Got Milk?
Milk Pasteurization and Mortality: 1900-1924

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In this paper, I analyze the impact of mandatory milk pasteurization in 38 large U.S. cities on five subsequent mortality rates: the mortality rate from diarrhea and enteritis for children under the age of two and the all-age mortality rates from non-pulmonary tuberculosis, typhoid fever, scarlet fever, and diphtheria. I analyze these outcomes using Vital Statistics data for 38 large U.S. cities spanning 1900 to 1924 in conjunction with decennial census data from 1900 to 1930. I find a statistically significant relationship between milk pasteurization ordinances and a decline in mortality from non-pulmonary tuberculosis and diarrhea and enteritis. I find evidence of a similar relationship between milk pasteurization ordinances and mortality rates from scarlet fever and diphtheria.

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Introduction

During the turn of the twentieth century, milk was extolled for being both nutritious and relatively inexpensive- a "perfect food" (Block 1999). Yet milk was also dangerous. By 1900, 44 states had laws regulating the sale of milk and 25 employed at least one public health official whose primary duty was to enforce those laws (Selitzer 1976). As early as the mid-1800s, unclean milk was being linked to outbreaks of septic sore throat, typhoid fever, diphtheria, and scarlet fever (US Public Health 1919). Additionally, cases of non-pulmonary tuberculosis and a large number of infant deaths from diarrhea had been connected to dirty milk (Selitzer 1976). At this time, unhygienic conditions in dairy farms, along with the transport of raw milk in unsealed and unrefrigerated vats, made cows' milk an often deadly concoction (Ward 2006).

Around this time, cities experimented with potential solutions to what was known as "the milk problem." In the 1890's and early 1900's, cities across the United States attempted to combat the

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problem through the passage of dairy farm regulations setting guidelines and protocols and requiring inspections to ensure that dairy farms were complying (Wiley 2011). To a significant degree, dairy farm inspections improved the sanitary conditions on farms that supplied milk to cities (Kober 1901). However, many public health officials at the time felt that such regulations failed to fully address many issues, notably those pertaining to the transportation and distribution of milk once it left the farms (Weekly Reports 1915). Additionally, although many cities had laws setting standards for dairy sanitation, their enforcement was handicapped due to a lack of funding or resources. For example, in Chicago in 1915, each of the city's fifteen dairy farm inspectors had to supervise and inspect an average of 933 farms, ideally multiple times each year (Weekly Reports 1915).

In order to address the high rates of death and disease that remained linked to milk, cities debated two other options: certification and pasteurization (Anderson 2014). Certified milk was obtained from cows that had been tested for bovine tuberculosis and was subjected to stringent requirements regarding its handling and bacterial counts within the milk. At the time, however, certified milk sold for twice the price of ordinary milk and remained susceptible to adulteration between the farm and the market due to technological limitations and gaps in knowledge regarding milk handling and storage (Schmid 2003).

In contrast, pasteurization (heating milk to 140° for 20 minutes to kill the harmful bacteria present) was an economical solution that created a supply of milk that was both affordable and systematically safer than even the certified raw milk of the day (Schmid 2003). The pasteurization process not only killed virtually all of the harmful bacteria in a way that was less costly than strictly certifying every step of the milk-handling process, but pasteurization plants were often located closer to the cities than dairy farms and there were fewer pasteurization plants to inspect, resulting in fewer opportunities for the milk to then become contaminated before reaching the consumer (Weekly Reports 1915).

While the timing of the adoption of mandatory pasteurization laws was likely not entirely random, there were several decades of ongoing debates between public health officials, dairy interests, and citizens as to the desirability of pasteurization. Some worried that pasteurization would allow dairy farms to get away with producing extremely unhygienic milk, while other individuals were under the false notion that the process of pasteurization would lower the nutritional value of milk or that pasteurization would be too costly (Steele 2000). The element of randomness inherent in the timing of the passage of these laws in each city and the associated changes in mortality allow us to identify the impact of pasteurization on subsequent mortality outcomes.

