Killer Cities: Past and Present *

W. Walker Hanlon
UCLA and NBER

Yuan Tian
UCLA

January 7, 2015

Abstract

The industrial cities of the 19th century were incredibly unhealthy places to live. How much progress has been made in reducing these negative health effects over the past 150 years? To help answer this question, we compare mortality patterns in 19th century England to those in Chinese urban areas in 2000. We document that substantial improvements have been made in improving health in cities over this period. Unlike historical English cities, large cities in China have lower mortality than less populated areas. However, we also provide evidence that in China a substantial relationship between industrial pollution and mortality remains.

*We thank Leah Boustan, Dora Costa, Edward Glaeser, Matt Kahn, Adriana Lleras-Muney, Till von Wachter and seminar participants at the UCLA Luskin/Law School workshop for helpful comments. This project was supported by grants from the California Center for Population Research and UCLA's Ziman Center for Real Estate. Corresponding author contact information: 8283 Bunch Hall, UCLA, 405 Hilgard Ave., Los Angeles, CA 90095, whanlon@econ.ucla.edu.

In the 19th century, industrial cities were incredibly unhealthy places to live due to a combination of infectious diseases and pollution (Cain & Hong (2009), Kesztenbaum & Rosenthal (2011)). Today, industrial cities in developing countries face similar challenges, particularly the threat of high pollution levels. For example, a 2012 World Health Organization report attributed 3.7 million premature deaths to ambient air pollution (WHO (2014)). Of these, about 88% occur in low- and middle-income countries, chiefly in East and South Asia. In Chinese cities the air of booming mega-cities is sometimes so thick with soot that news reports have dubbed it an "airpocalypse" and the contribution of air pollution is estimated to have led to 1.2 million excess deaths in 2010 (*New York Times*, April 1, 2013).

These observations raise a series of questions about the progress of health in cities. How much progress has been made in improving the health of cities over the past century and a half? Are the industrial cities of today's emerging economies less healthy than more rural areas, as was true in the past? What role does pollution play in the health of cities, and how has this changed over time? This paper takes a first step towards answering these questions. To do so, we study urban mortality patterns in 19th century England and in China in 2000. In both time periods, these countries represent leading industrial producers, and in both settings we find reports of high mortality levels and polluted urban environments.

Our approach to this issue involves constructing measures of urban pollution, mortality, city size and city density, as well as control variables, that are as similar across the two settings as possible. We then estimate the relationship between mortality and city size, city density, and city pollution in both the historical and modern setting, using simple cross-sectional regressions. Comparing how these relationships have shifted over time can give us an idea of how much progress has been made, and how much factors such as pollution continue to affect urban health.

One of the main challenges in this study is a shortage of direct pollution data, which is often scarce in both developing economies and historical settings. We bypass the need for direct measures of pollution by using the composition of industries in a location, together with information about the pollution intensity of different industries, to generate proxy measures for the level of pollution in a location. One advantage of this approach is that it can be applied in settings where direct pollution measures are often unavailable. A second advantage is that our measure will reflect a multi-dimensional version of pollution, rather than a single pollution measure, such as TSP, which will capture only one element of urban pollution. However, this also means that we cannot differentiate the impact of specific types of pollution. This approach is similar to that used by Glaeser & Kahn (2008) for the U.S. and Zheng *et al.* (2011) for China, except that we focus on industrial sources of pollution rather than pollution produced by households. One motivation for our focus on industrial pollution is that industry is a major pollution producer. For example, Zheng & Kahn (2013) report that industry consumes 89.1 percent of total energy in China. A second reason to focus on industry is that it tends to be geographically concentrated, leading some areas to have much higher pollution levels than others.

Data

We have attempted to construct data sets that are as similar across our two settings as possible. In England, detailed mortality data are available for each Registration District from the Registrar General's reports. We use decadal average mortality data for three decades from 1861-1890. The data we use come from 64 districts corresponding to the largest British cities.[1] For China, we use mortality data for urban districts or county-level cities (hereafter just districts) from the Fifth Population Census. We focus primarily on 221 urban districts, defined as those above the 90th percentile in terms of the share of population with non-agricultural registration status.[2]

In both settings, we have data on the population and population density of each district from census reports. These may reflect both factors that affect mortality positively, such as income, and factors that are negatively related to mortality, such as the disease environment of the district.

To construct our pollution measure, we use data describing the industrial composition of districts, together with information on the pollution level of different industries, to approximate the level of industrial pollution in cities. In both settings we use the same list of heavily polluting industries. This list was produced by the Chinese government, but it corresponds well to information on the major polluting

[1] This set does not include London, which is an outlier in many ways, as well as a few smaller cities for which we were not able to construct all of the control variables in a consistent way.

