Loss in the Time of Cholera

Long-run impact of a disease epidemic on the urban landscape

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Basic question:

- Can health shocks have long-run impact on the spatial distribution of poverty within a city?
  - Disease creates poverty, but no effect on infrastructure or land, so not obvious epidemics would leave economic footprint

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- More generally, if households on one block experience an income shock, will that lead to a lasting "pocket of poverty", or will residential migration preserve the spatial distribution of income over time?

Relevance of question:

- Ghetto formation: How do we explain small pockets of urban decay?
- Economic cost of income shocks: Could shocks to individuals lead to misallocation of residents or housing across space?
- In existing literature, evidence of path dependence operating through institutions or population growth - is there also more basic reason that income shocks lead to persistent differences in income across space?

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How do we answer these questions? We need:

- Significant income shock
- Happened long ago to allow assessment of long run persistence

Setting: Cholera Epidemic in 19th-century London

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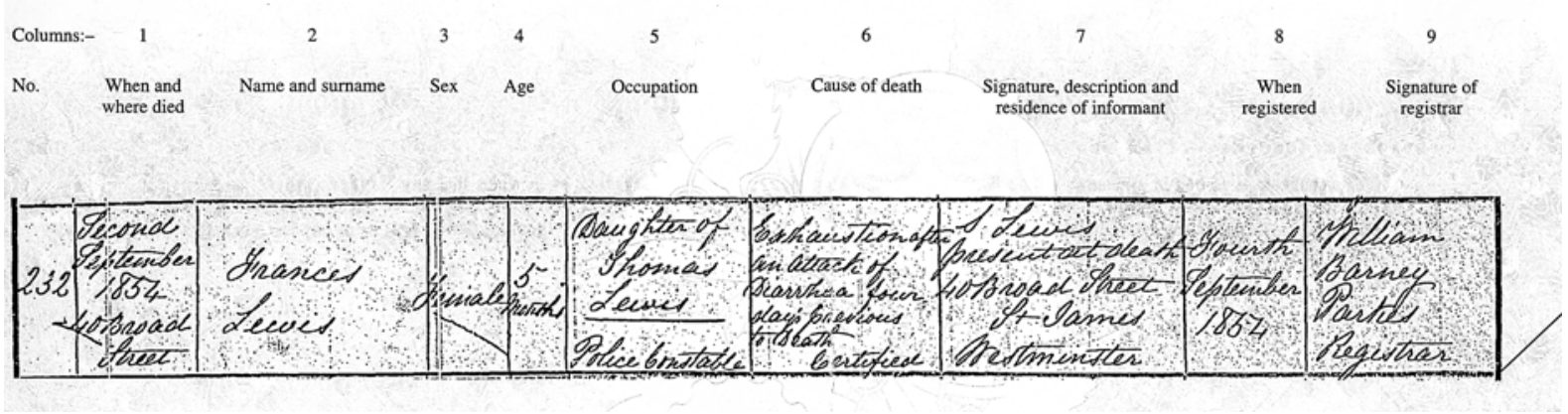
- First victim is a 5-month old baby named Frances Lewis living on 40 Broad Street



Columns:–	1	2	3	4	5	6	7	8	9
No.	When and where died	Name and surname	Sex	Age	Occupation	Cause of death	Signature, description and residence of informant	When registered	Signature of registrar
232	Second September 1854 40 Broad Street	Frances Lewis	Female	5 Months	Daughter of Thomas Lewis Police Constable	Exhaustion after an attack of Diarrhea four days previous to death Certified	S. Lewis present at death 40 Broad Street St James Westminster	Fourth September 1854	William Barney Parker Registrar

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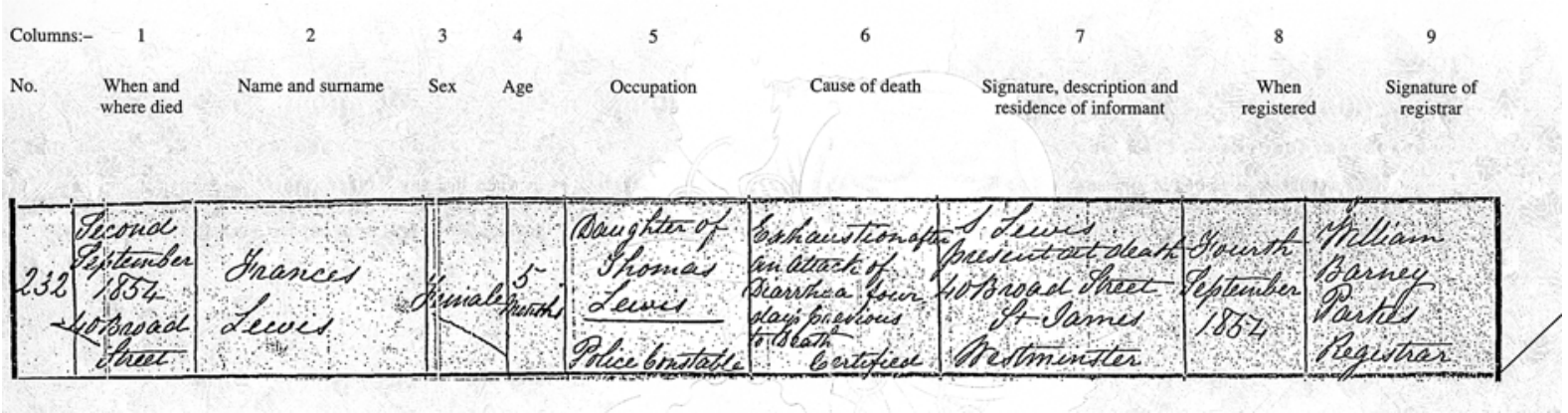

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- By the end of September, 630 residents living in 0.5-mile radius of St. James Parish (half of Soho district) died from cholera
- Spatially concentrated: 76% of deaths concentrated in catchment area of one pump (Broad street)

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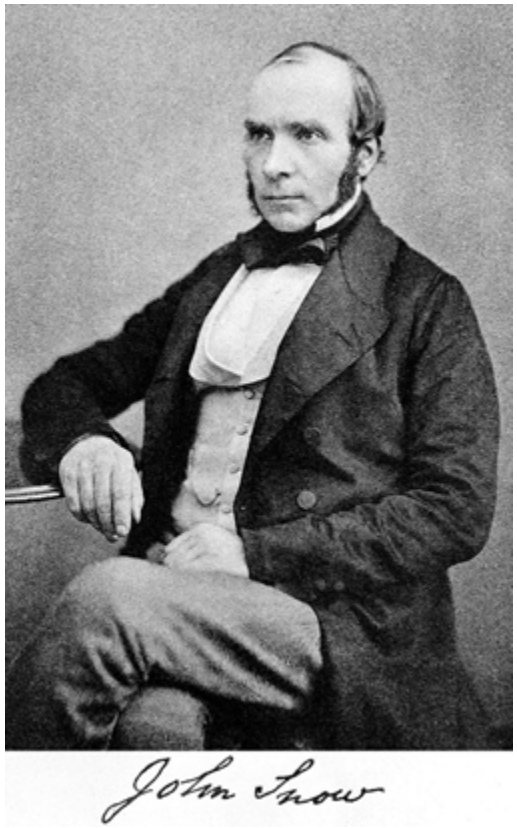

