Comment on “Pubic Health Efforts and the Decline in Urban Mortality”

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Abstract:
In this comment, we address points raised by Mark Anderson, Kerwin Charles, and Daniel Rees’s August 2018 NBER working paper entitled “Pubic Health Efforts and the Decline in Urban Mortality.” The points generally fall into three categories: (1) assignment of differing clean water intervention dates, (2) construction of differing mortality rates using different population denominators, and (3) computation of correct standard errors. Ultimately, a large share of the discrepancies between our 2005 analysis and theirs is due to the construction of population denominators for mortality rates when such denominators are not known for certain. After carefully considering their points and correcting the unambiguous mistakes in our original data, our revised estimates suggest that municipal water disinfection (filtration) explains 38% of the mortality decline in our sample cities and study years – a result not dramatically different from the estimated 43% in the original paper.

We thank Kim Singer Babiarz for assistance in preparing this comment and Kerwin Charles, Mark Anderson, and Daniel Rees for valuable feedback.

1. Introduction

In this comment, we address points raised by Mark Anderson, Kerwin Charles, and Daniel Rees's August 2018 NBER working paper entitled "Pubic Health Efforts and the Decline in Urban Mortality" ("ACR"). ACR is, in part, an examination of our 2005 *Demography* article entitled "The Role of Public Health Improvements in Health Advances: The 20th Century United States" ("CM"). During the summer of 2018, we shared data and code from CM with ACR. They replicated our original results. In conducting new analyses of both milk purification and water/sanitation technologies in American cities in the early 20th century, ACR then also identified differences between our original analysis and their new analysis. ACR communicated with us about these issues in a helpful and collegial manner. We very much appreciate their constructive feedback. In light of their results, we have evaluated the issues further. We report our findings here.

The issues raised by ACR generally fall into three categories: (1) assignment of differing clean water intervention dates, (2) construction of differing mortality rates using different population denominators, and (3) computation of correct standard errors. We discuss each of these points in turn.

Overall, several of the errors identified in ACR are in fact mistakes in the original paper. We are grateful to have these identified. The dataset available online includes updates to correct these errors.[1] However, a large share of the discrepancy in the estimates between CM and ACR is due to the construction of population denominators for mortality rates when such denominators are not known for certain.

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[1] This data is available at https://ngmiller.people.stanford.edu/sites/g/files/sbiybj4811/f/demography2005_0002_final.dta

After carefully considering the points raised by ACR and correcting the unambiguous mistakes in our original data, our revised estimates suggest that municipal water disinfection (filtration) explains 38% of the mortality decline in our sample cities and study years – a result not dramatically different from the estimated 43% in the original paper. Based on these results and others in the literature, we believe that these technologies have been important for historical urban mortality decline.

2. The Findings of Cutler and Miller

In our earlier paper, we estimated panel data models examining the impact of water filtration and chlorination on mortality. Our primary outcome was the total mortality rate in the city, with other outcomes including infant morality and mortality by cause. Our central result was that 43% of the reduction in total mortality between 1900 and 1936 was a result of clean water interventions.

That original analysis had one computational error, pointed out to us by Alsan and Goldin and discussed further in an unpublished note (Cutler and Miller, 2016): we used the change in log points in the numerator and divided it by the percent change in deaths in the denominator.[2] Correcting this error by using percent changes for both leads to a corrected clean water share of improved mortality of 41%. We use this estimate in examining the effect of the changes proposed by ACR.

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[2] An erratum note is available online at https://ngmiller.people.stanford.edu/sites/g/files/sbiybj4811/f/erratum.pdf.

3. Assignment of Clean Water Intervention Dates

ACR identify a number of differences in clean water intervention dates between CM and their reading of the evidence. All told, they estimate that dates of water filtration for 4 cities and chlorination for 7 cities are different than originally reported. To evaluate discrepancies in implementation dates, we focus on estimates explaining total mortality (the key variable in our original paper). Table 1, Columns 1 and 2 show the effect of these alternative intervention dates on our original results. For the filtration coefficient, the coefficient falls from -0.16 (p-value = 0.026) in our original data to -0.14 (p-value = 0.025) using their intervention dates.[3] For the filtration-chlorination interaction, the coefficient falls from 0.05 (p-value = 0.03) in our original data to 0.04 (p-value = 0.102).[4] Reviewing the data, these differences generally appear to be the result of two factors: differences in dates reported in various historical sources and differences in coding when an intervention was introduced in a phased manner over multiple years.

