Infrastructure and Service Delivery

ERSA/IGC/WB Winter School on Urban and Regional Economics in Africa

Matthew A. Turner
Brown University
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Introduction I

- We are more productive working at higher densities (and with different people) than the densities at which we want to live. Cities are how we solve this problem.
- This leads to three questions,
  - How much more productive, and why?
  - How does the cost of commuting affect the way cities are organized?
  - What determines our willingness to tolerate density?
- The first two are central questions in urban economics. They have been studied extensively.
- The third question has received less attention. It is also important to understanding how cities are organized.

Introduction II

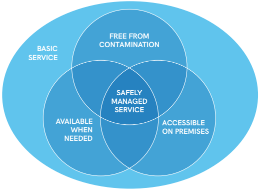
- Many other interventions also affect our willingness to tolerate density. For example;
  - drinking water delivery and quality,
  - law and order,
  - sewer service
  - vaccination,
  - trash collection,
  - fire protection,
  - noise and pollution.

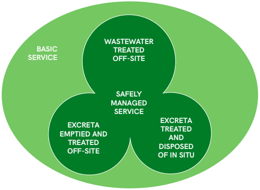
  The impact of these services on the organization of cities is also not well studied. My prior is that their importance corresponds approximately to their listed order.
- Transportation infrastructure should also be on this list, probably towards the bottom.

Introduction III

- Ideally, we could talk about the value of investment in any of these policies. But we don't really have the foundation for it yet.
- This lecture will describe the state of knowledge about the relationship between water and sewer infrastructure and the organization of cities. It is in three parts,
  - Evidence for the importance of public health for the organization of cities.
  - Evidence for the importance of sewage and sanitation services for public health.
  - Evidence for the importance of sewage and sanitation service for the organization of cities from McCulloch et al. (2025).
  - Conclusions.

World availability of water and sewer I



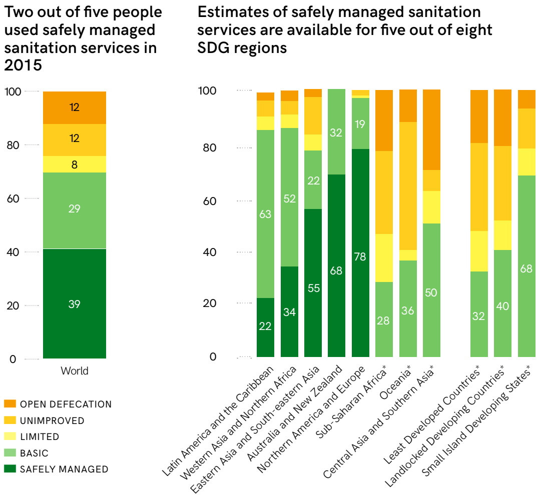


SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Drinking water from an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination
BASIC	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing
LIMITED	Drinking water from an improved source for which collection time exceeds 30 minutes for a round trip, including queuing
UNIMPROVED	Drinking water from an unprotected dug well or unprotected spring
SURFACE WATER	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal
***Note:** Improved sources include: piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water.*	

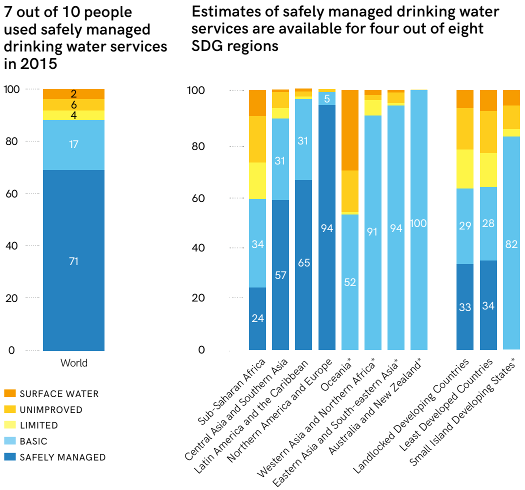
SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated offsite
BASIC	Use of improved facilities that are not shared with other households
LIMITED	Use of improved facilities shared between two or more households
UNIMPROVED	Use of pit latrines without a slab or platform, hanging latrines or bucket latrines
OPEN DEFECATION	Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches or other open spaces, or with solid waste
***Note:** improved facilities include flush/pour flush to piped sewer systems, septic tanks or pit latrines; ventilated improved pit latrines, composting toilets or pit latrines with slabs.*	

