Pandemics and Cities: Evidence from the Black Death and the Long-Run

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Comments Welcome
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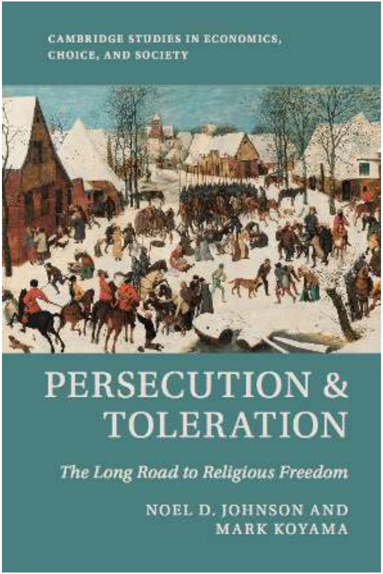

If you still want more economic history of disease after this talk (or want a preview of my book)…

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Research Questions: The Black Death (1347-1352)

- Killed **40%** of Europe's population, making it one of the largest demographic shocks in history.
- The Black Death has been **extensively studied** by historians, political scientists, economic historians and macroeconomists.
- However, despite its historical importance, little is know about its **spatial effects**, due to the lack of data on local mortality.
- Little is also known about the economic effects of continent-wide **pandemics**, given the rarity of such events.
- We use city-level data on mortality to study the short/medium and long-run spatial-economic effects of the Black Death across Western Europe.

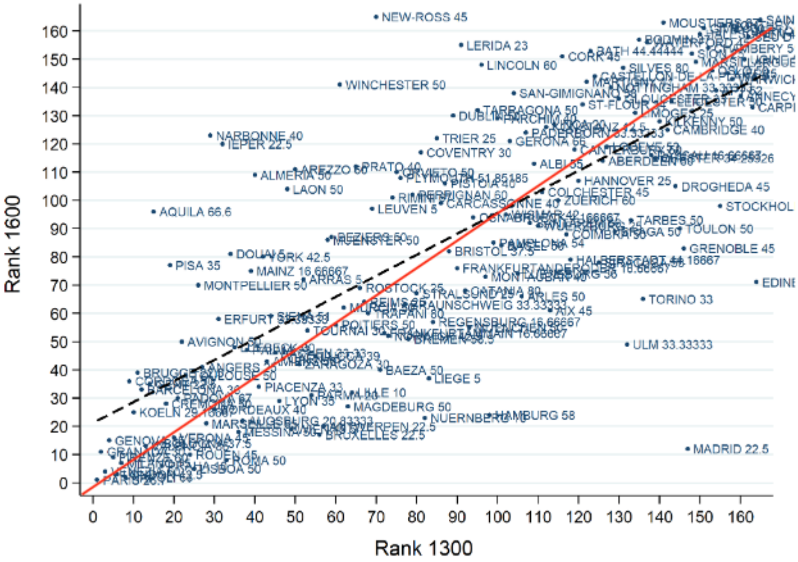
Explanations for Black Death Recovery

1. **Agglomeration Economies**
   - If strong increasing returns to population density, then high mortality cities would be expected to relatively decline post Black Death.
2. **Recovery Based on "Fixed Factors of Production"**
   - If production relies on fixed factors such as land or infrastructure, then high mortality leads to either migration or fertility/mortality response.
   - (i) Recover either to original growth path or: (ii) could be permutations based on endowments or (iii) higher aggregate population density if there is more optimal allocation of resources.

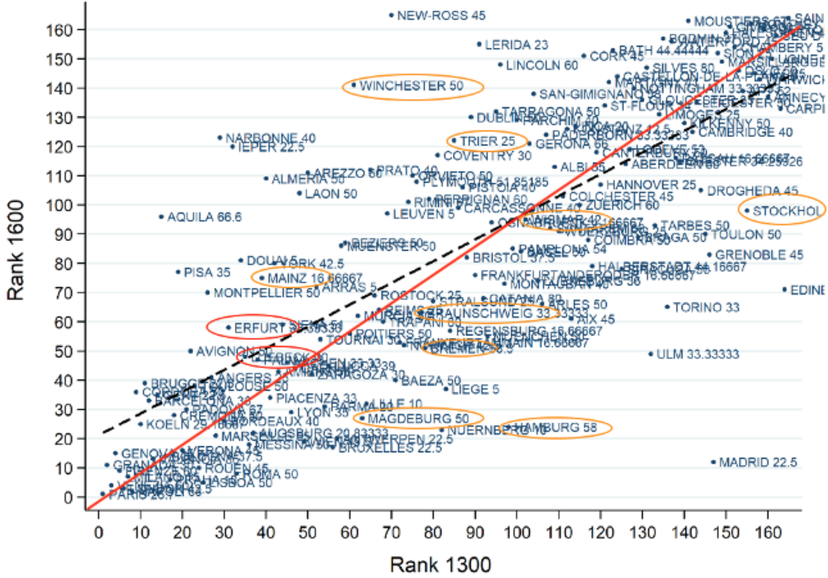
This Paper

- On average, Black Death had SHORT-RUN EFFECTS on city populations that DISSIPATED by 16th century.
- Mortality rates at city level were plausibly RANDOM.
- Evidence for AGGLOMERATION EFFECTS in the short/medium-run (based on our GE and state-level regs). Nothing in the long-run.
- Evidence that MIGRATION was important for recovery (based on missing villages). Marginal lands more likely to be abandoned in the hinterlands of cities with higher mortality.
- Evidence that RECOVERY was facilitated by fixed factors (urban and rural). Generated PERMUTATIONS in distribution of city sizes. $\rightarrow$ Think of as supporting Davis and Weinstein, but with the caveat that the relative importance of different fixed factors changed over time.
- UBAN RESET may be supported if marginal land was abandoned and if places with better fixed factors became larger.