On differences in intervention dates used by ACR and CM, different historical sources give different dates for clean water interventions. When writing the original CM paper, we addressed this inconsistency by making phone calls to individual waterworks to verify intervention dates through each waterworks' own records. Reaching some confidence on intervention dates through discussions with waterworks employees, in part, ultimately motivated our choice of dates (and cities) to incorporate.

On differences in coding when an intervention was introduced in a phased manner over multiple years, the case of Philadelphia provides an illustrative example. Philadelphia adopted

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[3] We note that results obtained using ACR intervention dates throughout this comment differ from those reported in ACR Tables 14 and 15, because we recode control variables capturing lagged intervention effects to correspond to the ACR intervention dates. These updates yield slight changes in ACR point estimates.

[4] Following ACR, we report p-values computed using standard errors clustered at the city level, but Section 4 considers the most appropriate approach to constructing standard errors.

filtration technology incrementally between 1902 and 1909: filtration systems were installed in Lower Roxborough in 1902, Kittanning in 1905, and Lancaster in 1906. However, the largest facility, Torresdale, which provided the majority of Philadelphia's drinking water (and was the largest facility in the world at the time), was not completed until 1909. ACR use 1906 as the date of filtration, while CM use 1908. Upon reconsideration of Philadelphia's history, we are inclined to think that 1909 is the most appropriate date to use. Using these differing filtration dates results in filtration estimates ranging between -0.16 (p-value = 0.028) to -0.15 (p-value = 0.016), with all other dates coded as in CM and ACR (Table 1, Columns 3-4).[5]

Ultimately, because we are unsure how best to resolve these differences, we take an empirical approach to assessing the sensitivity of the CM and ACR results to intervention dates. Specifically, we begin with our original intervention dates and change each city's date, one at a time, to those used in ACR. The results are shown in Table 2, Panel A. Similarly, we also repeated this exercise in reverse, beginning with the ACR intervention dates and changing them one at a time to those used in CM (shown in Panel B). In both Panels, the estimates do not change by more than 1 percentage point across all cases and easily fall within the 95% confidence intervals of the base CM and ACR estimates.

Overall, although there are different possible ways to code the dates of clean water interventions, ultimately these dates do not explain key differences between the two sets of results.

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[5] We also note one additional intervention date coding difference between CM and ACR. In CM, clean water intervention dates are coded as dummy variables equal to 1 if a municipality had a water filtration plant or used chlorination and 0 otherwise. In ACR, when the month an intervention is known, clean water interventions are assigned a fractional value equal to the share of the year for which an intervention was implemented (the fractional value does not measure the share of population served by clean water technology, etc.). Interestingly, when the fractional ACR intervention dummy variables are recoded as dichotomous dummy variables (1 in years with any intervention), the point estimate for the effect of filtration increases from -0.15 (p-value = 0.016) to -0.19 (p-value = 0.01) – although if they introduced noise/classical measurement error, we would expect the resulting estimates to be smaller.

4. Population Estimates

Although CM and ACR collect mortality counts and rates from the same sources (US Census Bureau, 1909-1940), CM and ACR differ in two types of mortality rates employed in the analysis: total mortality and infant mortality.[6] We consider each in turn.

Total Mortality Rates

ACR first identify a coding error made in CM in calculating lagged mortality rates for the city of Memphis, which did not report any mortality data in the year 1916. Although Memphis is correctly coded as missing for 1916, lagged rates for the 5 subsequent years were erroneously coded as zeros rather than missing. Correcting this error results in estimates for *filtration* of -0.14 (p-value = 0.026) (Table 3, Column 2).

ACR then identify slight differences in total mortality rates for years 1901-1909 and more substantial differences for years 1910-1917 (there are no differences for years after 1917). After reviewing these differences, they appear due to differences in methods for estimating population denominators. For readers unfamiliar with vital registration systems, the number of deaths is recorded directly through local death reporting. However, annual population counts needed to convert death counts to death rates (with population denominators) are not known precisely. Rather, they are known with near certainty only in census years.