Literature Review

A number of papers (Caldwell et al. 1990; Cutler and Miller 2004; Goff 2010; Leavitt 1996; Miller 2008; Meckel 1990; Wolf 2003) have analyzed various policies and infrastructural changes that impacted public health in cities during this time period. Most notably, these included the introduction of water filtration, water chlorination, and the handling of sewage in large cities. Cutler and Miller (2004) find large, significant health improvements corresponding with the advent of water purification in large U.S. cities, suggesting that an attempt to identify the causal impact of other public health advances during this period should control for these factors.

Komisarow (2017) explores the impact of the passage of regulations mandating dairy farm inspections in 40 large U.S. cities on child mortality around the turn of the 20th century. She finds evidence that dairy farm inspections caused a discernible drop in mortality rates for young children due to diarrhea and enteritis, measles, typhoid fever, and scarlet fever in large cities. In order to account for this effect, I include the dates of the passage of city ordinances mandating dairy farm inspections in my analysis.

In his dissertation, Wang (2015) analyzes the impact of milk pasteurization on deaths from diarrhea and enteritis for children in Chicago, subsequently expanding upon this analysis to include numerous other large cities. Wang finds a decline in deaths for children in Chicago following the milk pasteurization ordinance of 1916, but uncovers heterogeneity in this effect across places- some cities seemed to experience no change in the corresponding mortality rate as the result of the passage of a milk pasteurization law.

This paper adds to the literature by utilizing a novel dataset of five mortality outcomes in order to investigate the impact of total milk pasteurization on a city's mortality rates. Using a difference-in-difference approach, I leverage cross-city variation in the dates that cities passed milk pasteurization ordinances to uncover the mortality effects of mandatory milk pasteurization.

Mortality Rates in U.S. Cities

Historically, unclean milk was linked to outbreaks of scarlet fever, diphtheria, tuberculosis, and typhoid fever (Block 1999). Additionally, numerous public health officials, doctors, and humanitarians suspected that mortality rates from diarrhea and enteritis among infants and children were connected to unclean milk (Selitzer 1976). In the early twentieth century, outbreaks of scarlet fever, diphtheria, tuberculosis, and typhoid fever, and excessively high mortality rates among children from diarrhea and enteritis all resulted from a city milk supply that had too many vulnerabilities to infection by dangerous pathogens and the introduction of disease.

During to the early 1900s, infant mortality rates were as high as 50 percent in some cities and as many as half of those deaths were attributable to diarrhea (Schmid 2003; Ward 2006). During this time, more women began to join the workforce and mothers increasingly began eschewing breastfeeding in favor of cows' milk (Wolf 2003). Thus, young children were especially vulnerable to unclean milk due to their inability to fight off pathogens and their high exposure to milk (Caldwell 1990). Public health officials and scholars during this time period noted that there were quick and significant declines in infant mortality from diarrhea and enteritis following the pasteurization of cities' milk supplies (Crumbine and Tobey 1929). To investigate this impact, I use the mortality rate from diarrhea and enteritis for children under two years old as one of the mortality outcomes that may have been improved by milk pasteurization.

Before widespread pasteurization, the majority of cases of non-pulmonary tuberculosis resulted from infection by *M. bovis*, which was most commonly transmitted to humans through cows' milk, especially in urban regions where milk was frequently pooled together and transported in large vats (Grange 2001). Unlike pulmonary tuberculosis, bovine tuberculosis attacked the glands, intestines, and bones, killing or deforming those who became infected. Although not as widespread as the human strain of tuberculosis, it is estimated that in some U.S. cities, bovine tuberculosis could have accounted for as much as 65-85% of all tuberculosis cases (Selitzer 1976). Other estimates put the overall percentage of all tuberculosis infections accounted for by the bovine variety at roughly 25% for children under 16 and 1.6% for adults (Crumbine and Tobey 1929). Non-pulmonary tuberculosis mortality rates likely would have fallen with the widespread pasteurization of milk.