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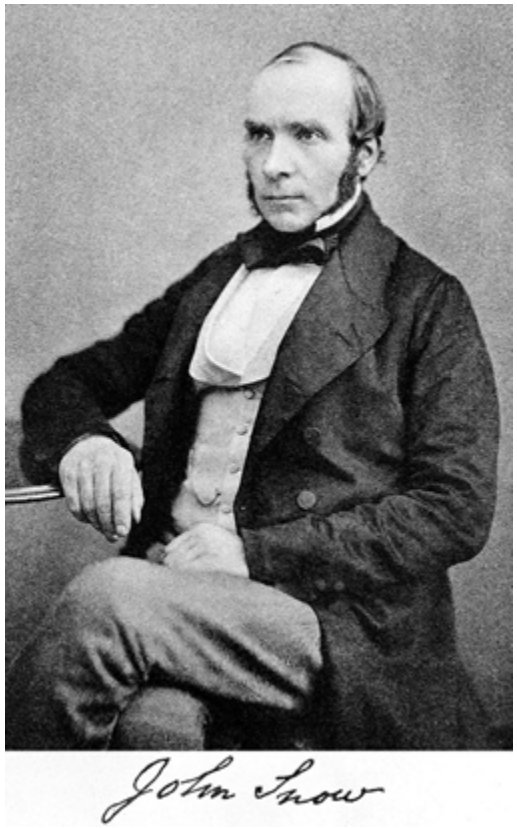
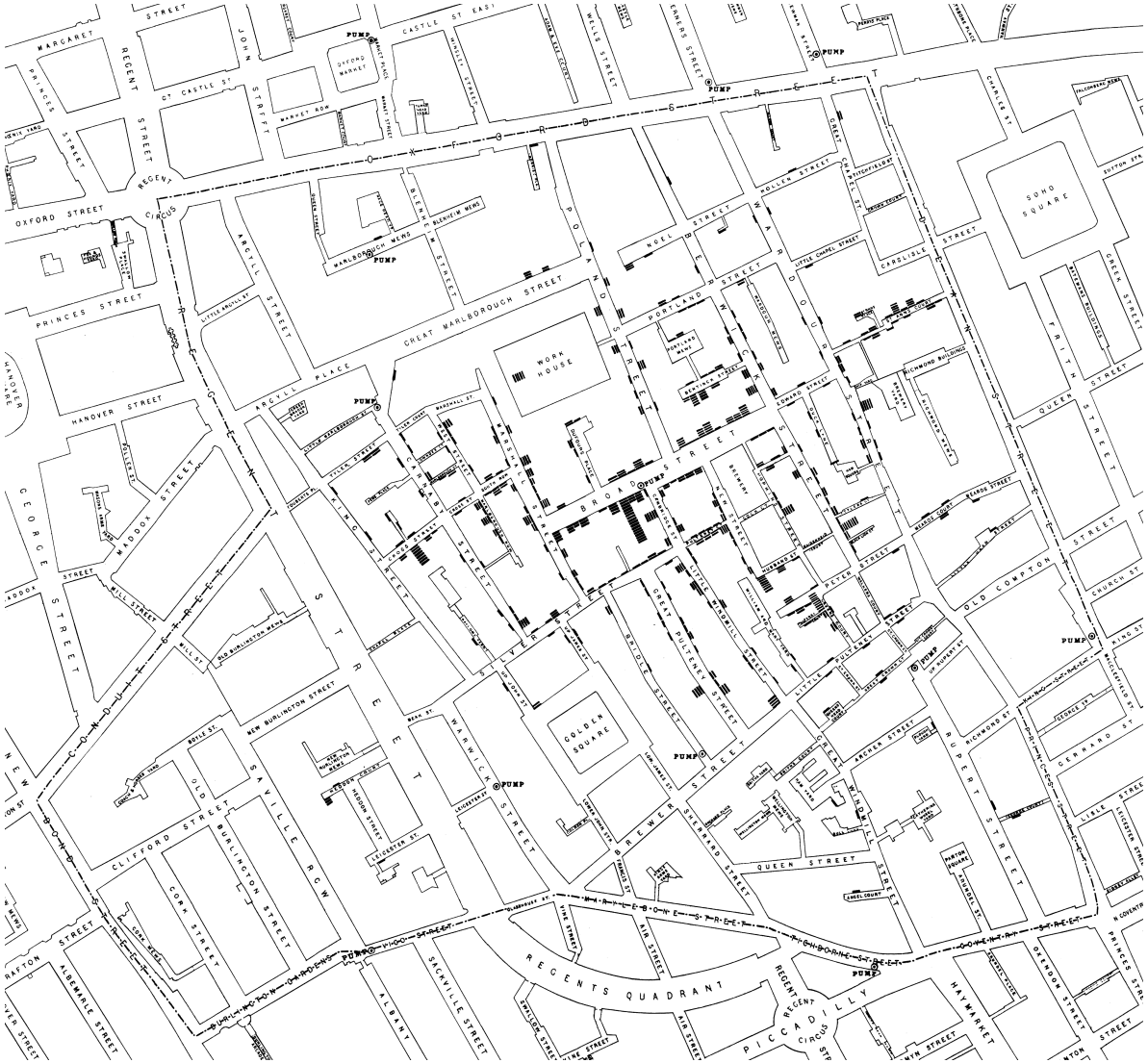


Setting: Cholera Epidemic in 19th century London



- Source: Bacteria entered one of 13 wells serving parish through an old cesspit leaking into nearby groundwater

A Few Details about St. James Parish, Soho

- Working-class neighborhood and heavy commercial district with large number of self-employed
  - Most common occupations tailor, shoemakers, domestic servants and masons
- Most occupants renters (93% renters, 7% owner occupiers)
- Rental contracts mainly took form of yearly tenancy
  - Landlord can raise price or evict tenant for no reason but has to wait until contract up

This Paper:

- What happens to house valuations soon after the epidemic?
- How do price differences evolve over time?
- How can we make sense of these patterns?

Data - Outcomes of interest

House rental price (1853, 1864, 1936):

- Obtained from yearly UK Land Tax Assessment records
- Introduced in England in 1692 to raise government revenues, stopped in 1965
- Provide:
  - Address
  - Rental price
  - Tax assessed (percentage of rental price)
  - Name of primary renter

Data - Land Tax, Broad st. 1853

No. 188

69

Rentals	Names of Proprietors	Names of Occupiers	Names or Description of Estates or Property	Sums Assessed and Exonerated			Sums Assessed and not Exonerated		
37		Chs Rozier	6				1	7	9
34		T Teeven	7				1	5	6
41		Jas James	8				1	10	9
38		Allison	9				1	8	6
38		Cook	10				1	8	6
44		Bromwell	11				1	13	—
44		J Sewell	12				1	13	—
44		Iddils	13				1	13	—
41		Rt Bilney	14				1	10	9
		Broad Street							
	Thos Dawson	Jas Frame	1	2	9	9			
53		Gs Tiskell	2				1	19	9
		Jas Wicks	3	2	17	—			
51		Oakley	4				1	18	3
78		Embs	5				3	19	6

Data - Outcomes of interest

Sales price (1993-2015): Obtained from the Land Registry of England and Wales

- Sold price and year of sale
- House characteristics (flat, lease, new, etc.)

Value estimates (2015): Obtained from *Zoopla.co.uk* (UK's largest property listing website)

- Estimated value of property
- House characteristics (flat, bed, baths, etc.)

Rental prices (2012-2015): Obtained from *LonRes* data archives

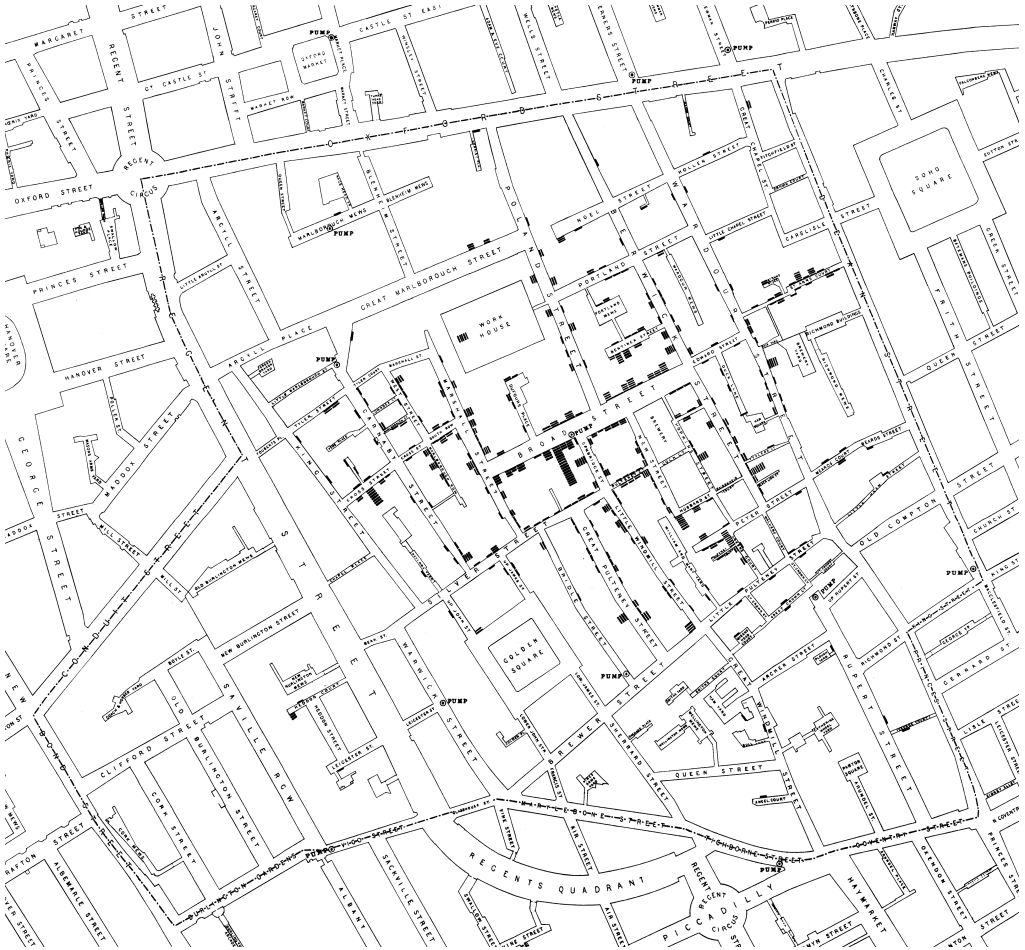
- Rental price
- House characteristics (flat, bed, baths, etc.)

Data - Outcomes of interest

Cholera deaths: Location and Number of deaths obtained from the *Cholera Investigation Commission* (1855) report.