Permutations in Black Death Recovery



The Role of Fixed Factors: Hanseatic League Membership

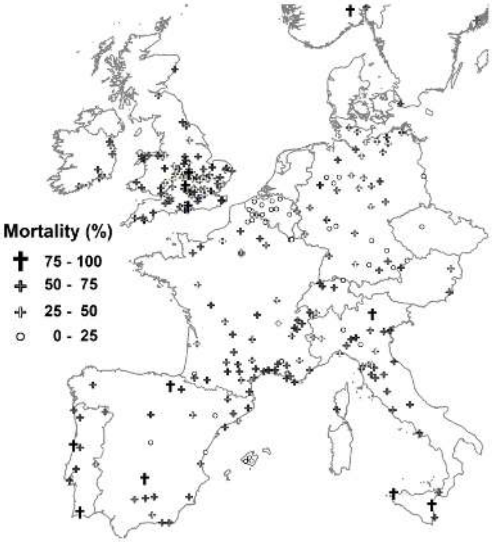


Data

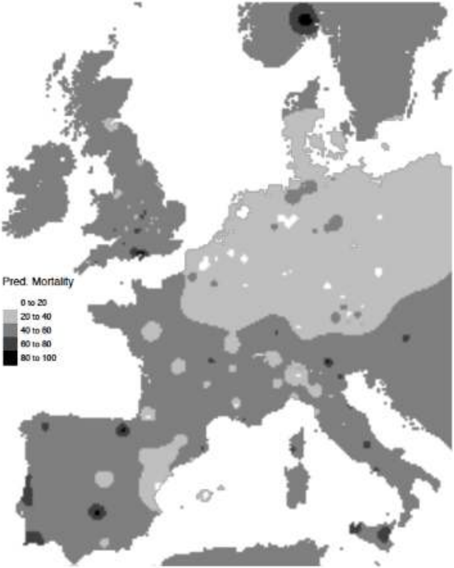
- **Black Death cumulative mortality rates** in 1347-1352. Data for 274 localities (Source: Christakos et al 2005).
- **Populations** of 1,801 towns & cities in 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1750, 1800 and 1850 (Sources: Bairoch 1988, Chandler 1987). 457 cities ($>$ 1,000 inh.) in 1300.
- **Main sample:** <u>165 cities</u> existing in 1300 for which we know mortality ($\approx$ 60% of Western Europe's urban pop then).
- GIS data on deserted medieval villages (England) as proxies for rural populations.
- Data on various **controls** proxying for *locational fundamentals*, *increasing returns*, *institutions*, and *contemporaneous shocks*:
  - Coast, rivers, soils, temperature, elevation, latitude, longitude;
  - Roman roads, land routes, trade networks, universities;
  - Political institutions, battles and other contemporaneous shocks.

Black Death Mortality for 274 Localities

Figure 1: Black Death Mortality Rates (%) for 274 Localities in 1347-1352

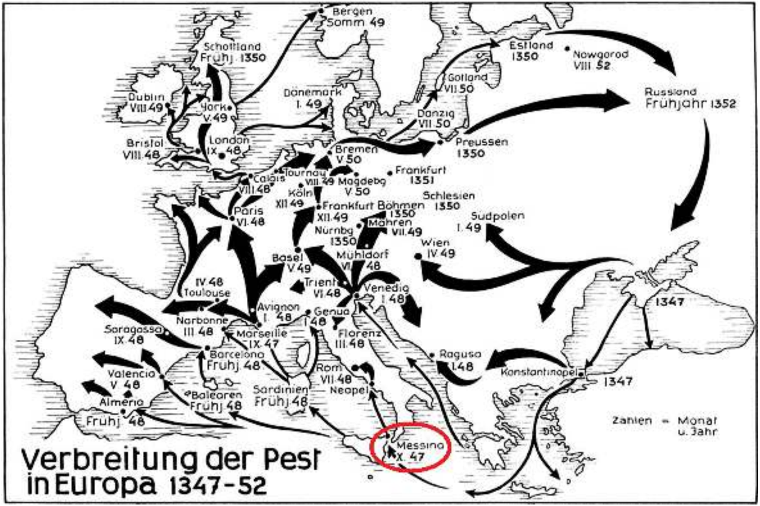


Spatially Averaged Black Death Mortality Rates Based on 274 Cities



Sample Selection?

European outbreak in 1347-52. Port of entry: Messina (Oct 1347)

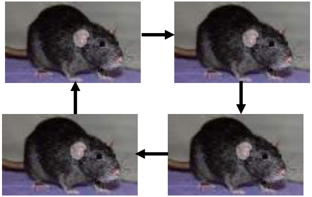


▸ Counterfactual Paths

Disease contagion process of the Black Death.

