – the cleaning of milk, the cleaning of water, environmental change, health-related changes, and women's groups. It looked at the national situation, and also highlighted corresponding examples of the local situation in Pittsburgh. The quantitative section offered evidence about the relative significance of these factors, speaking most importantly to the role of the cleaning of water and market milk. It provides evidence that the cleaning of milk and the cleaning of water each played a major role in causing the infant mortality decline in the United States. In all the specifications in the national analysis, the relationships between tuberculosis (the milk proxy) and typhoid (water proxy) with infant mortality were positive and statistically significant.

The national analysis also lends quantitative support for Lee's (2007) assertion that market milk was an extremely important factor in the infant mortality drop, more important than family income, medical intervention or other sanitary measures like the cleaning of water. In all the specifications in the national analysis, estimate for tuberculosis (the milk proxy) is at least double that of the estimate for typhoid (water proxy). Cutler and Miller's (2005) regression analysis indicates that clean water was responsible for 75% of the infant mortality drop; this analysis thus suggests that Cutler and Miller's analysis omitted an important variable, the cleaning of market milk.

The Pittsburgh evidence provides support for the national analysis, suggesting that the national picture corresponds to a local story in at least one region. The historical evidence makes it clear that Pittsburgh had a really awful water supply. My estimates suggest that the cleaning of milk significantly decreased Pittsburgh's infant mortality rate.

The national analysis also controlled for a number of other factors that likely affected infant mortality fluctuations. Estimates were statistically significant for several of these factors – state prohibitions, the seasonal flu, value of milk cows (proxy for nutrition), rainfall, the interaction of the 1912 Creation of the Children's Bureau with typhoid deaths, and Spanish influenza. The interpretation of the Spanish Influenza estimate – that infant mortality was 29% higher during the outbreak than during other years – speaks to the magnitude of the pandemic.

In addition, as my qualitative analysis suggests, the list of variables I included in my quantitative analysis is not exhaustive. For instance, adding yearly data on manure or horse population to test the effect of horse manure on infant mortality could improve the analysis, as could adding yearly data to control for the effect of air pollution. In addition, it seems clear that the work of local women's groups was important, though hard to measure. If a future researcher came up with a way to quantify the effect it could make the picture of the factors in the infant mortality decline clearer. Further research could also examine the situation in Pittsburgh more closely. A larger data set would increase the amount that one could conclude about the local infant mortality trends. Finally, further research could also look at current infant mortality trends. Infant mortality rates remain high in developing countries today, and similar analysis could help shed light about relevant factors and where Western countries could invest effectively in aid.-

In summary, this paper offered a broad qualitative and quantitative look at significant factors in the twentieth century infant mortality drop. It offered evidence that the cleaning of milk and the cleaning of water were particularly important, which indicates that pasteurization, filtration, and chlorination saved the lives of countless twentieth century infants.

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Table One – National Analysis: Infant Mortality

VARIABLES	(1) lninfant	(2) lninfant	(3) lninfant
lntboth	0.496***	0.398**	0.390**
	(0.142)	(0.166)	(0.160)
lntyph	0.212***	0.151***	0.154***
	(0.0462)	(0.0523)	(0.0526)
nmom		-8.781	-7.710
		(8.222)	(8.235)
nfborn		8.504***	8.144***
		(2.667)	(2.425)
nwhite		13.10	12.33
		(8.295)	(8.308)
nurban		-0.707	-0.704
		(1.316)	(1.264)
avpcp		-0.0264*	-0.0252
		(0.0155)	(0.0153)
avtemp		0.00532	0.00443
		(0.00459)	(0.00435)
pwheat		0.000505	0.000479
		(0.000378)	(0.000352)
vmilkcows		-0.00260*	-0.00294**
		(0.00129)	(0.00118)
_Iprohib_1			-0.0558*
			(0.0315)
_Ispanish_1			0.291***
			(0.0880)
State Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Constant	0.173	-1.403	-1.463
	(1.469)	(1.698)	(1.646)
Observations	1,098	1097	1,097
R-squared	0.926	0.939	0.940