World Health Organization (2017)

World availability of water and sewer II



World availability of water and sewer III

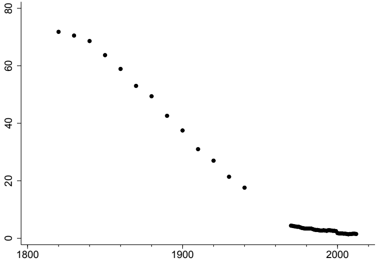


World availability of water and sewer IV

Water and sewer service is in short supply in much of the world, especially developing country slums. Sewers are scarcer than piped water.

About 15% and 40% of the world’s urban population does not have access to safely managed water and safely managed sanitation (Coury et al., 2024).

Public health and the organization of US cities



% US Employment in Ag. (FRED)

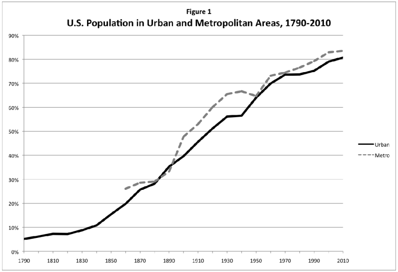
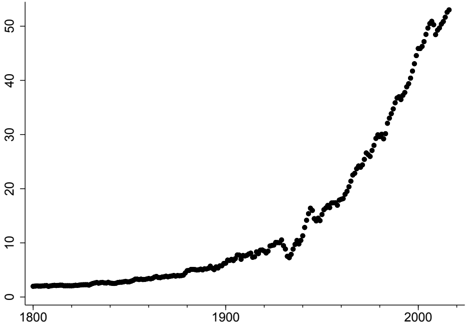


Figure 1: Before 1950, the urban share only includes residents living in incorporated places. From 1950 onward, the urban share includes residents living in both incorporated and unincorporated places. Data on urban population shares are from the U.S. Census Bureau. Metropolitan area population shares were calculated using data and the contemporaneous definitions provided by IPUMS in each year.

Boustan et al. (2013).



Real per capita GDP. From 1800 to 2016, US incomes increased by a factor of about 27 (Bolt and Van Zanden, 2014). During this time, the rural-urban wage gap was about 30%.

Fig. 2 *Crude Death Rate*
Boston, MA, 1811-1920

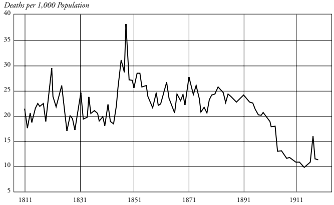


Fig. 3 *Crude Death Rate*
Philadelphia, 1802-1920

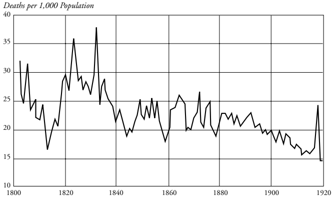


Fig. 1 *Crude Death Rate*
New York City, 1804-1900

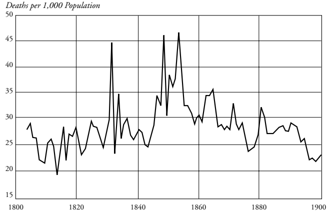
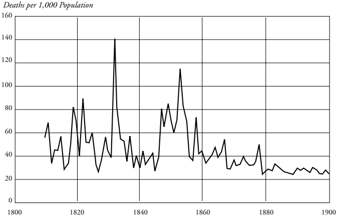


Fig. 5 *Crude Death Rate*
New Orleans, 1810-1900



Crude death rates were 20-80 in 19th century US cities, and fell in the 20th century (Haines, 2001).