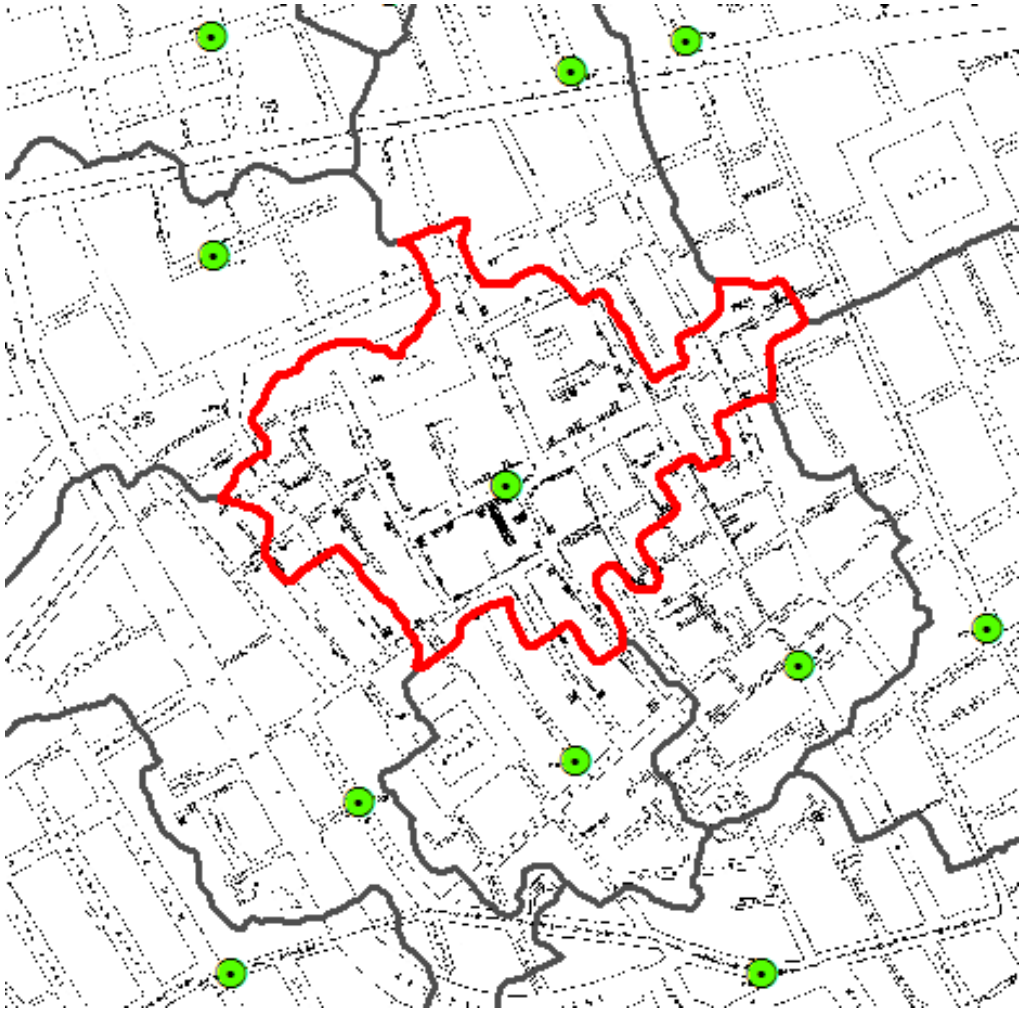
Data - Treatment Assignment

Use John Snow's original 1854 cholera map



Data - Treatment Assignment

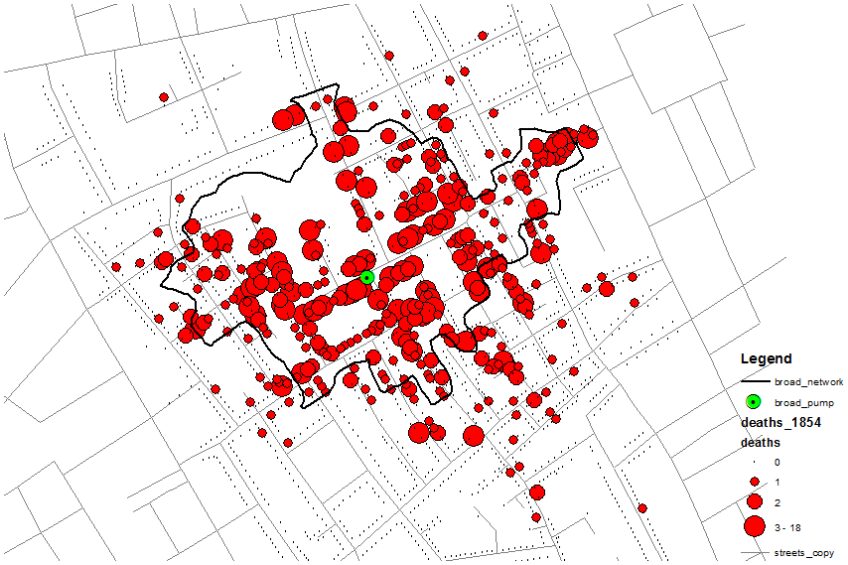
Create catchment/service areas based on shortest walking distance (Voronoi polygon)



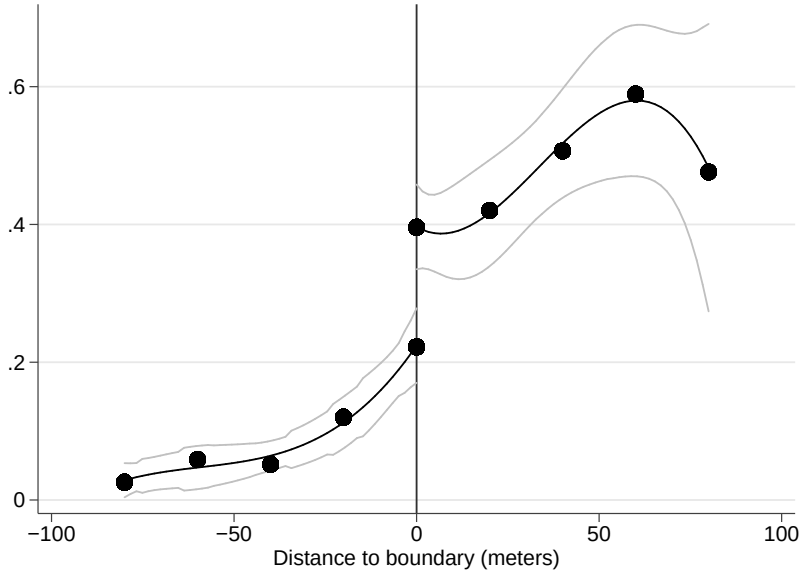
Intuition: Water is a homogeneous good. Only determinant of water source is how far away from the pump you live