Black rats infected with *Yersinia Pestis* traveling on boats and carts from Asia

They infect European rats that in turn infect other European rats.



Humans infect other humans (**pneumonic plague**) and rats.

Fleas drink rat's blood. Bite humans once rats die (**bubonic plague**).

Symptoms (you die one to seven days after initial infection).

Buboes

Black warts

Coughing of blood

Seizures

A Comparatively “Pure” Population Shock.

- Huge Shock
- Acute—plague recurrences tended to be much less deadly (not always!) and spread over following centuries. Also, we can control for these on the extensive margin.
- Only killed people—infrastructure left intact.
- Did not explicitly target a sub-group of the population (e.g. intellectuals or a particular ethnic group).
- No government or international organization sponsored aid in the aftermath.

Main Findings

- On average, Black Death had SHORT-RUN EFFECTS on city populations that DISSIPATED by 16th century.
- Mortality rates at city level were plausibly RANDOM.
- Evidence for AGGLOMERATION EFFECTS in the short/medium-run (based on our GE and state-level regs).
- Evidence that MIGRATION was important (based on missing villages). Marginal lands more likely to be abandoned in the hinterlands of cities with higher mortality.
- Evidence that RECOVERY was facilitated by fixed factors (urban and rural). Generated PERMUTATIONS in distribution of city sizes.
- URBAN RESET may be supported if marginal land was abandoned and if places with better fixed factors became larger.

Empirical Strategy

- **We estimate** (for city i):

$$\%\Delta \text{Pop}_{i,t} = \alpha + \beta_t BD_{i,1347-52} + X_i + \varepsilon_{i,t}$$

  - $\%\Delta\text{Pop}_{i,t}$: population growth (%) in 1300-t = [1400-1750].
  - $BD_{i,1347-52}$: Black Death mortality rate (%) in 1347-1352.
  - By construction, β_t = -1 in very short-run. X_i: Controls.

Table 1: BLACK DEATH MORTALITY RATES AND CITY GROWTH, 1100-1750

	Dependent Variable: Percentage Change in City Population (%) in Period t						
t:	1300-1400	1300-1500	1300-1600	1300-1700	1300-1750	1100-1200	1200-1300
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
β	-0.87***	-0.28	0.36	0.47	0.85	-0.25	0.16
	[0.28]	[0.38]	[0.80]	[1.00]	[1.17]	[0.34]	[0.59]
	[-1.4 - -0.3]	[-1.0 - 0.5]	[-1.2 - 1.9]	[-1.5 - 2.4]	[-1.5 - 3.2]	[-0.9 - 0.4]	[-1.0 - 1.3]
Obs.	165	164	164	164	164	62	93
R^2	0.12	0.01	0.00	0.00	0.00	0.01	0.00

Notes: This table shows the effect β_t of the mortality rate (%) in 1347-1352 on the percentage change in city population (%) for each period t. The main sample consists of 165 cities (i.e. loc. $\geq$ 1,000 inh.) that existed in 1300 and for which mortality is available. We use city population in the initial year of period t as regression weights. Robust SE's: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. The 95% confidence level intervals are shown into brackets below the SEs. See Web Appendix for data sources.

Strong negative short-run effect (close to -1.00, the immediate effect of Black Death mortality by construction), no long-run effect (beta coefficient ≈ 0).

$\rightarrow$ Measurement error of mortality or positive city growth between 1300-1347 would bias the coefficient towards zero.

$\rightarrow$ Recovery in the 50 years after Black Death was very slow.

$\rightarrow$ Also a lot of heterogeneity in recovery (or measurement error on RHS).

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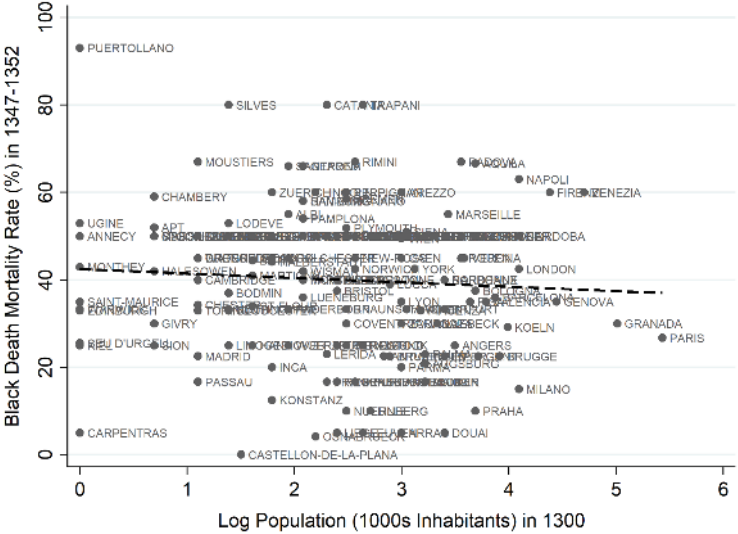
Empirical Strategy

- Suggestive evidence that mortality rates exogenous.
- No placebo effects before 14th century.
- Controls, drop outliers, and spatial FE (compare neighbors).
- Instrumental Variables ▸ More