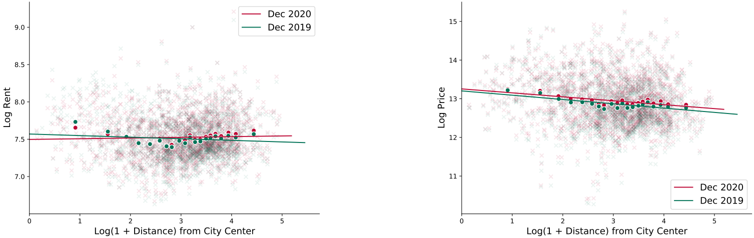
Decade	Ratio
1870-1880	1.38
1880-1890	1.50
1890-1900	1.35
1900-1910	1.33
1910-1920	1.21

Ratio of urban to rural crude death rates in the US, by decade. The urban mortality premium was about 40% in 1780 and declined to 20% by 1920 (Haines, 2001).

- Three events approximately coincided in the late 19th and early 20th century.
    - Urban population increased
    - Productivity increased
    - Urban mortality rates fell
- The conventional wisdom is that the decline in the absolute and relative level of urban mortality was an important contributor to the process of urbanization and growth in the US.
- It would be nice to have more evidence for this story.

Covid and US cities

Modern experience with Covid confirms the importance of public health for the process of urbanization in current day US.



Left panel: relationship between log distance from the city center and log rent before (green) and after (red) the pandemic. Right panel reports sale price gradients (Gupta et al., 2021).

Public health and the organization of African cities

- There is no evidence for a dramatic mortality or morbidity premium in African cities as there was in the 19th century US, but maybe there is something more subtle (Henderson and Turner, 2020).
- But the rural urban wage premium in modern Africa is at least as large as in the 19th century US.
- Is urbanization in Africa governed by the same trade-off between health and wealth that we suspect operated in the 19th century US?

Water and sewer interventions and public health

The effect of late 19th and early 20th century municipal water quality is well studied;

- (Alsan and Goldin, 2019) Interaction of water and sewer main in a municipality gives a 26% decrease in infant mortality, Boston Harbor watershed, 1880 to 1920.
- (Anderson et al., 2018) Sample of 25 US cities between 1900 and 1940. Manage sewage outflows 0% effect on infant mortality, water filtration 11% decline. Joint effect of all water quality related interventions is 4%. Note disagreement with (Alsan and Goldin, 2019).
- (Ferrie and Troesken, 2008) Event study of improved municipal water quality on mortality and future mortality in 19th century Chicago. Improved water quality reduces crude death rate by 18-30% from 1850-1925.

- (Kesztenbaum and Rosenthal, 2017). Completely sewering an unsewered Paris neighborhood between 1880 and 1915 gives 1-3 years of life expectancy at birth.
- (Troesken, 2004) Role that piped water and sewer service played in narrowing the black-white life expectancy gap in the US during the first half of the 20th century.
- Beach (2022) is a useful survey of the history literature.

The effects of improvements to water and sewer infrastructure have also been studied in the context of the modern day developing world.

- Galiani et al. (2005) finds that privatizing Argentina's water supply services led to an 8% reduction in child mortality, all from a reduction in waterborne disease.
- Bhalotra et al. (2021) looks at the roll-out of municipal water treatment in late 20th century Mexico reduced childhood mortality from diarrheal disease by about half.
- Gamper-Rabindran et al. (2010) finds that roll-out of piped water, but not sewer access, has an important effect on infant mortality in Brazil around 2000.
- Devoto et al. (2012) finds that access to piped drinking water increases time spent at leisure but does not affect childhood incidence of waterborne disease in Morocco in 2007.