For total (all-cause) mortality, the U.S. Bureau of the Census reported both mortality counts and mortality rates in its annual *Mortality Statistics* volumes for years 1901-1917 (US Census Bureau, 1909-1940). To calculate mortality rates, the Bureau estimated population in intercensal years using two methods. The 1909 volume of *Mortality Statistics* reported mortality

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[6] Cause-specific mortality rates do not differ in the two sources.

rate estimates for 1901-1909 by assuming that annual population increase was 1/10th of the total increase between 1900 and the preliminary results of the 1910 census. For volumes covering 1910-1917, the Bureau estimated population denominators assuming that the annual population increase was 1/10th of the increase in population between the previous two decennial censuses (1900 and 1910) (US Census Bureau, 1916). Additionally, for a subset of cities, the Bureau of the Census reported mortality counts and mortality rates disaggregated by race for years 1910-1917. After 1917, the Bureau no longer reported mortality rates, but instead reported only death counts.

For years 1901-1917, CM used mortality rates reported in annual mortality statistics volumes. For all city-years 1901-1909, CM used revised mortality rates published in the 1909 annual *Mortality Statistics* volume. For years 1910-1917, CM digitized race-specific mortality rates for the 9 sample cities for which the Bureau of the Census reported data disaggregated by race. These race-specific mortality rates were then weighted using the population share in each race category to obtain total mortality rates. Although the rates calculated in this way do not exactly match the overall rates reported directly for total mortality, the two are close.[7] For the purpose of this re-assessment, we re-entered the contemporaneously reported total mortality rates reported for the population as a whole using the annual *Mortality Statistics* volumes for years 1910-1917. Using these total mortality rates as reported in aggregated form does not change the CM findings to two decimal points (Table 3, Column 3). For years after 1917, because the *Mortality Statistics* report only counts, CM divides the number of deaths by population estimates

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[7] For example, in 1914, the *Mortality Statistics* volume reports that the city of Cincinnati had an all-cause mortality rate of 1521.2 per 100,000 among white residents (93.7% of the population) and a mortality rate of 2959.6 per 100,000 among non-whites (6.3% of the population). CM calculated the total mortality rate among all residents as $(1521.2 \times 0.937106) + (2959.6 \times 0.062894) = 1611.667$. Aggregate total mortality rates reported in the same *Mortality Statistics* volume were 1599.0 for Cincinnati in 1914.

interpolated between census year population counts. Alternatively, ACR calculate mortality rates for all years using mortality counts and interpolated population estimates, even when the Bureau of the Census reports rates directly.

While these differences in population denominators seem arcane, they have considerable impact on the results. Columns 3-5 of Table 3 show that changing the method of calculating population denominators cuts the estimated impact of water filtration by about one-half. The 95% confidence interval around the CM estimates in column 3 includes the ACR (2018) estimate, but the reverse is not true.[8]

It is unclear which approach to constructing a time series of total mortality rates is preferable. The approach used by ACR has the appeal of using the same method consistently for all study years. However, it also discards information provided by the Bureau of the Census produced using the Bureau's method of population projection. The approach used by CM uses as much information reported directly by the Bureau of the Census as possible, but as a result uses two different methods for population denominators, before and after 1918.

What would the correct, "gold-standard" approach to constructing population denominators be? Ideally, one would build city-specific life tables to generate intercensal population projections (Wunsch et al., 2002). Building these life tables would require data (or estimates) on four types of population flows: births, deaths, immigration, and emigration. With annual measures of each, the process would be a relatively straightforward population

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[8] The 95% confidence interval for the CM estimates using total mortality rates aggregated across racial groups as reported by the Census Bureau is (-0.255 to -0.018). The confidence interval around the ACR estimates are (-0.113 to -0.006).

accounting exercise.[9] Annual measures of births and deaths are generally available,[10] but to the best of our knowledge, annual information on immigration and emigration are not. Nonetheless, methods for estimating immigration and emigration may be possible (and cohort sizes in intercensal years could be adjusted accordingly).

Infant Mortality Rates

Unlike for total mortality, the Bureau of the Census only reports infant mortality counts in all study years. To calculate infant mortality rates, both CM and ACR transcribe death counts, which are then divided by age-specific infant population projections interpolated between decennial census years.