Milk-borne outbreaks of typhoid fever were another consequence of unpasteurized milk. Epidemics were traced back to milk that had been handled by someone who had been exposed to typhoid fever or from sewage that in some way came in contact with milk during the production process. Additionally, since the single largest source of typhoid fever in cities was infected water, milk would sometimes become infected with typhoid fever when dairymen or shippers watered down vats of milk in an effort to increase their profits (Weekly Reports 1915). Sometimes, dairymen in the cities would pool together milk from many farms, broadening the reach of diseased milk (Kober 1901). This milk was then delivered to customers in cities without undergoing pasteurization to eradicate the harmful *Salmonella typhi* bacteria (Bryan 1983). My analysis seeks to examine the impact of the widespread adoption of milk pasteurization on typhoid fever mortality rates in large U.S. cities.

From 1900 to 1930, epidemics of scarlet fever were the second most common type of milk-borne outbreaks, after typhoid fever (Bryan 1983). In an address to the International Medical Congress in 1881 Ernest Hart, the editor of the *British Medical Journal*, gave an account of fifteen epidemics of scarlet fever traceable to the milk supply (Kober 1901). In Kober's (1901) subsequent analysis of epidemics in the United States and Europe, he found the means of transmission of scarlet fever to be cow's milk in sixty-eight of the ninety-nine outbreaks. Scarlet fever entered the milk supply through contamination of the milk by an infected farm worker or by cows who were infected through lesions on their udders (Bryan 1983).

Kober's (1901) analysis also found that thirteen of thirty-six outbreaks of diphtheria that he studied were linked to the milk supply. *Corynebacterium diphtheria* contaminated milk via an infected individual coughing or sneezing the bacilli into the milk (Dhanashekar 2012). Diphtheria, the final mortality rate I analyze, accounted for a smaller share of milk-borne outbreaks than either typhoid or scarlet fever (Byran 1983).

Data

In this paper, I analyze the mortality impact of milk pasteurization in 38 U.S. cities which had populations near to or greater than 100,000 in 1900.[2] Of these, 18 cities passed ordinances mandating the pasteurization of milk sold within the city during the period of my analysis. I digitize selected mortality rates from Vital Statistics records spanning 1900 to 1924. From these records, I obtain the annual mortality rate from diarrhea and enteritis[3] for children under two years old, as well as the all-age mortality rates due to tuberculosis, typhoid fever, scarlet fever, and diphtheria in each of the cities in my analysis. In order to control for the demographic characteristics of each city, I obtain data from the IPUMS full count 1900, 1910, 1920, and 1930 decennial censuses. I linearly interpolate values for the log of the total population of each city, the share of white residents, and the share of foreign-born

[2] 36 cities had populations greater than 100,000 as of the year 1900, while two others reached populations of 100,000 by 1910.

[3] From 1900 to 1906, Vital Statistics only reports the mortality rate for diarrhea and enteritis for all ages. Mortality rates for children under 2 years of age account for 80-85% of these deaths. I use these rates from 1900 to 1906 multiplied by the share accounted for by children under 2 years old. For more information, see Appendix C.

residents for the years in between each decade. Table 1 reports summary statistics for my mortality measures and the cities' demographic characteristics.[4]

Table 1: Summary Statistics

	Obs.	Mean	Std. Dev.	Min	Max
Diarrhea & enteritis mortality rate (ages 0-2) per 100,000 population	930	78.818	49.520	7.1	401.2
Non-lung tuberculosis mortality rate (all ages) per 100,000 population	928	22.417	9.1405	0	116.4
Typhoid mortality rate (all ages) per 100,000 population	928	19.171	20.292	0.5	147.7
Scarlet fever mortality rate (all ages) per 100,000 population	908	8.473	9.123	0.3	96.1
Diphtheria mortality rate (all ages) per 100,000 population	926	22.188	13.875	1.7	136.2
Log(Total Population)	950	12.648	0.8469	11.350	15.631
Share Foreign-born	950	0.2223	0.1053	0.0265	0.4781
Share White	950	0.9297	0.0979	0.5133	1.011

I source dates regarding the advent of water filtration and chlorination for 21 of the cities included in my analysis from Cutler and Miller (2005) and the General Statistics of Cities (1916) in order to control for this contemporaneous public health advancement. I source dates designating the year that cities mandated dairy farm inspections from Komisarow (2017).