[2] These cities have a share of population with non-agricultural registration status greater than or equal to 45 percent.

industries in the 19th century based on historical sources. For example, almost all of the heaviest coal using industries based on the 1907 British Census of Production are included in the Chinese list of heavily polluting industries.

In England, information on the industrial composition of cities comes from a database constructed by Hanlon & Miscio (2014) based on the Census of Population. From this database we use data on employment, by industry, from 1861, for 27 analysis industries spanning nearly the entire private sector economy. Our measure of industrial pollution in cities is constructed by taking the ratio of employment in polluting industries to employment in all private sector manufacturing industries. We use only manufacturing industries in the denominator, rather than all private sector employment, to increase comparability with the Chinese data.[3]

In China, our data are based on the Industrial Enterprise Survey (IES) from 2000. This survey covers all state-owned industrial enterprises and privately-owned industrial firms with sales above five million RMB annually, a total of around 163,000 firms. The employment levels reported in this survey are suspect, so instead our pollution measure for each district is constructed by taking the share of polluting industry sales to total manufacturing sales in the IES database.

Finally, we have tried to construct a similar set of control variables for both settings. For China, we include controls for the Northern provinces because these are known to have higher pollution levels (Almond *et al.* (2009)). Similarly, for England we include the average number of air frost days based on modern data from the Met. We control for whether the district was a seaport (in England) or whether it was in a coastal province (in China). For England we also include a measure of the size of trade handled by the port, based on import levels in 1885, because trade was an important carrier of disease in the 19th century.

[3]The geographic unit for the city-industry data is the town level. Town boundaries do not correspond directly to the registration district boundaries available in our mortality data, but we believe that the town-level polluting industry employment shares can still provide a reasonable indicator of the overall pollution level in a location.

Table 1: Summary statistics for key variables

	Obs.	Average	Std. Dev.	Min.	Max.
Mortality (age-standardized)					
England in 1861	64	19.2	2.66	14.4	31.9
England in 1871	64	18.6	2.61	13.9	28.3
England in 1881	64	16.7	2.76	12.0	27.8
China in 2000	221	5.1	1.14	2.1	10.2
Polluting employment or sales share					
England in 1861 (employment share)	64	0.47	0.21	0.17	0.91
China in 2000 (sales share)	221	0.60	0.27	0.002	1.00
District population					
England in 1861	64	76,035	62,935	14,123	365,083
England in 1871	64	86,286	70,862	15,520	416,229
England in 1881	64	98,640	81,666	16,370	475,385
China in 2000	221	993,662	1,645,818	22,326	14,348,535
District population density (thousands per square kilometer)					
England in 1861	64	3.18	5.72	0.05	24.71
England in 1871	64	3.44	6.12	0.05	24.71
England in 1881	64	3.79	6.28	0.05	24.71
China in 2000	221	1.19	1.16	0.0002	6.35

District population density is reported in thousands of person per square kilometer. Population density is censored at 100 persons per acre in the English data, which generates a maximum density measure of 24.71 thousand persons per square kilometer. This censoring affects only 2-3 cities in each decade. For England, the pollution measure in all regressions is based on data from 1861.

Table 1 provides summary statistics for our key variables. We can see that mortality was much higher in 19th century England than in China in 2000. The share of employment in polluting industries was also somewhat higher. Not surprisingly, Chinese urban districts tended to have much larger populations than the English districts in our database, though the English districts were smaller and thus actually had higher population density on average.