ACR correctly identify several miscellaneous transcription errors in the infant mortality rates used in CM (for example, there were 856 infant deaths in Milwaukee in 1926, but the number of infant deaths was erroneously recorded as 865; these errors are reported in detail in ACR Appendix Table 6). Fortunately, they do not materially affect the results. Additionally, ACR identify a systematic error in the CM infant mortality rates for 9 cities in years 1910-1917. As was done for all-cause mortality, CM use age-specific death counts by race for these city-years and weight race-specific infant mortality using corresponding racial population shares. However, these weights were erroneously applied to infant death counts prior to calculating infant mortality rates, which were not ultimately calculated. Instead, the weighting approach should have been applied after calculating infant mortality rates for these city-years. This is a mistake that we are grateful to have identified.

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[9] In cases where birth and death counts were unavailable, one could use age-specific fertility and mortality rates in combination with census year population counts to estimate intercensal populations. Migration data would be required to adjust at-risk population shares in each age category.

[10] Birth counts by city are available for all years beginning in 1915.

Restricting to sample years used in CM, and using the corrected infant mortality rate observations in the CM analysis yields an effect size estimate of -0.13 (p-value = 0.050) (Table 4, Column 1). Similarly, using the interpolated population denominators to construct infant mortality rates for these 9 cities for years 1910-1917 yields revised, statistically insignificant estimates of -0.05 (p-value = 0.475) (Table 4, Column 2). Similarly, These effect sizes are markedly smaller than the ones originally reported in CM, and we agree with ACR that the share of infant mortality decline associated with clean water interventions appears smaller than reported earlier. However, we also note that given the composition and major causes of infant mortality during this era (concentrated in the neonatal period), along with the practice of exclusive breastfeeding, it is unclear that one would necessarily expect infants to be the demographic subgroup most sensitive to clean water interventions.[11] For example, Knutsson (2018) finds that clean water technology reduced Stockholm's total mortality rates by about 30%, but do not find statistically significant effects on infant mortality.

More generally, as with total mortality, the potential importance of the method for constructing population denominators for infant mortality rates is worth emphasizing. Given that annual variation in birth rates at the city level is presumably greater than annual variation in population, using population interpolation between decennial census years to construct population denominators is presumably more inaccurate for infant mortality rates than for total mortality rates. A preferable approach akin to the "life table" approach discussed for total mortality rates would be to use annual birth records to construct infant mortality rate denominators.

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[11] Because most infant deaths are birth-related and are concentrated in the first 28 days following birth (the neonatal period), obstetric factors are presumably more important, and there was little progress in obstetrics until the 1930s (birth conditions did not improve, and in fact maternal mortality rates did not decline in absolute terms until the mid-1930s despite background shifts in birthplaces from home to hospital) (Thomasson and Treber, 2004).

5. Standard Error Calculations

Finally, ACR note that CM do not adjust their standard errors for clustering at the city level. This is an important point and was not originally done because the well-known Bertrand et al. (2004) paper was not published at the time of writing the original CM paper. However, because the number of clusters is small (13 cities), the need to correctly bootstrap the standard errors is also relevant, as discussed in Cameron et al. (2008).

We therefore use the wild bootstrap to recompute standard errors (using newly re-entered total mortality rates as reported by the Bureau of the Census for years 1910-1917 and corrected infant mortality rates, adopting 1909 as the correct date for water filtration in Philadelphia, and correcting Memphis observations for missing data points). Doing so yields statistically significant estimates of water filtration for total mortality (-0.14, with a p-value of 0.021 and a 95% confidence set including the original CM estimates – Table 3, Column 6). The infant mortality rate results in CM are substantially reduced, although we noted reasons why this might be the case above (Table 4, Column 3). Overall, these revised estimates and bootstrapped standard errors imply that water filtration technology explains about 38% of the total mortality decline between 1900 and 1936.[12] This 38% reduction is similar to the 43% reduction in CM (2005) and the 41% reduction noted in an unpublished note in Cutler and Miller (2016)).

6. Conclusion

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[12] CM shows that mortality rates declined by about 30% between 1900 and 1936. Our revised results imply that, summing across water filtration and chlorination estimates, clean water technologies account for about $\frac{(e^{-0.12}-1)}{0.30} =$ 0.377 (38%) of total mortality rate decline.