Mortality Rate Vs. Initial City Population



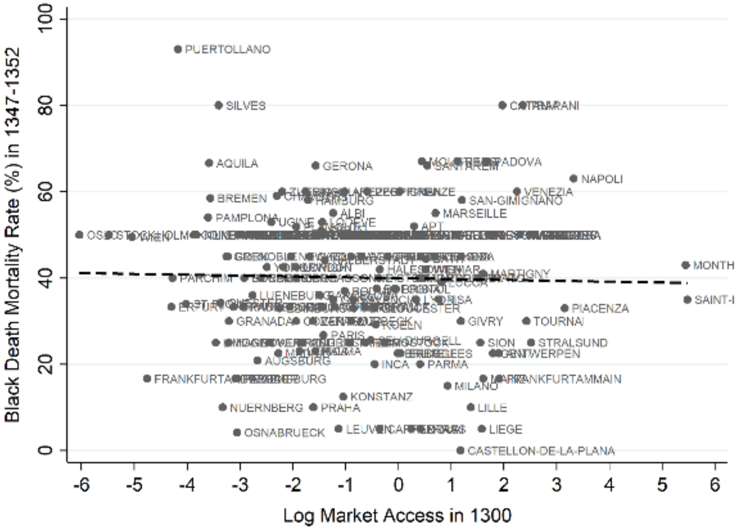
No correlation between mortality (1347-52) and initial city size.

Market Access (for city i and other cities j, $MA_i = \sum_j \frac{P_j}{D_{ij}^{\sigma}}$)

Different **travel speeds** for four transport technologies: *seas*, *rivers*, *Roman or medieval roads*, and *porters* (source: Boerner and Severgnini 2014). $\sigma = 3.8$

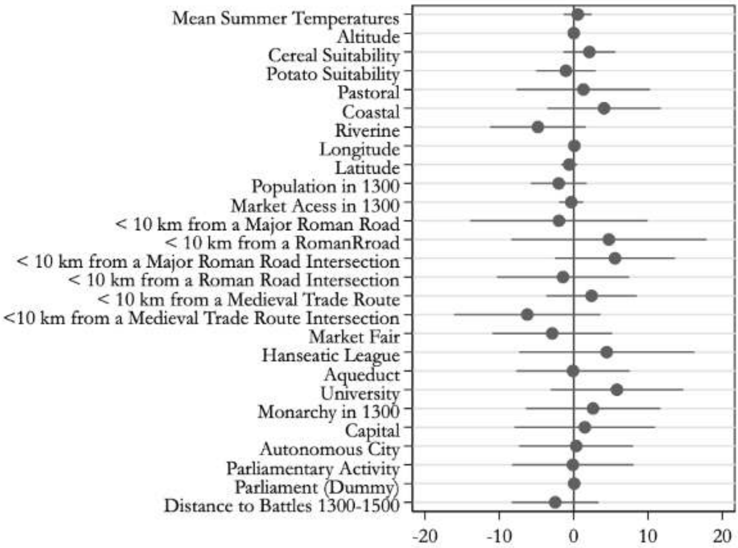
▸ MA Construction

Mortality Rate Vs. Initial Market Access



No correlation between mortality (1347-52) and market access (1300).

No correlation of BD Mortality Rates with city characteristics



Empirical Strategy

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β	-0.87***	-0.28	0.36	0.47	0.85	-0.25	0.16
	[0.28]	[0.38]	[0.80]	[1.00]	[1.17]	[0.34]	[0.59]
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No "placebo" effect before the 14th century.

Empirical Strategy

- Suggestive evidence that mortality rates exogenous.
- No placebo effects before 14th century.
- Controls, drop outliers, and spatial FE (compare neighbors). ▸ Regressions
- Instrumental Variables ▸ More

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Robustness Summary

Results are robust to:

- Controlling for the different sources of mortality data (number, description, desertion, clergy) in Christakos et al (2005).
- Using different city population data sets.
- Using neighboring cities or other cities of same state to impute missing mortality rate and increase sample size.
- Using spatially extrapolated mortality rates (based on 274 localities) for full sample of 457 cities existing in 1300.
- Reweighting observations to match full city distribution.
- Controlling for past population change(s).
- Using various specifications: no weights, panel.
- Clustering standard errors differently.
- Excluding each modern country one by one.

▸ Regressions

Main Findings

- On average, Black Death had SHORT-RUN EFFECTS on city populations that DISSIPATED by 16th century.
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Aggregate Effects: Short/Medium Run

Panel A: Dep. Var.:	Percentage Change in Total City Population (%) in Period 1300-1400					Dummy if Exists 1400	Log Pop. 1400
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mortality Rate (%)	-0.87*** [0.28]	-1.15*** [0.40]	-1.47** [0.57]	-1.13* [0.62]	-1.27** [0.58]	-0.002*** [0.001]	-0.004*** [0.001]
Unit	City	State	State	Country	Country	City	City
Population	Intensive	Intensive	Total	Intensive	Total	Extensive	Extensive
Observations	165	68	68	15	15	1,335	1,335

- When we consider the effect of average mortality at an aggregate level on aggregate population growth, there are significant negative effects. Think of as disintermediation or, as Broadberry and Hatcher call it, “Smithian Effects” (as opposed to a pure Malthusian impact of the BD.