Empirical Framework

Cholera is a discontinuous function of distance to BSP area boundary,



(g) Raw deaths

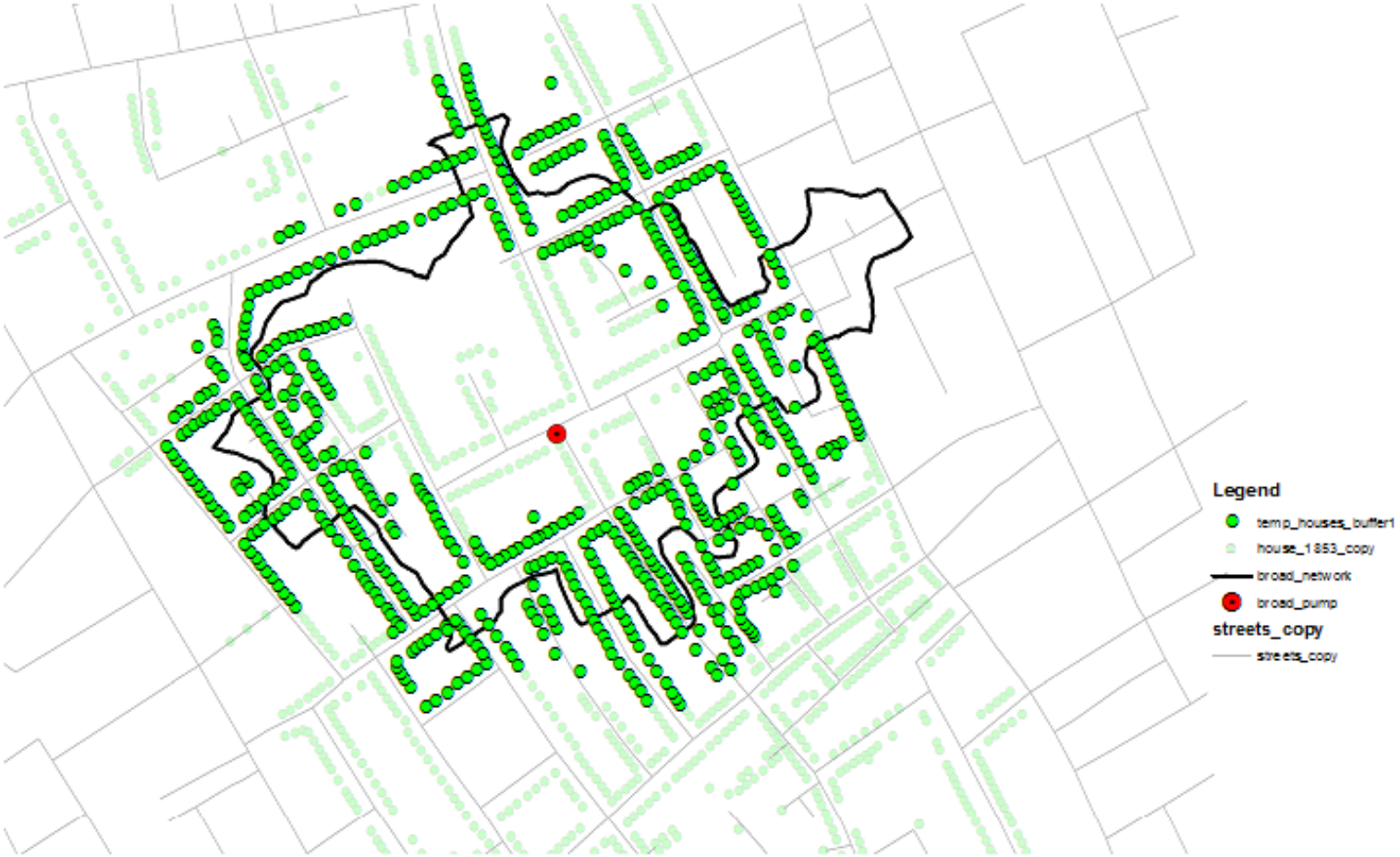


(h) Probability of at least one death

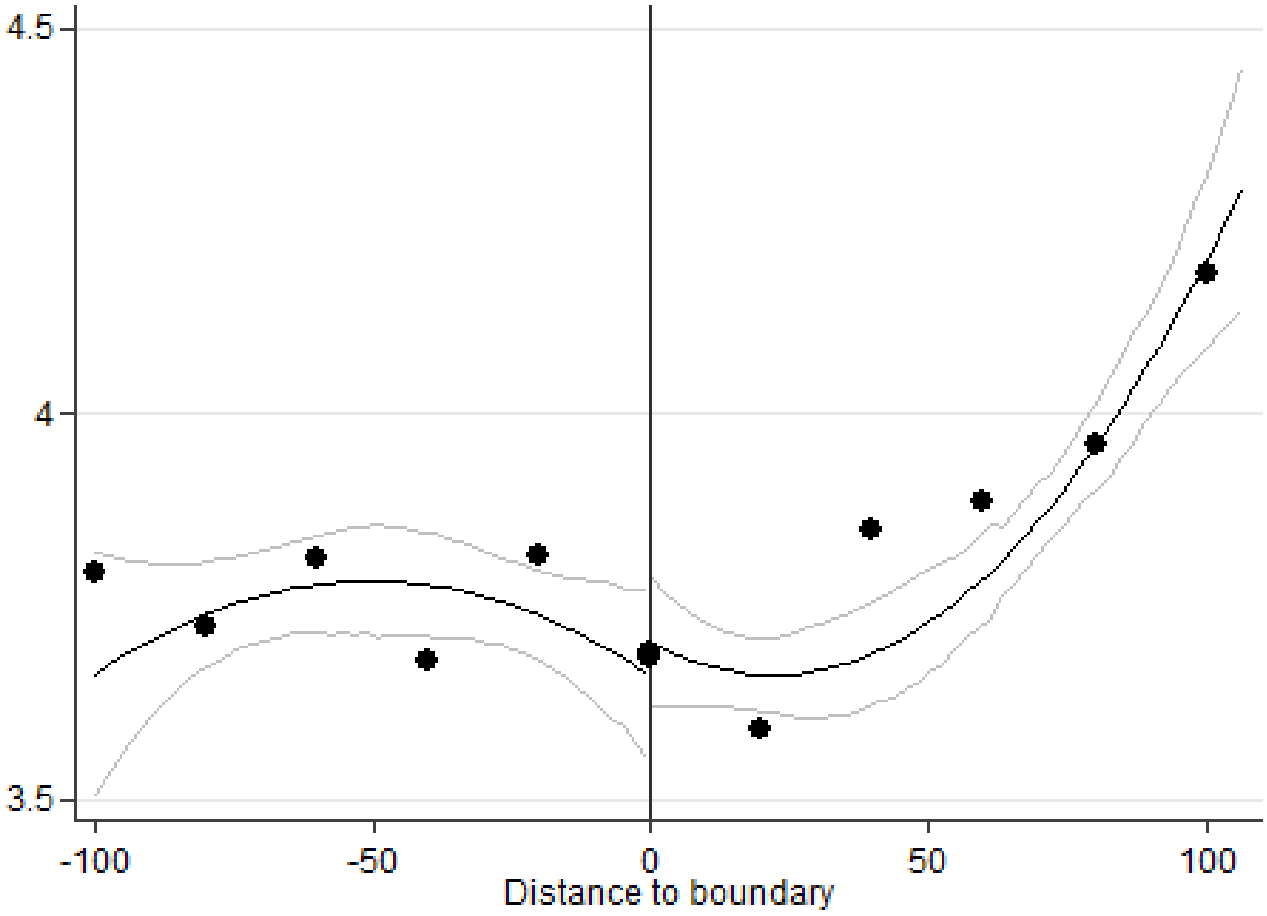
"*Deaths either very much diminished, or ceased altogether, at every point where it becomes decidedly nearer to send to another pump than to the one in Broad Street*" (Snow 1855a, p.47)

Empirical Framework

Given discontinuity, Regression Discontinuity is appealing choice for consistently estimating effect of cholera exposure on house values



Rental prices, 1853 (Pre-outbreak)



Rental Prices, 1853 (pre-outbreak)

	Boundary RD	One-dimensional RD			
	Averaged CTEs (1)	Optimal Band (2)	Narrow Band (3)	Cluster by Street (4)	Segment FE (5)
Inside BSP area	-0.0373	-0.0299	-0.0162	-0.0299	-0.0201
	(0.0397)	(0.0627)	(0.0560)	(0.0642)	(0.0644)
Observations	.	654	426	654	654
Boundary points	47	.	.	.	.
Bandwidth (Meters)	57	41	24	41	41

Summary of Results:

- No evidence of difference in rental values between houses inside and outside of the BSP area.

Change in Exposure to Cholera

	No. of deaths in house	At least one death in house	Deaths to houses on block	Percent of houses hit in block
Inside BSP area	0.531***	0.225***	0.531***	0.270***
	(0.0944)	(0.0417)	(0.171)	(0.0612)
Observations	933	894	77	77
Bandwidth (Meters)	56	52	54	55
Mean outside Broad St.	0.244	0.147	0.321	0.136

Summary of Results:

- Houses inside BSP area experience, on average, 3 more deaths than houses outside
- The likelihood of at least one death is about 23% higher inside BSP area

Implications of epidemic on poverty:

- 630 cholera victims, 76% inside Broad St. pump catchment area
- 68% of victims working age
- 42% of all properties in neighborhood experienced at least one cholera death, and 25% experienced multiple deaths
- 96% of households in BSP catchment experienced a death on the block

What happens shortly after the outbreak?

Rental Price 1864 (post-outbreak)

	Log Rental Price, 1864				
	Averaged CTEs (1)	Optimal Band (2)	Narrow Band (3)	Cluster Street (4)	Infra-structure (5)
Inside BSP area	-0.139**	-0.160**	-0.110*	-0.132*	-0.123*
	(0.065)	(0.065)	(0.063)	(0.077)	(0.071)
Observations	.	692	415	485	488
Boundary points	47	.	.	.	.
Bandwidth (Meters)	53	28	24	28	28

Summary of Results: Disease epidemic has immediate effect on property values of approximately 12 to 14% loss in value

What happens in long run?

Poverty map of Soho (Charles Booth, 1899)

Socioeconomic Status, 1899

	Very poor		Poor		Middle class	
	Averaged CTEs (1)	Optimal Band (2)	Averaged CTEs (3)	Optimal Band (4)	Averaged CTEs (5)	Optimal Band (6)
Inside BSP area	0.124**	0.086*	0.010	0.027	-0.103**	-0.072**
	(0.054)	(0.046)	(0.033)	(0.051)	(0.049)	(0.036)
Observations	.	1,138	.	774		670
Boundary points	23	.	23	.	23	.
Bandwidth (meters)	93.0	76.1	93	43.2	93	34.9

Summary of Results:

- 45 years after outbreak, the proportion of households classified as "very poor" is about 12% higher inside BSP area
- The likelihood of a "middle class" household is about 10% lower

Log Rental Price, 1936

	Boundary RD	One-dimensional RD			
	Averaged CTEs (1)	Optimal band (2)	Narrow band (3)	Cluster by Street (4)	Segment FE (5)
Inside BSP area	-0.300**	-0.366**	-0.301*	-0.366**	-0.356**
	(0.133)	(0.152)	(0.175)	(0.125)	(0.167)
Observations	.	230	180	230	230
Boundary points	25	.	.	.	.
Bandwidth (meters)	70.0	39.8	29.0	39.8	39.8

Summary of Results:

- By 1936, rental values continue to be lower inside the catchment area of the affected pump. (about a 30 percent difference)