Table 2 presents an overview of the years in which cities in my sample passed ordinances mandating milk pasteurization, as well as estimates of the percentage of milk in each city that was pasteurized by 1924 and 1931 respectively. Notably, at least 17 of the 18 cities that passed ordinances achieved almost complete pasteurization of their milk supply by 1924. Additionally, cities experienced varying levels of pasteurization prior to the passage of their ordinance. For example, in a study of mid-sized cities in the Ohio River Valley, Dayton was estimated to have had 65% of its milk supply pasteurized by 1915, even though the city did not pass its milk pasteurization ordinance until 1918 (Public Health Reports 1917). Unfortunately, complete records for cities' milk pasteurization levels appear not to exist prior to 1924.

[4] Tables reporting summary statistics separately according to whether a city passed a pasteurization ordinance during my analysis are available in Appendix D.

Table 2: Milk Pasteurization Ordinance Laws and Pasteurization Rates in Select Years

City	State	% of Milk in 1924	% of Milk in 1931	Ordinance Date
Baltimore	Maryland	98.2	98.5	1917
Boston	Massachusetts	97	99.6	1915
Buffalo	New York	---	99.7	1918
Chicago	Illinois	99	99.5	1916
Cincinnati	Ohio	98	100	1912
Cleveland	Ohio	98	99	1916
Dayton	Ohio	95	99.9	1918
Detroit	Michigan	98.5	99.6	1915
Indianapolis	Indiana	---	97.5	1916
Jersey City	New Jersey	89.0	98	1915
Los Angeles	California	---	82.3	1916
Milwaukee	Wisconsin	---	99.5	1920
New York	New York	98	98.3	1911
Philadelphia	Pennsylvania	---	99.7	1914
Richmond	Virginia	97	100	1916
Saint Louis	Missouri	97.6	99.5	1915
San Francisco	California	97	96.2	1916
Toledo	Ohio	99.5	99.5	1915

Note: Sources for pasteurization ordinance dates available in Appendix A. For pasteurization levels for cities that did not pass mandatory pasteurization ordinances, see Appendix B.

Empirical Strategy

I use a difference-in-difference approach to identify variation in mortality outcomes between cities that imposed ordinances requiring the mandatory pasteurization of milk and those that did not. I leverage variation in the dates of these ordinances to identify the relationship between city milk pasteurization ordinances and the corresponding mortality rate due to diarrhea and enteritis for children under two, and the all-age mortality rates from non-pulmonary tuberculosis, typhoid fever, scarlet fever, and diphtheria.

I regress the morality rate (Y_{it}) for city i in year t on an indicator for whether it has a milk pasteurization ordinance (P_{it}) in place:

$$Y_{it} = \alpha_i + \delta_t + \boldsymbol{X}_{it}'\beta + \gamma P_{it} + \varepsilon_{it}$$

where α_i is a city fixed effect for city i, δ_t a year fixed effect for year t, and $\mathbf{X_{it}}$ a vector of controls. P_{it} is an indicator variable denoting whether a city in a given year is under the effects of a milk pasteurization ordinance.