- Intensive = only cities that existed in 1300. Extensive = all cities that existed in Bairoch (catches cities that emerge between 1300 and 1400).

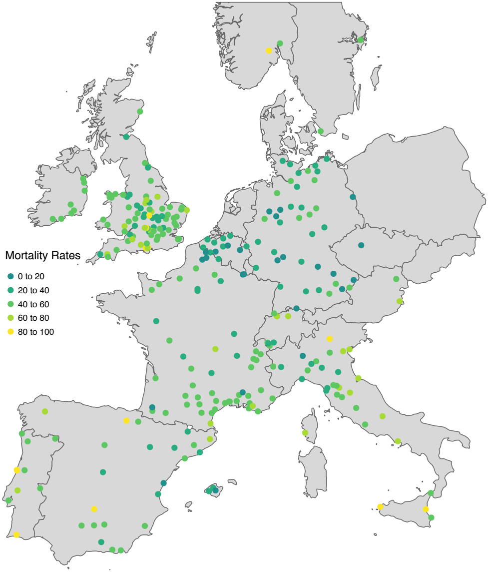
Aggregate Effects: Long Run

Panel B: Dep. Var.:	Percentage Change in Total City Population (%) in Period 1300-1600					Dummy if Exists 1600	Log Pop. 1600
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mortality Rate (%)	0.36 [0.80]	-1.49 [1.32]	-1.34 [3.17]	-1.64 [2.71]	-2.49 [5.35]	-0.001 [0.001]	0.002 [0.002]
Unit	City	State	State	Country	Country	City	City
Population	Intensive	Intensive	Total	Intensive	Total	Extensive	Extensive
Observations	164	68	68	15	15	1,335	1,335

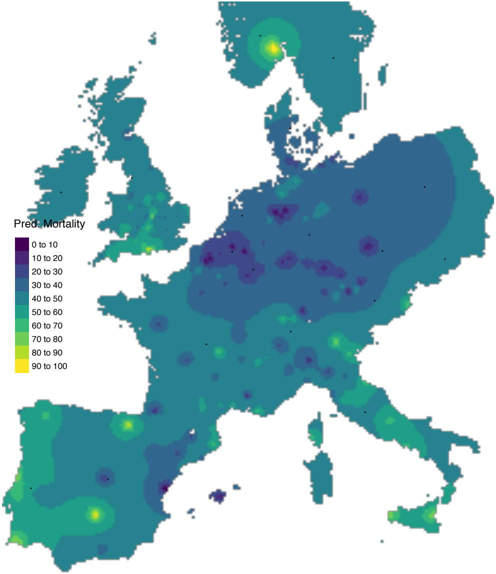
City Formation: Short/Medium Run

Panel A: Dep. Var.:	Percentage Change in Total City Population (%) in Period 1300-1400					Dummy if Exists 1400	Log Pop. 1400
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mortality Rate (%)	-0.87***	-1.15***	-1.47**	-1.13*	-1.27**	-0.002***	-0.004***
	[0.28]	[0.40]	[0.57]	[0.62]	[0.58]	[0.001]	[0.001]
Unit	City	State	State	Country	Country	City	City
Population	Intensive	Intensive	Total	Intensive	Total	Extensive	Extensive
Observations	165	68	68	15	15	1,335	1,335

274 Mortality Cities. . .



Create an Inverse Distance Weighted Surface...



More

Cities Eventually Above 1,000 pop. in Bairoch…

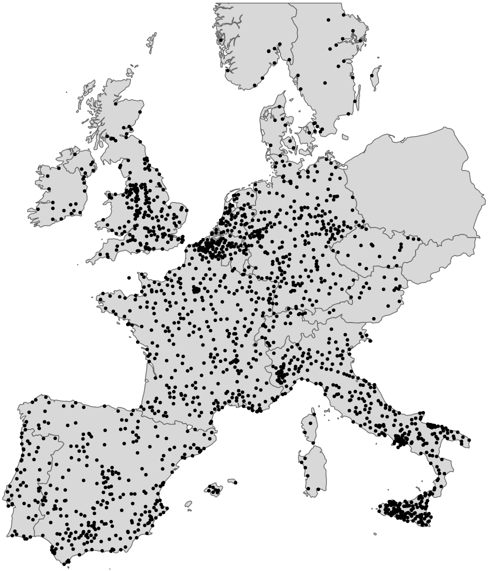


Table 7: MORTALITY AND CITY GROWTH, AGGREGATE EFFECTS, 1300-1600

Panel A: Dep. Var.:	Percentage Change in Total City Population (%) in Period 1300-1400					Dummy if Exists 1400	Log Pop. 1400
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mortality Rate (%)	-0.87***	-1.15***	-1.47**	-1.13*	-1.27**	-0.002***	-0.004***
	[0.28]	[0.40]	[0.57]	[0.62]	[0.58]	[0.001]	[0.001]
Unit	City	State	State	Country	Country	City	City
Population	Intensive	Intensive	Total	Intensive	Total	Extensive	Extensive
Observations	165	68	68	15	15	1,335	1,335
R^2	0.12	0.16	0.12	0.05	0.07	0.01	0.01
Panel B: Dep. Var.:	Percentage Change in Total City Population (%) in Period 1300-1600					Dummy if Exists 1600	Log Pop. 1600
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mortality Rate (%)	0.36	-1.49	-1.34	-1.64	-2.49	-0.001	0.002
	[0.80]	[1.32]	[3.17]	[2.71]	[5.35]	[0.001]	[0.002]
Unit	City	State	State	Country	Country	City	City
Population	Intensive	Intensive	Total	Intensive	Total	Extensive	Extensive
Observations	164	68	68	15	15	1,335	1,335
R^2	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Intensive margin: Cities that already existed by 1300. Total margin = intensive + extensive margin, with extensive margin = new cities that emerged after 1300.