House Price, Rentals, and Zoopla Estimates, 1995-2015

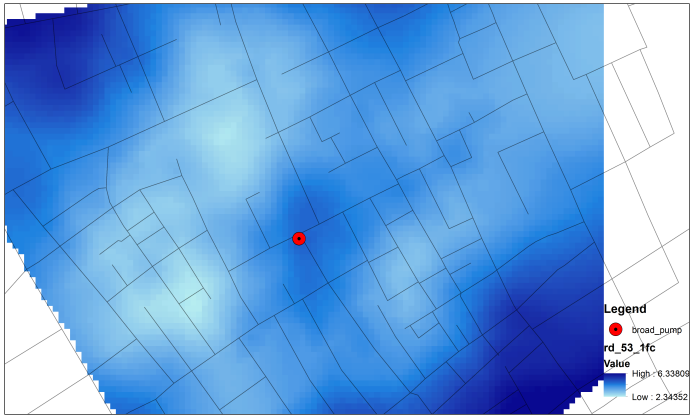
	House Prices and Zoopla Estimates		Zoopla Estimates Only		House Prices Only	House Rental Prices
	Averaged CTEs (1)	Optimal Band (2)	Averaged CTEs (3)	Optimal Band (4)	Optimal Band (5)	Optimal Band (6)
Inside BSP area	-0.158**	-0.238**	-0.124***	-0.168**	-0.286**	-0.163**
	(0.051)	(0.095)	(0.0391)	(0.073)	(0.128)	(0.076)
Observations	.	717	.	466	221	176
Boundary points	26	.	26	.	.	.
Bandwidth (meters)	85.0	41.2	85.0	35.1	43.5	50

Summary of Results:

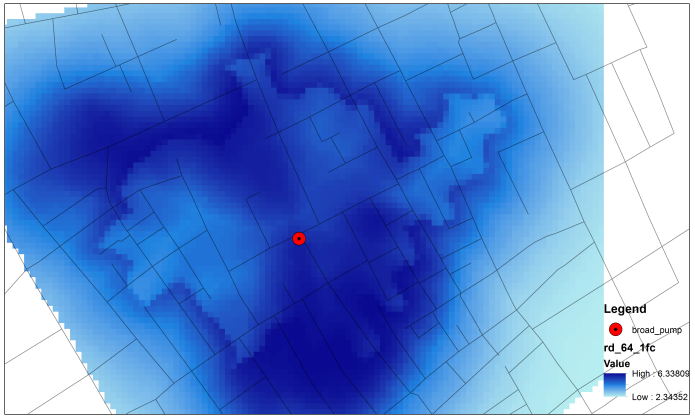
- Differences in house values, sale prices, and rental prices across the historic BSP boundary persist even today

Graphical Analysis

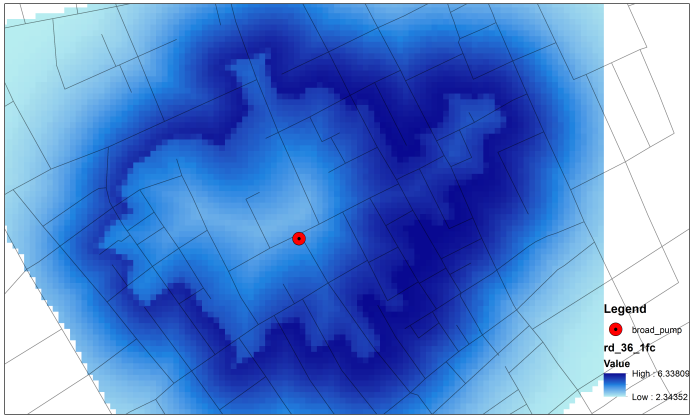
Color scale gives rental values predicted from model. Darker shades represent higher rent values.

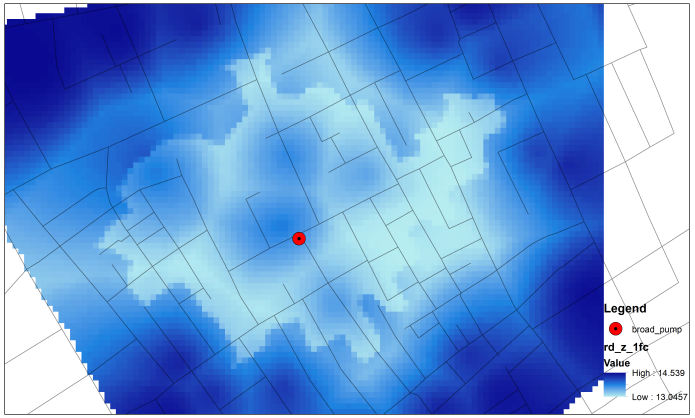


(a) Rental price (1853)



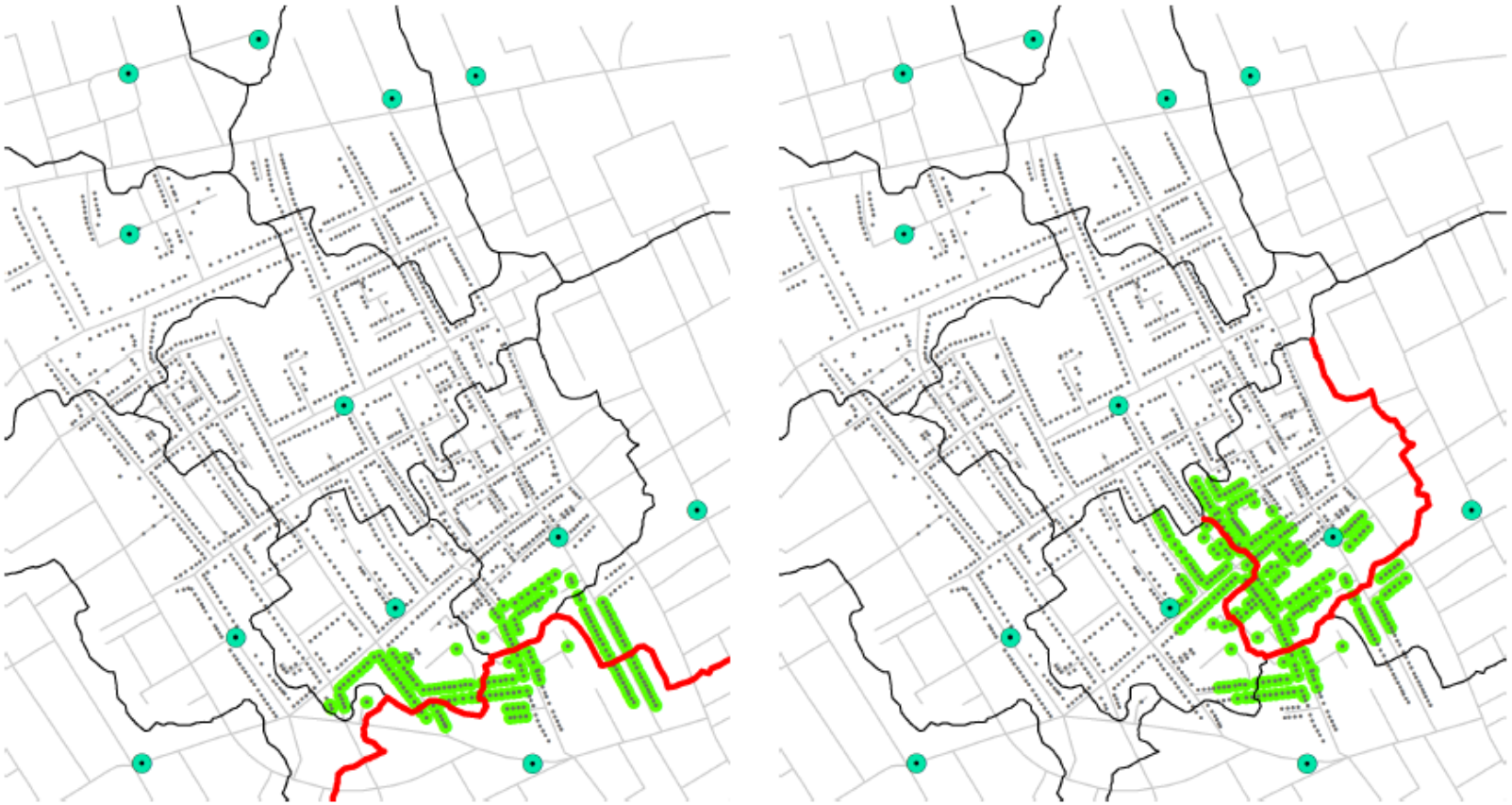
(b) Rental price (1864)