Anecdotally, the advent of milk pasteurization improved health outcomes in cities, but attempting to identify the impact of milk pasteurization in particular is challenging as there were numerous other improvements in public health that occurred during this period (Schmid 2003). To address these unobserved influences, I include controls for the timing of a city's implementation of water filtration, water chlorination, and requirement for dairy farm inspections. I also include city-level demographic controls for the share of white residents, the share of foreign born residents, and the log of the city population. I control for the log of the city population because it relates to crowding conditions and thus the spread of disease. Finally, my analysis is weighed by city population.[5]

Results and Discussion

Table 3 presents the main results of my analysis. The primary coefficient of interest is that on *ordinance*. This coefficient can be interpreted as the change in mortality rates associated with the passage of a pasteurization ordinance. I regress the mortality rate from diarrhea and enteritis for children under 2 years old (column 1), the non-lung tuberculosis mortality rate for all ages (column 2), the typhoid mortality rate for all ages (columns 3), the scarlet fever mortality rate for all ages (column 4), and the diphtheria mortality rate for all ages (column 5) on the passage of a milk pasteurization ordinance in a given city. All columns include city fixed effects to control for unobserved heterogeneity across cities and year fixed effects to account for shared year-to-year fluctuations in mortality. Panel B adds demographic controls, controls for the timing of the implementation of water chlorination and filtration systems, and the timing of the passage of laws mandating dairy farm inspections.

[5] Full regression results for this analysis not weighted by population can be found in Appendix E.

Table 3: Mortality Rates					
	Diarrhea & Enteritis Mortality Rate (Ages 0-2)	Non-lung Tuberculosis Mortality Rate (All Ages)	Typhoid Fever Mortality Rate (All Ages)	Scarlet Fever Mortality Rate (All Ages)	Diphtheria Mortality Rate (All Ages)
Panel A: City and year fixed effects					
Ordinance	-12.94	-1.859*	5.355	-3.344*	-4.897*
	(9.445)	(1.077)	(4.761)	(1.726)	(2.812)
Observations	930	928	928	908	926
R-squared	0.819	0.710	0.638	0.489	0.614
Panel B: All Covariates[6]					
Ordinance	-10.60*	-2.834***	5.683	-1.451	-1.218
	(6.250)	(0.812)	(4.622)	(1.271)	(1.851)
Dairy Farm Inspections	8.391	2.374**	-11.39**	1.902	4.471*
	(5.333)	(1.104)	(1.104)	(4.808)	(1.663)
Share Foreign-born	35.90	-105.6***	128.8	-34.35	-196.7***
	(289.3)	(38.01)	(185.9)	(64.15)	(69.53)
Share White	-359.9*	-9.329	-129.4	59.53	118.2
	(212.4)	(55.47)	(134.8)	(49.62)	(82.22)
Log(population)	27.82	13.69***	-6.068	4.764	14.04***
	(19.92)	(3.633)	(15.60)	(4.008)	(4.996)
Water Filtration	-15.40*	0.593	-13.81**	-0.382	-2.741
	(7.784)	(0.905)	(5.765)	(1.314)	(2.992)
Water Chlorination	-10.32	1.995**	-3.076	-2.662*	-4.208*
	(6.315)	(0.791)	(3.896)	(1.525)	(2.284)
City Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	930	928	928	908	926
R-squared	0.839	0.748	0.698	0.501	0.651

Robust standard errors in parentheses. All mortality rates are per 100,000 population.

[6] Changes in coefficients seen from first panel to second are primarily driven by inclusion of demographic controls.

*** p<0.01, ** p<0.05, * p<0.1

Panel A reports results for each regression without the inclusion of demographic and public health controls. As these results are suggestive of the more refined analysis in Panel B that includes controls for demographic composition and public health advancements, I will primarily discuss results from Panel B.

In column 1, the coefficient on ordinance suggests that the passage of a milk pasteurization ordinance resulted in a decrease in the mortality rate from diarrhea and enteritis of 10.6 deaths per 100,000 people. This decrease is statistically significant at the 10% level. Since the mean mortality rate from diarrhea and enteritis is 78.8, this drop represents a 13% decrease in the mean.