Main Findings

- On average, Black Death had SHORT-RUN EFFECTS on city populations that DISSIPATED by 16th century.
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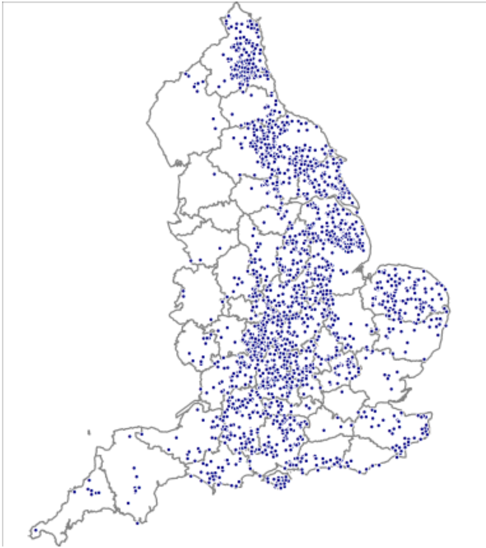
Abandoned Medieval Villages



Medieval county boundaries (N = 41) and deserted medieval villages (missing for 2).
Source: Beresford (1971) and Fenwick, Turner and others (2018).

Villages more likely to be abandoned when mortality rate higher and further from cities…

Table 9: BLACK DEATH MORTALITY AND DESERTED VILLAGES, ENGLAND

Dep. Var.:	Percentage Change in Population (%) in Period *t*			Number of DMVs per 1000 Sq Km			Abs. Change Urban Share
	1290-1377	1290-1756	1086-1290	All	$\leq$10Km	>10Km	1290-1756
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
β_t	-0.64**	-0.96	0.05	-1.13***	-0.11	-1.01***	-0.16
	[0.31]	[2.06]	[2.77]	[0.33]	[0.10]	[0.30]	[0.21]
Obs.	27	27	27	28	28	28	27
R2	0.13	0.01	0.00	0.31	0.06	0.35	0.02

Sample of 28 English counties with data on mortality and deserted medieval villages (DMVs). (1)-(3) Same population results as for cities. (4)-(6) More DMVs when low mortality, especially if far from cities. (7) No change in urbanization.

Main Findings

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Four possible sources of mechanisms of recovery

1. Population in 1353 (agglomeration)
2. Institutions
3. Rural Fixed Factors
4. Urban Fixed Factors
5. We estimate regressions of the form:

$$\%\Delta \text{Pop}_{i,t} = \alpha + \theta * (\text{Mort}_{i,1347-52} * \text{FixFact}_i) + \beta * \text{Mort}_{i,1347-52} + \xi * \text{FixFact}_i + \varepsilon_{i,t}$$

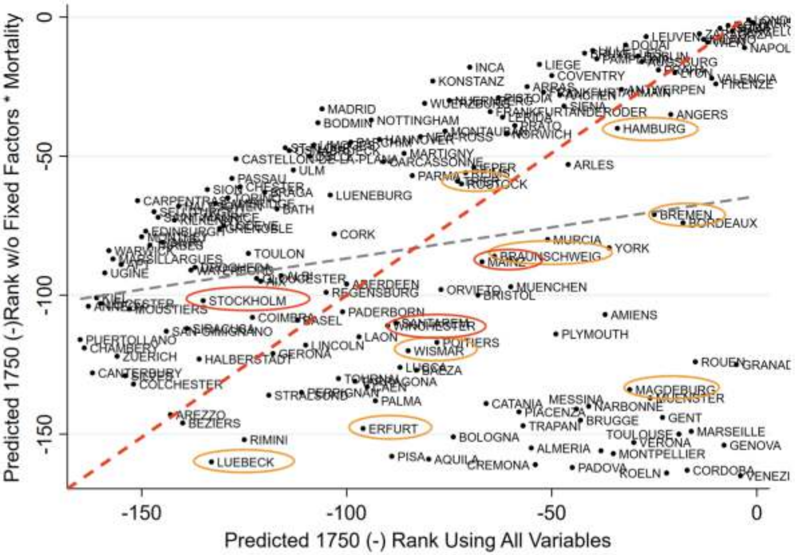
6. We include all potential sources in the regressions.