Falsification Tests

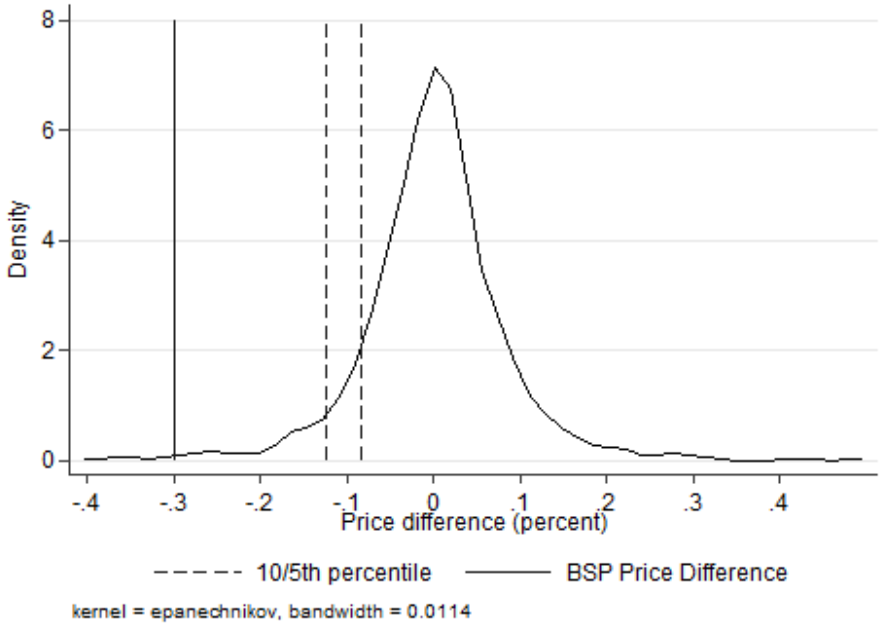
Test difference in prices across the boundaries of the catchment areas of non-affected pumps



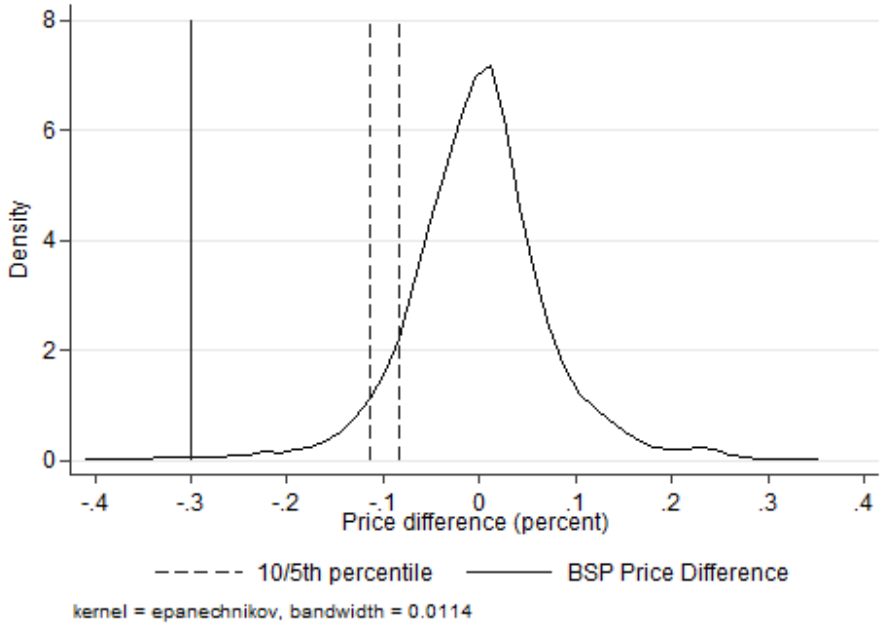
(a) Boundary 1 (b) Boundary 2

Summary of Results: No evidence of difference in prices across non-affected boundaries

Cross-cell differences in avg prices, all London



(i) All Prices



(j) Prices within range observed in Soho

Summary of Results: Price dispersion in treatment area is significantly higher than in most parts of London (extreme outlier)

Summary of long-run results:

- Effects on property prices in property values persist for for 150 years, even appear to grow (though not statistically distinguishable)
- Also see evidence of same pattern in survey data collected in 1899

What is explanation for persistence?

Migration Patterns (post-outbreak)

	Diff. Resident	Diff. Resident
House has at least one death	0.253***	0.322***
	(0.0831)	(0.0961)
Number of deaths in neighborhood	0.00335***	
	(0.000923)	
(House death)*(Neigh. deaths)	-0.00485***	
	(0.00141)	
Neighborhood cholera houses		0.00884***
		(0.00280)
(House death)*(Neigh. cholera houses)		-0.0139***
		(0.00361)
Observations	491	491

Summary of Results:

- If only one household hit by cholera in neighborhood, higher likelihood that it leaves neighborhood
- However, if a neighborhood is severely hit, the chance that an affected household leaves actually decreases

House Occupancy Characteristics (pre and post-outbreak)

	Number of occupants at address		Number of immigrant families at addres		Proportion of immigrant families at address	
	Averaged CTEs (1)	Optimal band (2)	Averaged CTEs (3)	Optimal band (4)	Averaged CTEs (5)	Optimal band (6)
Panel A: Census data (1851)						
Inside BSP area	2.029	1.610	0.067	0.109	0.014	0.016
	(1.493)	(1.297)	(0.049)	(0.106)	(0.010)	(0.0264)
Observations	.	547	.	547	.	547
Panel B: Census data (1861)						
Inside BSP area	4.004***	4.707**	0.297***	0.281**	0.020*	0.0355
	(0.758)	(1.785)	(0.071)	(0.107)	(0.011)	(0.024)
Observations	.	483	.	483	.	483

Summary of Results:

- Difference in number of occupants per household inside affected area doubles after outbreak
- Difference in number of immigrant families inside affected area triples after outbreak

Summary of Results

- Evidence on migration consistent with a story in which neighborhood impoverishment encourages unaffected to leave and affected to stay
- Evidence of residential crowding – increase in density of occupants after outbreak
- Evidence of lowering socioeconomic status of blocks – increase in immigrant households

Intuition behind model

- Consider rental market in which tenants face income shocks
- When several individuals hit by negative shock at same time, value of neighborhood falls because of externalities poor neighbors impose on block (poor tenants can only move out gradually)
- Landlord wants to retain rich, but costly to do so if too many tenants become poor
- We show that, if at some point enough existing renters hit by negative shock and become poor, block of apartments that formerly had all rich renters can converge to block with all poor renters
- Intuition: If composition of neighborhood can only change gradually, and in meantime landlord has to give big discount to rich people to live with poor neighbors, it can be more profitable to change strategy and attract/retain poor renters

Historic events that contribute to persistence:

1. *Property rights* (1915-1985): tenants given extremely strong occupancy rights and rent control. During that period, landlord would have had very little opportunity to reoptimize
2. *Property investment path*: Reduction in incentive to invest in properties, neighborhood even more likely to get stuck in poor equilibrium
3. *Ethnic sorting*: Demographic trends could play a similar role if it lowers willingness of rich to live in poor neighborhood that are increasingly occupied by immigrants
4. *Zoning laws*: Allowed red light district businesses to operate with special permit on distinct blocks. These permits very valuable, so establishments fought hard to stay over time. Could lead to further decay of already poor blocks

Conclusions:

1. Shocks to individuals can have permanent effect on spatial distribution of poverty, even in thick rental market with few frictions in which only renters are shocked
2. Simple channel through which we may observe persistence of historic events - resorting of individuals can put otherwise rich neighborhood onto different growth trajectory even when infrastructure untouched
3. Implies one cost of spatially correlated shocks is misallocation of land
   - Provides rationale for third-party intervention such as "urban renewal" projects or other attempts to upgrade poor neighborhoods located on intrinsically valuable property
4. On the other had, also implies a form of insurance to those who experience disease (or other) shock - the more their network is hit, the less likely they are to be priced out of neighborhood

lidity of RD assumptions

Identification requires two assumptions:

- Household characteristics are a continuous function of distance to BSP boundary
- No endogenous sorting into BSP area (pre-outbreak)

Some evidence from contemporary accounts

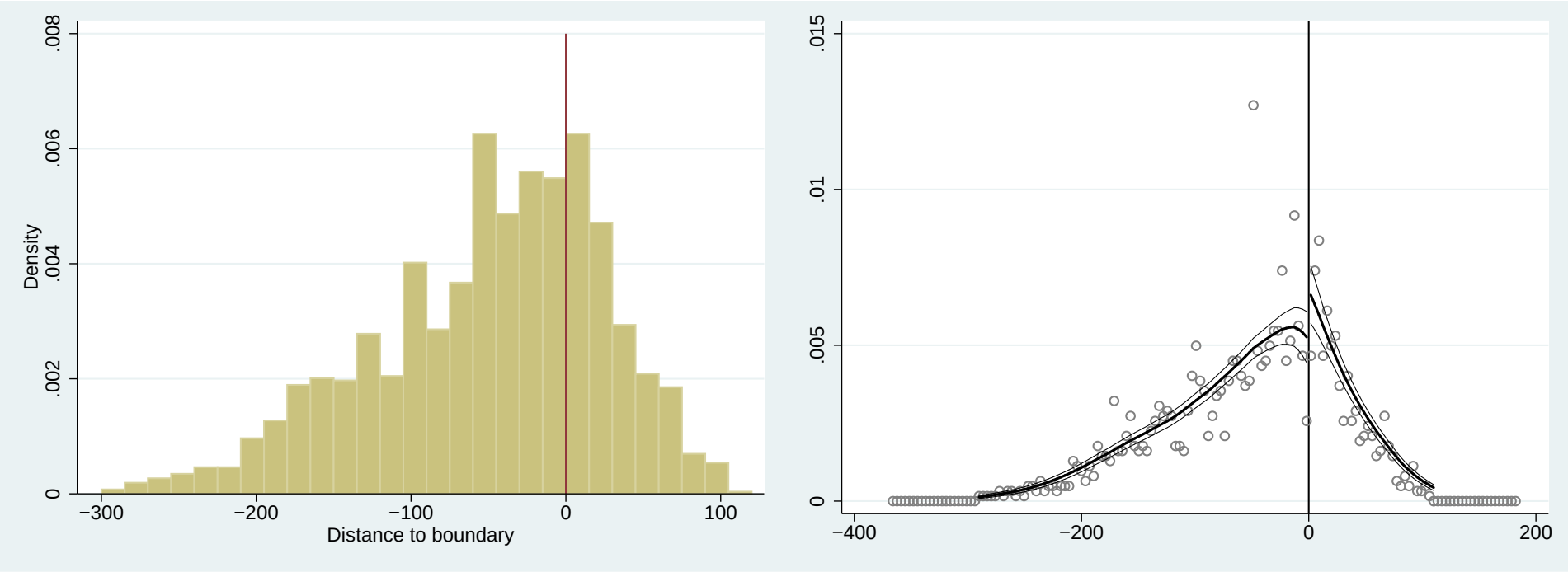
- "*for affected district stood alone in its intense suffering although embraced on all sides by closely populated neighbourhoods which almost escaped*" (Cholera Inquiry Committee, 1855)
- *"What class of persons did the disease principally destroy? (...) it attacked and destroyed all sorts and classes alike"* (Whitehead 1854, p.7)