We are very grateful to ACR for the careful re-analysis of our earlier paper and deeply appreciate both the constructive nature of our exchanges with them and the identification of several mistakes in our original paper. Many of the other discrepancies identified, including those that substantively and quantitatively matter most for the results, are ones which we believe require judgment – and for which there is no clearly correct approach. In this paper, we have done our best to evaluate these fairly, considering both the coding of city intervention dates and the construction of population denominators. We also show how advances in standard error estimation affect the results.

Our bottom line is that the discrepancies between CM (2005) and ACR (2018) is largely due to differences in the population denominators used to turn mortality counts into mortality rates. The gold standard, which neither CM nor ACR follow, would be to construct population denominators using city-specific life tables and population inflows and outflows. We consider this to be a topic deserving more attention in future research.

Overall, correcting the unambiguous mistakes in our earlier paper yields the finding that municipal water disinfection explains 38% of the mortality decline in our sample cities and study years – a result not dramatically different from the calculation of 41% noted above (Cutler and Miller, 2016). More generally, based on the findings of other papers studying municipal water and sanitation interventions in similar historical contexts, we believe that these technologies have been quite important for historical urban mortality decline (Alsan and Goldin, 2018, Cain and Rotella, 2001, Ferrie and Troesken, 2008, Ketzenbaum and Rosenthal, 2014, Knutsson, 2018, Ogasawara et al., 2015).

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Table 1: Alternate Water Sanitation Intervention Dates and All-Cause Mortality

Cause Mortality Rate Source:	CM	CM	CM	CM
Intervention Date Source:	CM	ACR	CM	ACR
Philadelphia Filtration Year:	1908	1906	1909	1909
Filtration	-0.16**	-0.14**	-0.16**	-0.15**
	(0.064)	(0.053)	(0.065)	(0.055)
Chlorination	-0.02	-0.04	-0.02	-0.05*
	(0.034)	(0.029)	(0.034)	(0.027)
Filtration * Chlorination	0.05	0.04	0.05	0.05
	(0.031)	(0.033)	(0.031)	(0.032)
Filtration Within 5 Years	-0.09	-0.06	-0.09	-0.07
	(0.066)	(0.049)	(0.065)	(0.048)
Chlorination Within 5 Years	0.02	-0.02	0.01	-0.03
	(0.022)	(0.018)	(0.020)	(0.017)
Observations	415	415	415	415
R-squared	0.957	0.955	0.956	0.957
F-test	7.754	1.784	2.279	4.311
Prob > F	5.09e-05	0.204	0.132	0.0279

Table shows the results of alternate water filtration and chlorination intervention dates on Equation 1 in Cutler and Miller (2005). Column 1 shows the original specification as estimated in Cutler and Miller (2005), with standard errors clustered at the city level. Column 2 adopts newly proposed water santiation intervention dates as given in Anderson, Charles, and Rees (2018). Column 3 revises CM intervention dates, changing the year of water filtration in Philadelphia to 1909. Column 4 adopts ACR (2018) intervention dates, but revises the date of Philadelphia's water filtration system to 1909. Standard errors are clustered at the city level. *** p<0.01, ** p<0.05, * p<0.10.

Table 2: Sensitivity to City-Specific Intervention Dates

Outcome:	Starting with CM (2005) Intervention Dates, Changing one City at a Time to ACR (2018) Intervention Date													
CM 2005 (Reentered)	Reference	Change only Chicago	Change only Louisville	Change only New Orleans	Change only Baltimore	Change only Detroit	Change only St Louis	Change only Jersey City	Change only Cinncinati	Change only Cleveland	Change only Philadelphia	Change only Pittsburgh	Change only Memphis	Change only Milwaukee
Filtration	-0.16**	-0.15**	-0.16**	-0.16**	-0.16**	-0.15***	-0.16**	-0.16**	-0.15**	-0.17**	-0.16**	-0.16**	-0.17**	-0.16**
	(0.064)	(0.062)	(0.064)	(0.064)	(0.062)	(0.049)	(0.066)	(0.064)	(0.064)	(0.063)	(0.064)	(0.063)	(0.064)	(0.065)
Chlorination	-0.02	-0.01	-0.03	-0.02	-0.02	-0.02	-0.01	-0.03	-0.02	-0.02	-0.03	-0.01	-0.03	-0.01
	(0.034)	(0.033)	(0.039)	(0.034)	(0.036)	(0.035)	(0.039)	(0.033)	(0.034)	(0.034)	(0.025)	(0.033)	(0.032)	(0.030)
Filtration * Chlorination	0.05	0.03	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.04
	(0.031)	(0.029)	(0.030)	(0.031)	(0.031)	(0.031)	(0.033)	(0.032)	(0.030)	(0.033)	(0.031)	(0.033)	(0.030)	(0.032)
Observations	415	415	415	415	415	415	415	415	415	415	415	415	415	415
R-squared	0.957	0.956	0.956	0.957	0.957	0.956	0.957	0.957	0.956	0.957	0.956	0.956	0.957	0.956
F-test	3.085	2.505	2.714	3.112	3.418	3.992	2.440	2.968	3.269	3.060	2.259	2.739	3.117	2.352
Prob > F	0.0681	0.109	0.0915	0.0667	0.0528	0.0348	0.115	0.0746	0.0591	0.0694	0.134	0.0896	0.0664	0.124