Analysis

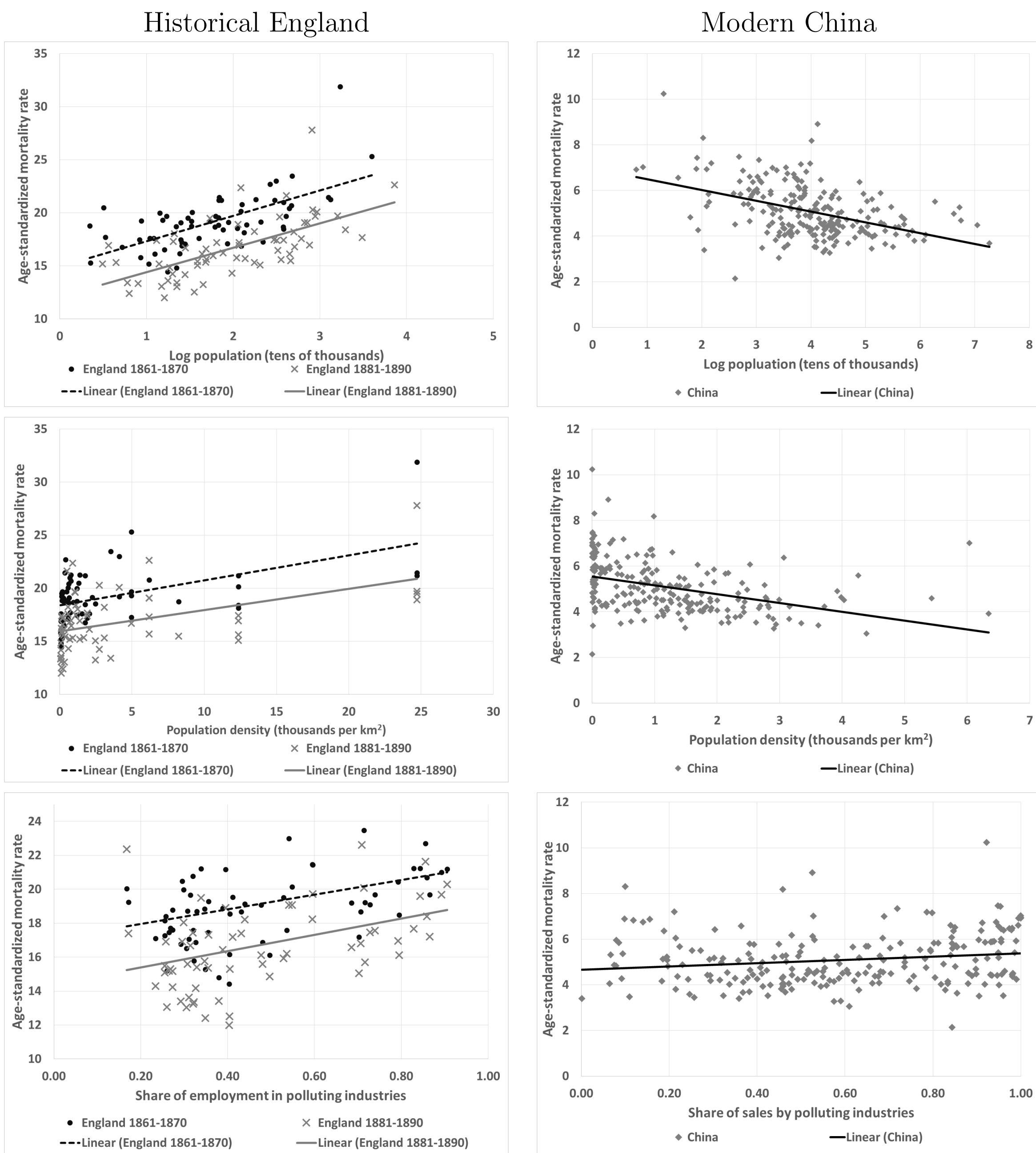
A good starting point for our analysis is to consider the raw relationship between mortality and our key variables of interest: city size, city density, and pollution. This is done in Figure 1. The top panel compares the log of population to mortality in historical England (left panel) and modern China (right panel).[4] The middle panel undertakes a similar comparison for population density, while the bottom panel compares mortality to our pollution measure.

In the top two graphs, we can see that there are striking differences between the observed patterns. While in England there is a clear urban mortality penalty, larger Chinese cities appear to be healthier than smaller cities. The middle graphs show that a similar reversal has taken place if we look at the relationship between mortality and population density. A number of potential channels may be behind these patterns. One channel that is likely to be important is the reduction in infectious disease mortality, which was a substantial contributor to mortality in 19th century England. Improved medical and public health technology may also allow people in larger (and often wealthier) cities to invest in improving health. A third potentially important channel is that the relationship between population, pollution, and health may have changed. This is suggested by the bottom graphs, which shows a strong positive relationship between polluting industries and health in England, but a much weaker relationship between pollution and mortality in modern China.

To understand the relationships between mortality and pollution shown in Figure 1, it is important to keep in mind that these raw correlations will pick up two opposing forces related to the pollution measure. While the pollution produced by industry is likely to have negative health effects, industries also mean jobs and income, which can positively affect health. Controlling for population and population density is likely to absorb some of this income effect. Thus, we now turn to regression results.

[4]The same patterns appear in data from England in 1871-1880, but these are omitted to keep the graph from becoming too cluttered.

Figure 1: Mortality relationship to population, density, and pollution in historical England and modern China



The population density values in the English data show discrete patterns because the original data were reported as acres per person with two decimal places of precision.