sting Validity of RD assumptions

	Within 100 m			Optimal bandwidth	
	Inside	Outside	S.E.	RD	S.E.
Rental price (in logs)	3.719	3.743	(0.067)	0.126	(0.113)
Tax assessed (in logs)	0.453	0.496	(0.065)	0.110	(0.114)
Old/Existing sewer	0.479	0.589	(0.091)	0.082	(0.135)
New sewer	0.399	0.260	(0.084)	0.116	(0.105)
No access	0.128	0.151	(0.063)	-0.198*	(0.100)
Closest pump	1.052	1.066	(0.093)	0.111	(0.079)
Soho centroid	1.325	2.177	(0.131)***	-0.104	(0.202)
Presumed plague pit	2.358	2.630	(0.215)	0.260	(0.301)
Public square	2.584	2.715	(0.138)	-0.109	(0.189)
Church	1.323	1.609	(0.141)**	0.071	(0.163)
Police station	4.364	4.797	(0.221)*	-0.078	(0.438)
Fire station	3.597	2.864	(0.227)***	0.452	(0.353)
Theater	4.011	4.679	(0.219)***	-0.397	(0.335)
Pub	0.287	0.406	(0.046)**	-0.184	(0.111)
Urinal	0.874	1.019	(0.088)	-0.144	(0.141)
Sewer ventilator	0.431	0.563	(0.050)***	-0.023	(0.100)
Primary school	1.306	2.023	(0.109)***	-0.152	(0.195)
Bank	3.947	4.095	(0.315)	-0.005	(0.520)
Observations	491	815		534	

sting Validity of RD assumptions

No jump in frequency of houses at BSP boundary (No evidence of endogenous sorting)

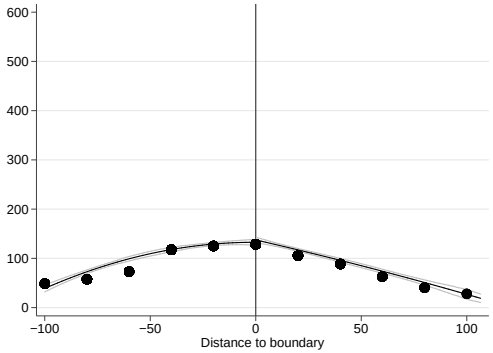


(k) Distance to BSP boundary

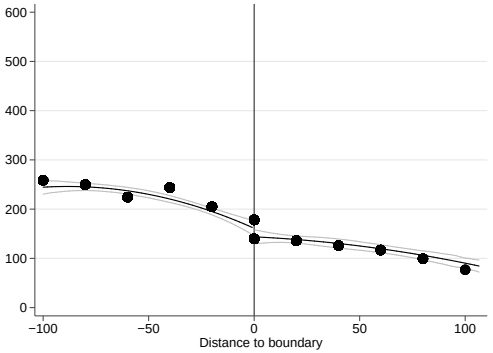
(l) McCrary's (2008) test

Figure: Histogram and density of forcing variable (Distance to BSP boundary)

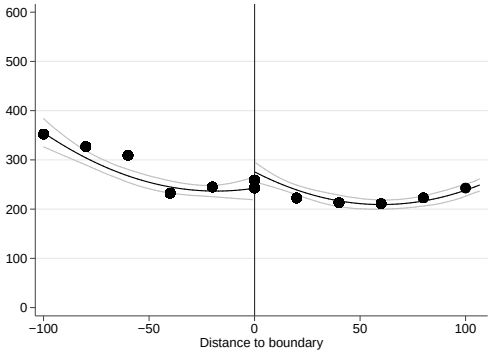
variate RD Plots



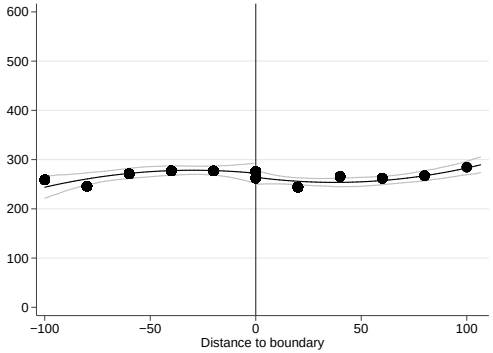
(a) Closest pump



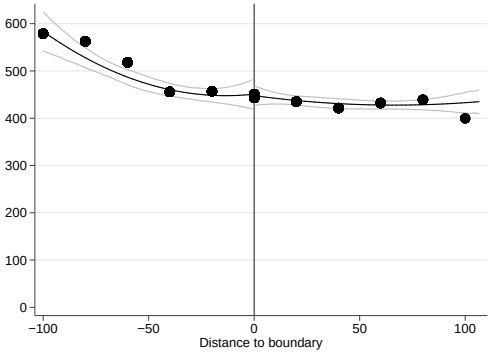
(b) Soho centroid



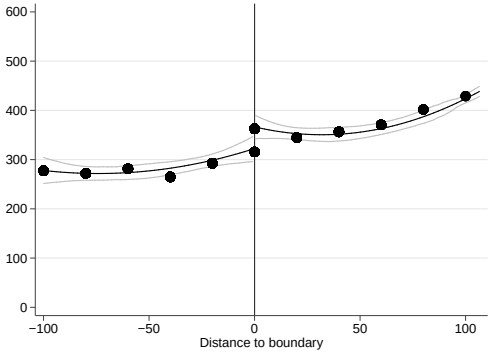
(c) Pressumed plage pit



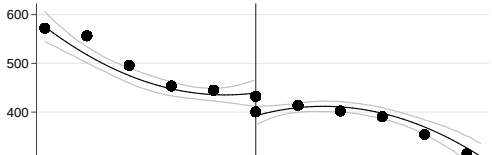
(d) Public square



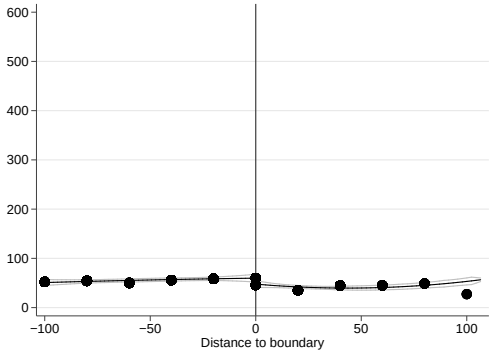
(e) Police station



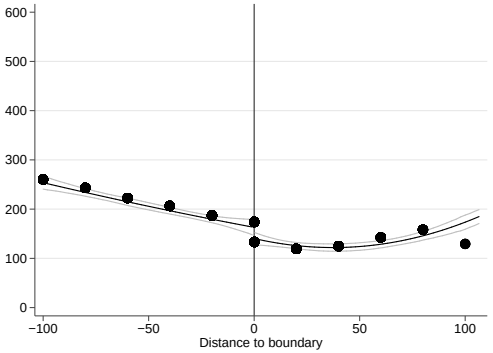
(f) Fire station



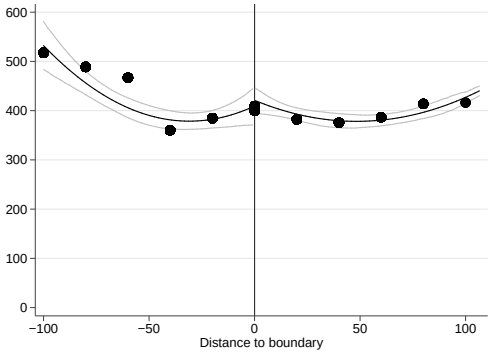
variate RD Plots (cont)