Outcome:	Starting with ACR (2018) Intervention Dates, Changing one City at a Time to CM (2005) Intervention Date													
CM 2005 (Reentered)	Reference	Change only Chicago	Change only Louisville	Change only New Orleans	Change only Baltimore	Change only Detroit	Change only St Louis	Change only Jersey City	Change only Cinncinati	Change only Cleveland	Change only Philadelphia	Change only Pittsburgh	Change only Memphis	Change only Milwaukee
Filtration	-0.14**	-0.15**	-0.13**	-0.14**	-0.14**	-0.15**	-0.13**	-0.13**	-0.15**	-0.13**	-0.14**	-0.14**	-0.13**	-0.14**
	(0.053)	(0.053)	(0.055)	(0.053)	(0.054)	(0.066)	(0.050)	(0.053)	(0.052)	(0.053)	(0.053)	(0.050)	(0.055)	(0.051)
Chlorination	-0.04	-0.06*	-0.03	-0.04	-0.04	-0.04	-0.04	-0.03	-0.04	-0.04	-0.03	-0.04	-0.03	-0.05
	(0.029)	(0.029)	(0.024)	(0.029)	(0.029)	(0.029)	(0.027)	(0.029)	(0.028)	(0.029)	(0.033)	(0.027)	(0.031)	(0.030)
Filtration * Chlorination	0.04	0.06	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.05
	(0.033)	(0.033)	(0.039)	(0.033)	(0.033)	(0.031)	(0.030)	(0.032)	(0.035)	(0.031)	(0.033)	(0.029)	(0.037)	(0.031)
Observations	415	415	415	415	415	415	415	415	415	415	415	415	415	415
R-squared	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956	0.956
F-test	2.893	4.128	2.548	2.921	3.036	2.288	2.769	2.648	4.027	2.620	2.494	3.081	2.192	3.250
Prob > F	0.0792	0.0316	0.105	0.0774	0.0707	0.131	0.0875	0.0965	0.0339	0.0988	0.110	0.0683	0.142	0.0599

Table shows the results of CM (2005) Equation 1 using original CM (2005) mortality rates. Panel A begins with CM (2005) intervention dates, and changes one city at a time to the date used in ACR (2018). Panel B begins with intervention dates shown in ACR (2018) and changes one city at a time to CM (2005) intervention dates. All specifications include sewage treatment dummy variables, lagged mortality, lagged intervention indicators, year and city dummy variables, city trends, and demographic characteristics (population share by gender, race, birthpace, and age). Robust standard errors clustered at the city level shown in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 3: Alternate Approaches to All-Cause Mortality Rate Calculation