- Ashraf et al. (2017) find that more reliable drinking water supplies decreases childhood diarrheal disease and increases the time girls spend at school in urban Lusaka in 2000.

Where does this leave us?

- Interventions to improve municipal water *quality* have been well studied. They have important health benefits in the developing world and the 19th century US. There is some disagreement about effect sizes, or else treatment effects are heterogenous in a way that is not understood.
- Evidence about household piped water access is less clear. This is a big labor saver and has pervasive effects on time use. Effects on health are less clear/heterogenous.
- Evidence about the provision of sewers on health is mixed.
- Interventions are diverse, e.g., installation of municipal water and sewer mains, moving intakes to deeper water, chlorination, disruptions of piped water supply, etc. This complicates cost benefit analysis.

Water and sewer interventions and cities

There are really just 3-4 papers,

- Alsan and Goldin (2019) fail to reject zero effect of interaction of arrival of municipal water and sewer mains on; demographics or population density. Confidence intervals are large.
- Coury et al. (2024) find that land values in 19th century Chicago more than double with access to sewer network.
- McCulloch et al. (2025) 1% increase in census tract share with sewer access gives 6% increase in density. No effect on literacy or income.
- Bancalari (2024) finds that living near a sewer construction project increases sickness and accidents.

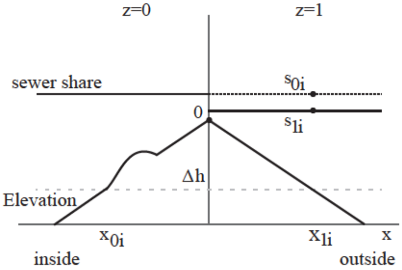
I am going to talk about McCulloch et al. in more detail.

How do sewers affect density?

McCulloch et al. asks how the density of a census tract varies with the share of households connected to a sewer system.

- The central problem to estimating the effects of sewer access on places is that they are not randomly assigned.
- Sewers work on gravity. Moving sewage on a grade of less than 1:200 is hard. Uphill is harder.
- Sewer networks generally serve a (part of a) single drainage basin.
- Two census tracts on opposite sides of a basin divide should be similar (on average), but one may require moving sewage uphill to get to an existing sewer network.
- Use this fact to solve the identification problem.

Identification

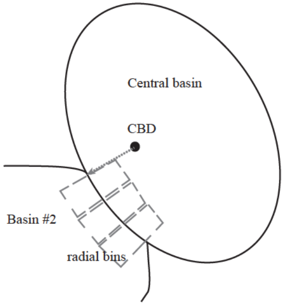


Plot of elevation and sewer share in a neighborhood of a basin divide. ‘inside’ is uphill from existing network. x is distance to the basin divide. Elevation is relative to basin divide.

Treatment is $s_0 - s_1$.

Inside is a control for outside. First stage regression will be an estimate of $s(x)$.

Geography: Central basins and radial bins



- Define 'radial bins', 2km wide, and $2 \times$ 2km deep.
- Tract elevation is relative to highest tract centroid in the same radial bin $\leq$ 2km from the basin divide. NB: larger elevations are lower.
- Say a census tract is 'inside' if its centroid lies in the central basin.

Data

Cities

- The UN Cities data is a census of all cities that had a population 300,000 or more in 2014. These data report the location of the center of each city.
- We focus attention on areas (1) near the boundary of the drainage basin containing the city center, and (2) within 75km of the city center.
- We estimate treatment effects using all Cities in the UN Cities data in; Brazil, Colombia, South Africa, Jordan, and Tanzania.

Data

Sewers

Sewer data all comes from census questions;

- Brazil: ‘Is the bathroom or toilet drain connected to the public sewer system?’
- Colombia: ‘Does your house have sewage service?’
- South Africa: ‘Is the main type of toilet facility used by this household a flush toilet connected to sewerage system’
- Tanzania: ‘Does your house have a flush toilet connected to a piped sewer system?’
- Jordan: ‘Does your house have sanitation connected to a public network?’