In column 2, the coefficient on ordinance becomes greater in magnitude and more precise from Panel A to Panel B with the inclusion of controls for demographic and public health advances. My results suggest that the passage of a milk pasteurization ordinance lowered the mortality rate for non-pulmonary tuberculosis by 2.834 deaths per 100,000 people. While this is only a modest reduction in the mortality rate, this decrease is highly statistically significant.

In column 3, the coefficient on ordinance is fairly large and positive, although statistically insignificant. In this column, we see that dairy farm inspections and water filtration are both highly significant predictors of large decreases in the typhoid fever mortality rate. These results are unsurprising given Cutler and Miller's (2004) investigation regarding the ability of water purification to decrease mortality rates due to typhoid fever. Additionally, while most milk pasteurization ordinances came about after city's water purification efforts, almost all regulations mandating dairy farm inspections preceded water sanitization efforts. Thus it is possible that dairy farm inspections were able to successfully moderate high pre-water-purification typhoid fever mortality rates.

In both column 4 and column 5, the coefficient for the passage of a milk pasteurization ordinance on the mortality rates from scarlet fever and diphtheria decreases from Panel A to Panel B with the inclusion of demographic and public health controls. While neither coefficient is statistically significant, both are suggestive of a decrease in the mortality rate from scarlet fever and diphtheria respectively following the imposition of milk pasteurization ordinances.

One of the greatest challenges to identifying the impact of milk pasteurization ordinances is that cities experienced different initial levels of pasteurization prior to the passage of their ordinances. This makes it difficult to reliably and consistently identify the exact time at which a significant change in the quality of the milk supply took place. An interesting avenue for further analysis would be to endeavor to locate information on cities' levels of pasteurization prior to the passage of their ordinances. One would expect a smaller "effect" for an ordinance in a city that already had a high level of pasteurization prior to passing an ordinance and this would perhaps allow us to better identify corresponding changes in subsequent mortality rates.

Conclusion

Shortly following the turn of the twentieth century, large U.S. cities experienced major public health advancements as the result of greater understanding of the dangerous bacteria that were transmitted via disease vectors such as unpurified water and unpasteurized milk (Selitzer 1976). In an effort to address the disease outbreaks and high mortality rates associated with unpasteurized milk, cities underwent a period during which there was widespread adoption of mandatory milk pasteurization. However, efforts to identify the effects of these ordinances requiring the pasteurization of milk have been confounded by simultaneous public health advancements during the time period, as well as a lack of historical records regarding the timing and extent of pasteurization in many cities.

In this paper, I leverage variation in dates of the adoption of milk pasteurization ordinances in a subset of large U.S. cities to identify the causal effects of the passage of ordinances requiring complete milk pasteurization on mortality rates for diarrhea and enteritis, non-lung tuberculosis, typhoid fever, scarlet fever, and diphtheria. I find that the passage of milk pasteurization ordinances is associated with a statistically significant decrease in mortality rates due to diarrhea and enteritis for children under 2 and non-lung tuberculosis for all ages. I also find evidence suggesting a similar relationship between pasteurization ordinances and the mortality rate from scarlet fever and diphtheria. In this paper, I find empirical evidence to support anecdotal accounts suggesting the value of milk pasteurization as a momentous public health advancement that has safeguarded many lives.