Cause Mortality Rate Source:	CM	CM	CM (Reentered)	ACR	ACR	CM (Reentered)
Intervention Date Source:	CM	CM	CM	CM	ACR	CM
Philadelphia Filtration Year:	1909	1909	1909	1909	1909	1909
		Fix Memphis	Fix Memphis	Fix Memphis	Fix Memphis	Fix Memphis
Filtration	-0.16**	-0.14**	-0.14**	-0.08**	-0.07**	-0.14**
	(0.065)	(0.054)	(0.054)	(0.028)	(0.030)	[-0.294 - -0.017]
Chlorination	-0.02	-0.01	-0.01	-0.04	-0.06***	-0.01
	(0.034)	(0.023)	(0.023)	(0.026)	(0.020)	[-0.071 - 0.039]
Filtration * Chlorination	0.05	0.03	0.03	0.06**	0.06**	0.03
	(0.031)	(0.025)	(0.025)	(0.024)	(0.024)	[-0.024 - 0.094]
Filtration Within 5 Years	-0.09	-0.07	-0.07	-0.02	-0.01	-0.07
	(0.065)	(0.047)	(0.047)	(0.013)	(0.015)	[-0.281 - 0.037]
Chlorination Within 5 Years	0.01	0.01	0.01	0.01	-0.01	0.01
	(0.020)	(0.013)	(0.013)	(0.010)	(0.009)	[-0.018 - 0.039]
Observations	415	410	410	410	410	410
R-squared	0.957	0.964	0.963	0.970	0.969	0.963
F-test	2.902	2.808	2.835	2.924	3.464	
Prob > F	0.0786	0.0848	0.0830	0.0773	0.0510	

Table shows the results of alternate methods of calculating mortality rates on Equation 1 in Cutler and Miller (2005). Column 1 shows the original specification as estimated in Cutler and Miller (2005), with standard errors clustered at the city level and revising the date of water filtration in Philadelphia to 1909. Column 2 fixes a coding error associated with a missing data point in Memphis for 1916. Column 3 revises the method of calculating all-cause mortality rates used in CM (2005). Column 4 uses all-cause mortality rates as calculated in ACR (2018), using intervention dates from CM (2005) and restricts the analysis to years used in CM. Column 5 uses all-cause mortality rates as calculated in ACR (2018) using intervention dates from ACR (2018), revising Philadelphia and restricting to years used in CM. Column 6 shows the 95% confidence set for preferred results (using revised CM (2005) mortality rates, and CM (2005) intervention dates revised for Philadelphia) using the wild bootstrap method with 1000 replacations. All specifications include sewage treatment dummy variables, lagged mortality, year and city dummy variables, city trends, and demographic characteristics (population share by gender, race, birthpace, and age). Standard errors for Columns 1-5 are clustered at the city level. *** p<0.01, ** p<0.05, * p<0.10.

Table 4: Alternate Water Sanitation Intervention Dates and Infant Mortality

Infant Mortality Rate Source:	ACR	ACR	ACR
Intervention Date Source:	CM	ACR	CM
Philadelphia Filtration Year:	1909	1909	1909
Filtration	-0.13**	-0.05	-0.13*
	(0.058)	(0.063)	[-0.276 - 0.030]
Chlorination	0.01	0.03	0.01
	(0.043)	(0.042)	[-0.100 - 0.109]
Filtration * Chlorination	0.07	-0.01	0.07
	(0.047)	(0.047)	[-0.041 - 0.184]
Filtration Within 5 Years	-0.03	0.01	-0.03
	(0.028)	(0.027)	[-0.010 - 0.086]
Chlorination Within 5 Years	0.03	-0.05*	0.03
	(0.025)	(0.027)	[-0.033 - 0.086]
Observations	410	410	410
R-squared	0.977	0.977	0.977
F-test	3.014	0.508	
Prob > F	0.0720	0.684	

Table shows the results of corrected infant mortality rate data and alternate water filtration and chlorination intervention dates on Equation 1 in Cutler and Miller (2005) for infant mortality rates, restricted to years used in CM. Column 1 shows the estimates using corrected infant mortality rates intervention dates as original specification in Cutler and Miller (2005), revising Philadelphia's filtration date to 1909. Column 2 shows estimates using corrected infant mortality rates and and and newly proposed water santiation intervention dates as given in Anderson, Charles, and Rees (2018) (revising the date of filtration in Philadelphia to 1909). Column 3 shows the 95% confidence set for preferred results (using corrected infant mortality rates, and CM (2005) intervention dates revised for Philadelphia) using the wild bootstrap method with 1000 replacations. All specifications include sewage treatment dummy variables, lagged mortality, year and city dummy variables, city trends, and demographic characteristics (population share by gender, race, birthpace, and age). Standard errors for Columns 1-2 are clustered at the city level. *** p<0.01, ** p<0.05, * p<0.10.