We calculate the share of households in a ‘tract’ with sewer access and map the extent of tracts with sewers.

Data

Population density, other outcomes

Population density, income measures, and other outcomes all come from the same censuses.

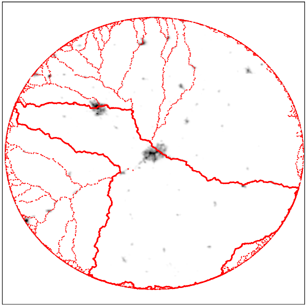
For all countries but Jordan, population density is the full count of people divided by tract area. For Jordan, it is the full count of households divided by tract area.

Demographic and neighborhood outcomes also come from these censuses and vary from country to country.

Data

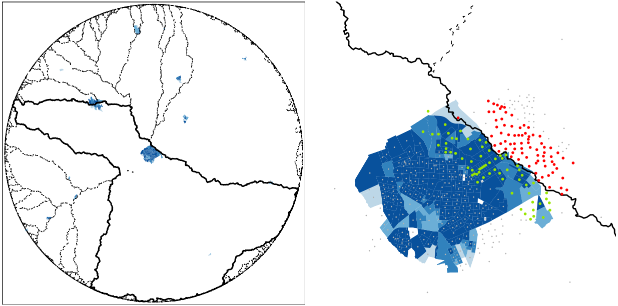
Drainage basins

We construct drainage basins from digital elevation maps using tools for this purpose in ARCGIS.



Drainage basin boundaries in a 75km disk centered on Uberlandia, Brazil. Background is lights at night.

Sewers and ‘Inside’ near Uberlandia, Brazil



- Blue is sewer share.
- Tracts in the central basin are ‘inside’.
- Drop tracts with centroids more than 2km from the basin divide.

Estimation/Identification

$$
\begin{aligned}
k &\sim \text{radial bin}\\
i &\sim \text{tract}\\
s_i &\sim \text{sewer share \% (treatment)}\\
y_i &\sim \text{tract log pop (outcome)}\\
x_i &\sim \text{distance to basin divide}\\
\mathbb{1}(outside)_i &\sim \text{outside indicator (instrument)}
\end{aligned}
$$

Econometric model (a little informal)

$$
\begin{aligned}
s_i &= A_k^0 + A_k^1 x_i + A_1 \mathbb{1}(outside)_i + A_1 \mathbb{1}(outside)_i x_i + \eta_i\\
y_i &= B_k^0 + B_k^1 x_i + B_1 s_i + \mu_i
\end{aligned}
$$

Estimate with TSLS. $B_1 \approx 6$ is treatment effect. Adding 1% of tract households to sewer network increases population by 6%, literacy rate and income by 0%.

How important are sewers? I

- Add sewer connections for 1% of people to a city.
- Assume each 1% increase in sewer connections increases tract population by 6%.
- This gives a 6% increase in population
- Compare: (1) Baum-Snow (2007) finds that each radial interstate highway decreased the density of US central cities by 9%. (2) Baum-Snow et al. (2017) find that radial highways in China have no impact on total population and lead to a 4% decline in central city population density
- Sewers are about as important for density as limited access highways.

Conclusion I

- Building cities that will attract and accommodate the rural poor looks like an important pathway for development. The rural urban wage premium equals many years of growth.
- We don't have a good understanding of economics that guide this process, but the role of non-transportation infrastructure is understudied.
- The result in McCulloch et al. (2025) tells us that sewer infrastructure is about as important as transportation infrastructure, but no evidence of sorting.
- There is (probably) the foundation for a pretty nuanced understanding of water and sewer infrastructure and health, but it's probably time to talk to some doctors.

Conclusion II

- What about law and order, vaccination, or even access to schools?
- We have very little systematic information about costs.
- Be careful about econometrics, it would be nice to have more design based studies.

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