Mechanisms of Recovery

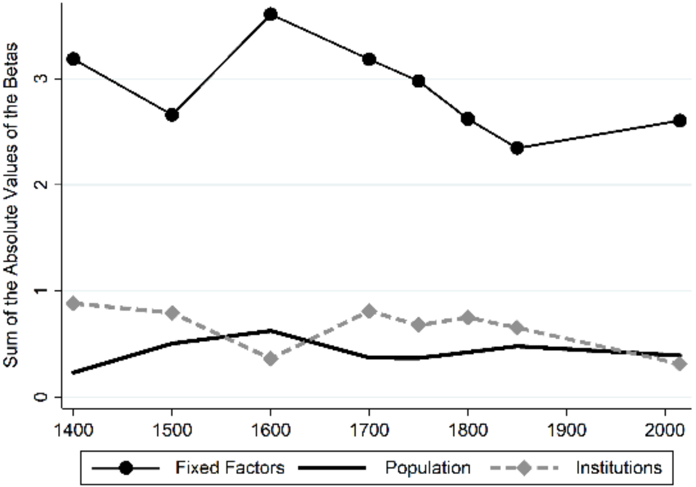
Dependent Variable: Percentage Change in City Population (%) in Period 1300-*t*						
Period 1300-*t*:	1400 (1)	1500 (2)	1600 (3)	1700 (4)	1750 (5)	2015 (6)
Mort.*Cereal Suitability Index	-0.1	0.2	0.6	0.9	1.0	8.8
	[0.3]	[0.3]	[0.7]	[1.5]	[1.7]	[33.0]
Mort.*Potato Suitability Index	0.3	-0.2	0.9	2.6**	3.0**	51.6**
	[0.3]	[0.4]	[0.6]	[1.3]	[1.5]	[23.9]
Mort.*Pastoral Suitability Index	0.6	-0.3	-4.1*	-3.2	-5.7*	-63.7
	[0.7]	[1.1]	[2.1]	[2.8]	[3.2]	[61.4]
Mort.*Coast 10 Km Dummy	1.2**	2.9***	4.8***	7.3*	7.6*	72.6
	[0.5]	[0.7]	[1.8]	[3.7]	[4.3]	[79.3]
Mort.*Rivers 10 Km Dummy	-0.5	0.3	1.7	5.0**	6.0**	112.4***
	[0.5]	[0.7]	[1.1]	[2.1]	[2.4]	[39.7]
Mort.*Road Intersection 10 Km Dummy	0.6	1.5*	1.3	2.2	2.7	31.3
	[0.6]	[0.8]	[1.5]	[2.7]	[3.1]	[57.7]
Mort.*Hanseatic League Dummy	2.9***	2.3*	4.1*	7.3*	8.5	92.2
	[0.9]	[1.2]	[2.4]	[4.4]	[5.8]	[104.2]
Mort.*Log Est .City Population 1353	-0.2	0.6	1.4	1.7	2.2	35.7
	[0.2]	[0.4]	[1.0]	[2.0]	[2.3]	[42.0]
Mort.*Monarchy 1300 Dummy	-0.2	0.7	1.2	2.3	1.9	-26.4
	[0.5]	[0.6]	[1.2]	[2.1]	[2.4]	[43.0]
Mort.*State Capital 1300 Dummy	-0.6	-1.5	-0.3	4.7	4.7	-19.1
	[0.8]	[1.3]	[2.5]	[4.3]	[5.3]	[87.1]
Mort.*Representative Body 1300 Dummy	0.8	-0.2	-0.5	-2.1	-3.1	-22.7
	[0.6]	[0.7]	[1.1]	[2.0]	[2.4]	[39.5]
Mortality	-3.9***	-1.8	-6.1*	-19.6**	-20.7**	-373.8**
	[1.4]	[1.9]	[3.5]	[9.2]	[10.2]	[156.9]
Observations	165	164	164	164	164	165
R-squared	0.45	0.29	0.39	0.35	0.35	0.25

Your sheep... that commonly are so meek and so little, now, as I hear, they have become so greedy and fierce that they devour men themselves. —Sir Thomas More (Utopia, 1516)

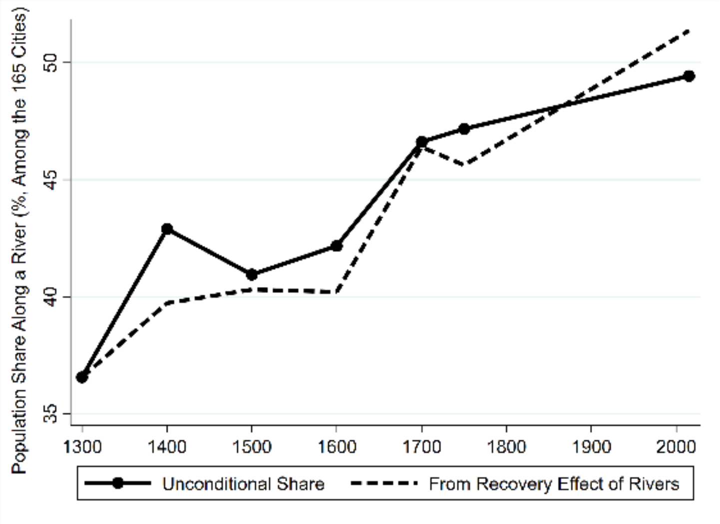
Recovery: Hanseatic League



Relative Contributions of Mechanisms of Recovery



Urban Reset?