Table 2 displays regression results exploring the relationship between mortality, district population, population density, and our proxy for district industrial pollution. The first three columns describe the regressions run on British data for each of the three decades from 1861-1890. The fourth column describes results for urban districts in China. For both population and population density, these results confirm that a dramatic shift has taken place. More populous and more densely populated districts appear to have better health in China, whereas that was clearly not the case in 19th century England. For pollution the story is somewhat different. While we can see that the impact of pollution on mortality has decreased substantially in modern China compared to 19th century England, we still observe a clear positive relationship between the presence of heavily polluting industries and mortality. Moreover, because overall mortality has fallen so much in modern China compared to 19th century England, the importance of the contribution of pollution to overall mortality has fallen very little. This is shown in the last row of Table 2.

Table 2: Regression results for the impact of pollution on age-standardized mortality

	Historical England			**Modern China**
	1861-70	1871-80	1881-90	2000
Log Population	1.262**	1.492***	1.617***	-0.289***
	(0.514)	(0.430)	(0.513)	(0.0708)
Population density	0.0740**	0.0931***	0.0703*	-0.194***
	(0.0313)	(0.0295)	(0.0387)	(0.0646)
Polluting industry shr.	2.351*	3.280**	1.614	0.430*
	(1.315)	(1.249)	(2.258)	(0.245)
Other controls	Yes	Yes	Yes	Yes
Observations	64	64	64	221
R-squared	0.669	0.691	0.618	0.294
Avg. mortality rate	19.2	18.6	16.7	5.1
Pollution coefficient /average mortality	0.122	0.176	0.097	0.085

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parenthesis. Additional control variables in regressions for England: average number of air frost days, seaport indicator variable, seaport import tonnage. Additional control variables in regressions for China: indicator for provinces north of the Huai River, indicator for coastal provinces.

We have explored the robustness of our results to including additional control variables. For example, we have constructed measures of the level of education in each district and included these as controls. For China, we find that much of the reduced mortality in larger and more dense cities is explained by higher education levels. In England, controlling for education has little effect on our results. For China, we have also run additional regressions including a measure of district-level GDP per capita. We find that GDP per capita is negatively related to mortality, but including this variable does not substantially change our other results. Some of these additional results are available in an Online Appendix.

We may be concerned that the relationship between polluting industries and mortality is due to factors other than pollution, such as higher on-the-job accident rates in polluting industries. It is possible to explore this concern in the English data, where detailed cause-of-death information is available. These results (available upon request) show that the relationship between polluting industry employment share and mortality in England is driven primarily by higher levels of mortality due to respiratory causes. This is consistent with the impact we would expect pollution, particularly air pollution, to have.

Discussion

The results of this study suggest that, even in some of the most polluted cities on Earth, substantial progress has been made in improving urban health. The urban mortality penalty of the 19th century industrial cities has turned into a health premium. However, our results also suggest that pollution remains a substantial threat to urban health in China. Based on our estimates, a one standard deviation increase in the polluting industry share of an urban district in China (0.27) is associated with an increase in the mortality rate of about 0.117, which is 2.3% of the average mortality rate in these districts.

References

Almond, Douglas, Chen, Yuyu, Greenstone, Michael, & Li, Hongbin. 2009. Winter Heating or Clean Air? Unintended Impacts of China's Huai River Policy. *American Economic Review*, **99**(2), 184–90.

Cain, Louis, & Hong, Sok Chul. 2009. Survival in 19th century cities: The larger the city, the smaller your chances. *Explorations in Economic History*, **46**(4), 450 – 463.

Glaeser, Edward L, & Kahn, Matthew E. 2008 (August). *The Greenness of Cities: Carbon Dioxide Emissions and Urban Development*. NBER Working Paper No. 14238.

Hanlon, W.W., & Miscio, A. 2014 (December). *Agglomeration: A Dynamic Approach*. NBER Working Paper No. 20728.

Kesztenbaum, Lionel, & Rosenthal, Jean-Laurent. 2011. The health cost of living in a city: The case of France at the end of the 19th century. *Explorations in Economic History*, **48**(2), 207 – 225.

WHO. 2014. Burden of Disease from Ambient Air Pollution for 2012. Available at: http://www.who.int/mediacentre/factsheets/fs313/en/.

Zheng, Siqi, & Kahn, Matthew E. 2013. Understanding China's Urban Pollution Dynamics. *Journal of Economic Literature*, **51**(3), 731–772.

Zheng, Siqi, Wang, Rui, Glaeser, Edward L., & Kahn, Matthew E. 2011. The Greenness of China: Household Carbon Dioxide Emissions and Urban Development. *Journal of Economic Geography*, **11**(5), 761–792.