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

Table Two – National Analysis: Diarrheal Mortality

VARIABLES	(4) lndiar	(5) lndiar	(6) lndiar
lntboth	0.716***	0.340***	0.340***
	(0.122)	(0.107)	(0.107)
lntyph	0.446***	0.281***	0.281***
	(0.0746)	(0.0629)	(0.0629)
lnflu		0.203***	0.203***
		(0.0406)	(0.0406)
nfborn		23.35***	23.35***
		(5.250)	(5.250)
nwhite		14.46	14.46
		(10.56)	(10.56)
nurban		2.110	2.110
		(2.469)	(2.469)
avpcp		-0.0652***	-0.0652***
		(0.0194)	(0.0194)
avtemp		0.0392***	0.0392***
		(0.00738)	(0.00738)
pwheat		0.000682	0.000682
		(0.000671)	(0.000671)
vmilkcows		-0.00461***	-0.00461***
		(0.00168)	(0.00168)
_Ispanish_1		0.0739	0.0739
		(0.146)	(0.146)
_Iprohib_1		-0.0561	-0.0561
		(0.0550)	(0.0550)
nmom		-14.65	-14.65
		(11.50)	(11.50)
State Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Constant	3.034**	-1.647	-1.647
	(1.237)	(1.752)	(1.752)
Observations	1,109	1,097	1,097
R-squared	0.925	0.951	0.951

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

Table Three – National Analysis and the Children's Bureau

VARIABLES	(7) lninfant	(8) lninfant	(9) Lntboth	(10) Lntboth
lntboth	0.634***	0.424**		
	(0.0375)	(0.159)		
lntyph	0.214***	0.155***		
	(0.0141)	(0.0381)		
lnflu		0.173***		
		(0.0269)		
nfborn		8.486***		
		(1.951)		
nwhite		2.830		
		(2.416)		
nurban		-0.690		
		(1.106)		
cldbur_lntboth	-0.182***	-0.146**		
	(0.0382)	(0.0709)		
avpcp		-0.0120		
		(0.0137)		
avtemp		0.00651		
		(0.00441)		
_Iprohib_1		-0.0590*		
		(0.0340)		
cldbur	-1.491***		-0.0121	-0.605***
	(0.343)		(0.0266)	(0.0387)
State Fixed Effects	Yes	Yes	Yes	No
Year Fixed Effects	Yes	Yes	Yes	No
Constant	1.542***	-0.166	-8.700***	-8.985***
	(0.321)	(1.824)	(0.0808)	(0.0387)
Observations	1,098	1,108	1,098	1,098
R-squared	0.928	0.949	0.916	0.576

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

Table Four – Pittsburgh Analysis

VARIABLES	(11) lnpinfant	(12) lnpinfant
lnptboth	0.398***	0.277***
	(0.0881)	(0.0853)
lnptyph	0.0100	0.00173
	(0.0436)	(0.0373)
year	-0.0348***	-0.0480***
	(0.0101)	(0.00977)
lnflu		0.0709
		(0.0507)
vmilkcows		0.00195
		(0.00143)
State Fixed Effects	No	No
Year Fixed Effects	No	No
Constant	64.44***	89.19***
	(18.50)	(17.78)
Observations	26	25
R-squared	0.971	0.982

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix A

State Prohibitions

Before 1900; Kansas, Maine, New Hampshire, North Dakota
1907: Georgia, Oklahoma
1908: Alabama, Mississippi, North Carolina
1909: Tennessee
1912: West Virginia
1914: Arizona, Colorado, Oregon, Virginia, Washington
1915: Alabama, Arkansas, Idaho, Iowa, South Carolina
1916: Michigan, Montana, Nebraska, South Dakota
1917: Indiana, New Hampshire, New Mexico, Utah
1918: Florida, Nevada, Ohio, Wyoming
1919: Kentucky, Texas
Note: New Hampshire repealed its 1855 prohibition in 1903. Alabama repealed its 1908 prohibition in 1911.

Source: Dill and Miron (2003)