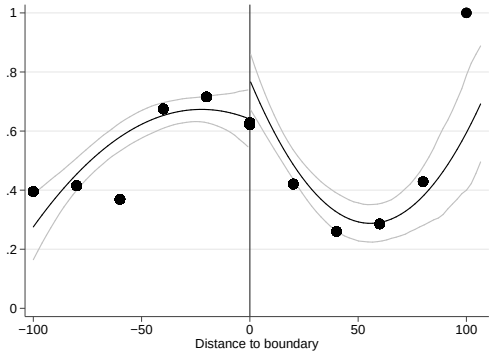
(a) Sewer vent



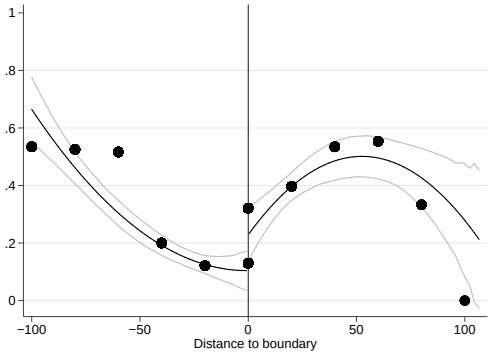
(b) Primary school



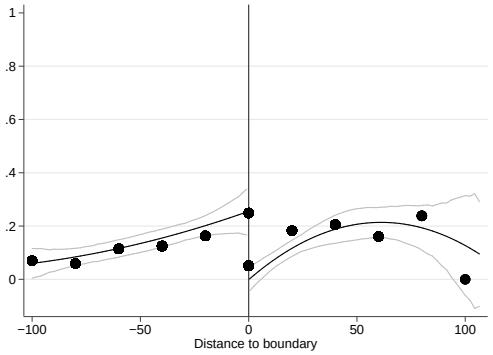
(c) Bank



(d) Old/Existing sewer



(e) New sewer



(f) No sewer access

lsification Tests (Cont'd)

	Pre-Outbreak (1853)	Cholera Exposure		Post-outbreak (1864)			Current (1995-2013, 2015)	
	Rental price	Number of Deaths in House-hold	House has at least one death	Rental price	Change in Rental price	Different Resident in 1864	Sales price	Price and Zoopla estimates
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Panel A. False Boundary 1					
RD coefficient	0.013	0.077	0.077	0.049	0.043	0.255		
	(0.154)	(0.101)	(0.098)	(0.178)	(0.050)	(0.210)		
Obs.	133	159	159	129	128	159		
R^2	0.31	0.13	0.13	0.31	0.22	0.24		
Bandwidth	37	37	37	37	37	37		
			Panel B. False Boundary 2					
RD coefficient	-0.035	-0.032	0.045	-0.175	-0.108	-0.161	0.045	-0.181
	(0.162)	(0.116)	(0.070)	(0.165)	(0.066)	(0.156)	(0.159)	(0.150)
Obs.	227	261	261	215	215	261	190	455
R^2	0.44	0.15	0.20	0.47	0.16	0.31	0.48	0.31
Bandwidth	49.7	49.7	49.7	49.7	49.7	49.7	55	55

Great Pulteney-inside BSP area

Great Pulteney-outside BSP area

Little Windmill (now Lexington)-inside BSP area

Little Windmill (now Lexington)-outside BSP area

Bridle Lane-inside BSP area

Bridle Lane-outside BSP area

Bridle Lane-Corner inside BSP area

Bridle Lane-Corner outside BSP area

Upper James-Corner inside BSP area

Upper James-Corner outside BSP area

lsification Tests (Cont'd)

	Pre-Outbreak (1853)	Cholera Exposure		Post-outbreak (1864)			Current (1995-2013, 2015)	
	Rental price	Number of Deaths in Household	House has at least one death	Rental price	Change in Rental price	Different Resident in 1864	Sales price	Price and Zoopla estimates
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C. False Boundary 3								
RD coefficient	0.033	-0.037	-0.064*	0.052	0.039	0.003		
	(0.110)	(0.051)	(0.035)	(0.125)	(0.064)	(0.111)		
Obs.	260	287	287	250	249	287		
R^2	0.49	0.14	0.12	0.50	0.14	0.19		
Bandwidth	34	34	34	34	34	34		
Panel D. False Boundary 4								
RD coefficient							-0.050	-0.069
							(0.199)	(0.125)
Obs.							217	453
R^2							0.40	0.29
Bandwidth							55.1	55.1

ntal Price, House Occupancy and Cholera Exposure within P area (block FE)

	Log Rental Price (1)	Number of immigrant families at address (2)	Proportion of immigrant families at address (3)
Panel A. Pre-Outbreak (1851,1853)			
House had at least one death (1854)	-0.069	0.080	0.010
	(0.045)	(0.085)	(0.022)
Observations	457	458	458
Mean (no deaths)	48.76	0.407	0.105
Panel B. Post-Outbreak (1861,1864)			
House had at least one death (1854)	-0.050	0.186	0.025
	(0.043)	(0.132)	(0.042)
Observations	447	414	414
Mean (without deaths)	50.35	0.665	0.162

Baseline model:

- Block with n apartments, owned by single landlord
- 2 types of potential renters: poor (p) and rich (r)
- Outside option of renter: live somewhere else with neighbors of same type, and pay rent W_p if poor and $W_r > W_p$ if rich
- Renters of type r dislike poor neighbors: if at given period x number of poor renters live in block, imposes negative externality c_x on any type r renter, where c_x increases in x (more poor neighbors implies more severe negative externality)
- Renters of type p do not care about composition of block (can be generalized to lower WTP to avoid poor neighbors)

Timing:

- Suppose previously rich block hit by negative income shock, making some renters poor. How does severity of shock (number of residents that became poor) affect optimal strategy of owner, and composition of neighborhood in long run?
- Existing renters have previously negotiated rental contracts, but at idiosyncratic times have an opportunity to move out and obtain type-dependent outside options. At such occasions, owner can either renew rental contract by offering new rent inducing tenant to stay, or get new tenant
- Model starts at $t = 0$ with a renegotiation like that between a tenant and the owner, with x other tenants currently poor ($n - 1 - x$ rich)
- At periods $t = 1, 2, ...$ with probability q one (randomly selected) tenant has opportunity to move out
- Common discount factor δ.

Owner's decisions:

- Owner can observe types of potential renters, and in case of vacancy can choose whether to take rich or poor tenant
- Profit-maximizing and sets rent such that it makes tenant indifferent to outside option. Assume that, when indifferent, owner retains current tenant
- Rent of type p is W_p, independently of current and expected future composition of block
- However, rent type r willing to agree on depends on current number of poor tenants and how number of poor tenants expected to change over time
- If x high enough, owner can only retain/recruit rich tenants by offering rent below W_p, introducing trade-off between recruiting rich type and losing money in short run, but making block more attractive for future rich renters, vs hiring poor type

Results:

- Always optimal for owner to either play *always poor* (at every renegotiation, retain poor tenant and replace rich tenant with poor one) or *always rich* (at every renegotiation, retain rich tenant and replace poor tenant with rich one). In first case, block composition converges to all poor, in second case converges to all rich
- Optimal strategy depends on $W_r - W_p$, x, $(c_i)_{i=0,..,n-1}$ and δ:
  - Increase in x decreases expected payoff from *always rich* relative to *always poor*, making it more likely that latter increase in optimal
  - Increase in c_i (for any $i = 0, ..., n-1$) decreases expected payoff from *always rich* relative to *always poor*; note c_0 can represent potential negative externality from poor neighboring blocks
  - Increase in $W_r - W_p$ increases expected payoff from *always rich* relative to *always poor*
  - If high enough δ, makes *always rich* optimal (but threshold increases as x increases)

Summary:

- For other parameters fixed, there is threshold x^* such that if initial x higher than x^* block converges to all poor and all current rich tenants eventually move out (current poor retained), otherwise block converges to all rich and all current poor tenants eventually move out
- Despite in long run an all good neighborhood more profitable for owner, if too many tenants hit by negative shock and owner can only change composition of tenants gradually, it might be optimal for her to aim for new steady state with all poor tenants
- In short, an income shock only affecting current tenants can permanently change composition of block (and average rents)

Extensions:

1. Apartments owned by different owners with different discount rates. Makes it more likely that neighborhood becomes poor
   - Formally: Set of parameter values in which only equilibrium among tenants is playing the strategy *always poor* by all owners is strictly larger than set of parameter values for which it is optimal for one owner to play strategy *always poor*
2. Investment/maintenance: does not change qualitative conclusions. If these costs differentially higher when catering to rich tenants, attractiveness of all poor strategy increases
3. Willingness to pay of poor type also depends on composition of neighborhood (poor types also value having more rich neighbors); qualitative results generalize to this setting as long as willingness to pay of poor types affected less for poor types than for rich types
4. No price discrimination: landlord can only set posted price for a vacant apartment and has to take first person willing to take it. Makes it more likely that block converges to all poor

Back of the Envelope Calculations

Can "all poor" equilibrium be optimal for realistic parameter values?

Assume,

- Linear disutility function $c_x^r = x \times y$, y is marginal disutility of each additional poor neighbor
- Block size = 40 apartments (average size observed in sample)
- Discount factor $\delta = \frac{1}{1.20}$ (High returns to capital during period (Allen, 2005))
- $W^p = 1$ and $W^r = 1.26$ (Based on estimates 10 years after epidemic)
- Threshold of 25% (i.e., 10 out of 40 households transition to poor)

Implications: Landlord has to offer initial rent of 0.29 (71% discount over W^p to retain/attract rich tenant)