Appendix A: Sources for Milk Pasteurization Ordinance Dates

Baltimore: Medical news, Journal of the American Medical Association, 1917, 68, p. 1418; Atlantic reporter, Volume 104, West Publishing Company, 1918, p. 181-182.
Boston: Anderson, Christopher M. "Striking a balance: regulation of raw milk and a new approach for Indiana." *Ind. Health L. Rev.*11 (2014): 399.
Buffalo: Food Inspection, Annual report of Department of Health, 1919, p. 114; US Public Health Service, Public Health Reports 1917-1919, p. 318-319.
Chicago: Illinois Health News, Illinois State Department of Health, 1922, p. 144-145.
Cincinnati: US Public Health Service, Public Health Reports 1915, p. 2567.
Cleveland: US Public Health Service, Municipal Ordinances and Regulations Pertaining to Public Health 1915, p. 217-224.
Dayton: The Creamery and Milk Plant Monthly, 1918, August, p. 37.
Detroit: Hedrick W. and Anderson A., Detroit Commission Plan of City Milk Administration, 1919, p. 12.
Indianapolis: Journal of the Indiana State Medical Association, 1916, February, p. 71; US Public Health Service, Municipal Ordinances and Regulations Pertaining to Public Health 1916, p. 130-134.
Jersey City: US Public Health Service, Municipal Ordinances and Regulations Pertaining to Public Health 1915, p. 291-296.
Los Angeles: US Public Health Service, Municipal Ordinances and Regulations Pertaining to Public Health 1915.
Milwaukee: Hibbard B. and Erdmann H., Marketing Wisconsin milk, 1917, p. 49-50; Levitt J. W., The Healthiest City: Milwaukee and the Politics of Health Reform, 1996, p. 187.
New York: Monthly Bulletin of the Department of Health in the City of New York, New York Department of Health, 1912, p. 4-9.
Philadelphia: National Municipal Review, Vol. 2, National Municipal League, 1913, p. 716-717
Richmond: US Public Health Service, Municipal Ordinances and Regulations Pertaining to Public Health 1915, p. 364-365.
St. Louis: Health Departments Reports and Notes, American Journal of Public Health, 1914, 7, p. 619.
San Francisco: US Public Health Service, Reprint from the Public Health Reports, 1916, p. 160-173
Toledo: US Public Health Service, Municipal Ordinances and Regulations Pertaining to Public Health 1915, p. 386- 389.

Appendix B: Milk pasteurization rates for cities without a milk pasteurization ordinance

Milk Pasteurization Rates: Non-ordinance Cities

City	State	% of Milk in 1924	% of Milk in 1931
Columbus	Ohio	90	95.2
Denver	Colorado	80	100
Fall River	Massachusetts	55	100
Kansas City	Missouri	50	50
Louisville	Kentucky	---	96
Memphis	Tennessee	49.7	71
Minneapolis	Minnesota	95.9	96.6
New Haven	Connecticut	90	80
New Orleans	Louisiana	20	---
Newark	New Jersey	90	98
Omaha	Nebraska	---	70
Paterson	New Jersey	---	---
Pittsburgh	Pennsylvania	---	98
Providence	Rhode Island	63.3	86.5
Rochester	New York	95	98.4
Saint Paul	Minnesota	---	79.7
Scranton	Pennsylvania	90	95
Syracuse	New York	92.4	99.2
Washington	District of Columbia	95	97
Worcester	Massachusetts	85	91.5

Appendix C: Mortality rates from diarrhea and enteritis under 2 years – 1900 to 1907

From 1900 to 1906, Vital Statistics only reports the mortality rate for diarrhea and enteritis for all ages. Mortality rates for children under 2 years of age account for 80-85% of these deaths. I use these rates from 1900 to 1906 multiplied by the share accounted for by children under 2 years old.

In 1907, Vital Statistics reports both the total mortality rate and the under 2 mortality rate, so I use this year to check the validity of my estimates. The correlation between the estimated and reported under-2 mortality rates from diarrhea and enteritis for 1907 is .9927, with the estimated values exceeding the reported values by an average of 1.7 deaths. As compared to the mean for this year of 107.11 deaths, this difference is small.

Diarrhea and Enteritis				
	Estimated Values 1900-1906		No Data 1900-1906	
Ordinance	-12.94	-10.60*	-9.737	-7.813
	(9.445)	(6.250)	(5.917)	(5.176)
Dairy Farm Inspections		8.391		4.074
		(5.333)		(10.69)
Share Foreign-born		35.90		514.1*
		(289.3)		(303.7)
Share White		-359.9*		-82.92
		(212.4)		(326.1)
Log(population)		27.82		45.10**
		(19.92)		(17.38)
Water Filtration		-15.40*		1.931
		(7.784)		(8.812)
Water Chlorination		-10.32		-6.272
		(6.315)		(5.764)
City Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	930	930	680	680
R-squared	0.819	0.839	0.861	0.876

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

Appendix D: Summary statistics by ordinance-passing status

Summary Statistics: Ordinance cities

	Obs.	Mean	Std. Dev.	Min	Max
Diarrhea & enteritis mortality (ages 0-2) per 100,000 population	321	70.920	37.501	8.4	169.9
Non-lung tuberculosis mortality (all ages) per 100,000 population	429	22.426	8.553	5.5	55.5
Typhoid mortality rate (all ages) per 100,000 population	430	17.297	15.963	1	115
Scarlet fever mortality rate (all ages) per 100,000 population	421	8.643	8.381	0.5	55.6
Diphtheria mortality rate (all ages) per 100,000 population	429	23.731	14.322	2.9	92.4
Log(Total Population)	450	13.111	0.9428	11.350	15.631
Share Foreign-born	450	0.2296	0.1033	0.0265	0.4099
Share White	450	0.9387	0.0783	0.6228	1.011

Summary Statistics: Non-ordinance Cities

	Obs.	Mean	Std. Dev.	Min	Max
Diarrhea & enteritis mortality (ages 0-2) per 100,000 population	499	78.678	57.869	7.1	401.2
Non-lung tuberculosis mortality (all ages) per 100,000 population	499	22.410	9.6249	0	116.4
Typhoid mortality rate (all ages) per 100,000 population	498	20.789	23.290	0.5	147.7
Scarlet fever mortality rate (all ages) per 100,000 population	487	8.327	9.7265	0.3	96.1
Diphtheria mortality rate (all ages) per 100,000 population	497	20.855	13.34991	1.7	136.2
Log(Total Population)	500	12.230	0.4425	11.532	13.338
Share Foreign-born	500	0.2157	0.1069	0.0289	0.4781
Share White	500	0.9215	0.1121	0.5133	1.005

Appendix E: Unweighted regression results

Table 3: Mortality Rates					
	Diarrhea & Enteritis Mortality Rate (Ages 0-2)	Non-lung Tuberculosis Mortality Rate (All Ages)	Typhoid Fever Mortality Rate (All Ages)	Scarlet Fever Mortality Rate (All Ages)	Diphtheria Mortality Rate (All Ages)
Panel A: City and year fixed effects					
Ordinance	-0.124	-2.665*	0.715	-0.538	-1.233
	(7.098)	(1.548)	(3.692)	(1.481)	(2.350)
Observations	930	928	928	908	926
R-squared	0.826	0.547	0.608	0.325	0.465
Panel B: All Covariates					
Ordinance	-6.436	-3.395***	2.569	-0.240	-0.643
	(5.883)	(1.051)	(4.213)	(1.406)	(2.365)
Dairy Farm Inspections	2.167	3.781**	0.305	1.820	3.698*
	(6.244)	(9.376)	(1.693)	(4.272)	(2.114)
Share Foreign-born	293.2	-110.7***	32.45	10.37	-81.28
	(227.4)	(37.94)	(115.5)	(48.17)	(78.30)
Share White	-421.7**	41.41	-99.89	40.34	127.3**
	(200.7)	(63.46)	(100.5)	(36.25)	(61.67)
Log(population)	45.79*	13.57***	-17.20	6.762	13.02*
	(27.13)	(4.580)	(17.40)	(4.520)	(7.158)
Water Filtration	-10.29	-0.265	-19.63***	0.990	-1.240
	(6.142)	(1.454)	(6.437)	(1.516)	(2.603)
Water Chlorination	1.856	2.675**	-3.351	-1.013	0.876
	(6.506)	(1.020)	(3.452)	(1.278)	(2.410)
City Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	930	928	928	908	926
R-squared	0.843	0.584	0.672	0.333	0.479

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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