Population Share Along a River (%, Among the 165 Cities)
35
40
45
50
1300
1400
1500
1600
1700
1800
1900
2000
Unconditional Share
From Recovery Effect of Rivers

Conclusion

- On average, Black Death had SHORT-RUN EFFECTS on city populations that DISSIPATED by 16th century.
- Mortality rates at city level were plausibly RANDOM.
- Evidence for AGGLOMERATION EFFECTS in the short/medium-run (based on our GE and state-level regs).
- Evidence that MIGRATION was important (based on missing villages). Marginal lands more likely to be abandoned in the hinterlands of cities with higher mortality.
- Evidence that RECOVERY was facilitated by fixed factors (urban and rural). Generated PERMUTATIONS in distribution of city sizes.
- URBAN RESET may be supported if marginal land was abandoned and if places with better fixed factors became larger.

Research in Progress: Long-run impact on institutional change

- The Black Death generated a massive change in relative prices.
- The price of labor rises relative to capital and land.
- We know this reduced inequality (at least for a couple hundred years).
- But what impact did it have on institutional change (think about the relative bargaining power of labor relative to owners of the other factors of production).

Craft Guilds

- Craft guilds: early labor institutions, first established between the 12th and 13th centuries
- Formal associations of specialized artisans
- Authority backed by political sanction
- Entrance into a guild was in many places **necessary** to pursue a craft

Relative prices created two types of incentives…

- Relative prices dictated how individuals would trade *within the existing set of institutions*. E.g. laws, regulations, norms.

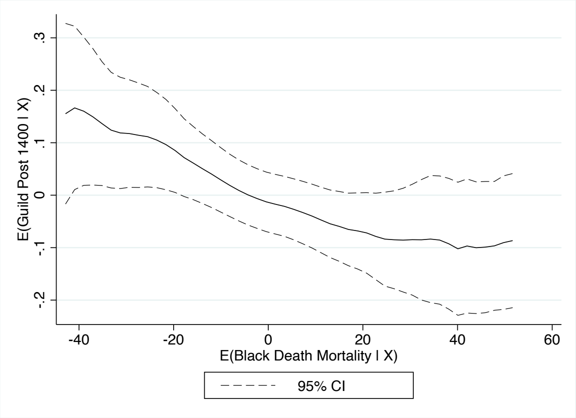
- But sometimes they also created incentives to *change those institutions*.

  The great pestilence had led to a rise in prices and particularly in wages, and the king took this as a motive for making the local bodies in Paris, above all the gilds, dependent on the royal institutions (titre 14). —Eli Heckscher, Mercatilism vol. 1, p. 138

  …the decree tended to make it easier for strangers to practise their crafts within the town; it even stipulated (titre 50) that any person who was able to practise a craft or introduce a commodity might do so and allow others to do the same (faire et venir faire) within the provisions of the law, so long as his craft was a good and honourable one. —Eli Heckscher, Mercatilism vol. 1, p. 141

Guilds less likely to be present in places with higher BD mortality…

Based on 8,000 observations of guild activity mentioned in primary and secondary sources



Did the Black Death encourage state formation?

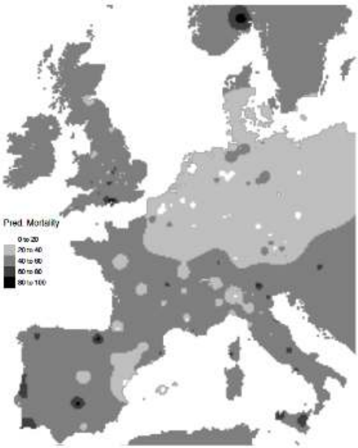
- The idea is that BD $\rightarrow$ increase in relative price of labor and increased urbanization $\rightarrow$ increased ability of the state to tax and govern.
- This last step could be because elites/nobles are weakened and this opened up space for the state. Could also be because those who are easiest to tax (the non-elites) are becoming more wealthy (though there's an issue here with whether the intensive vs extensive margin dominates).
- First step is to see if there is a correlation between BD mortality rates and increases in state capacity.
- One test of this is whether local variation in BD mortality is correlated with state consolidation.

Combine historical maps of state boundaries with 400km grids and count number of political entities over time. . .

(a) State Boundaries (1300) & 400km Grids

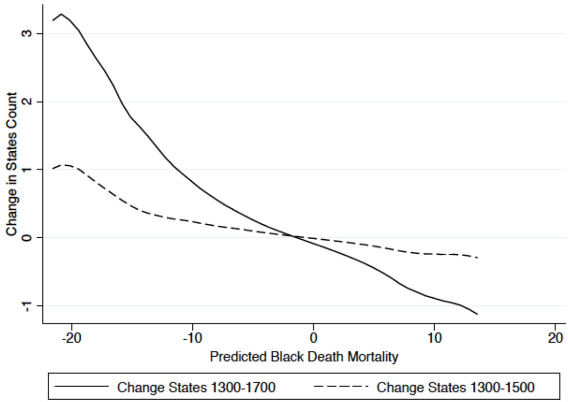
Extract imputed Black Death mortality into the gids. . .

Figure 2: Spatially Averaged Black Death Mortality Rates Based on 274 Cities.



Negative correlation between number of states in grid and Black Death mortality. . .

(b) Predicted Black Death Mortality & State Consolidation



Black Death Mortality and Market Access

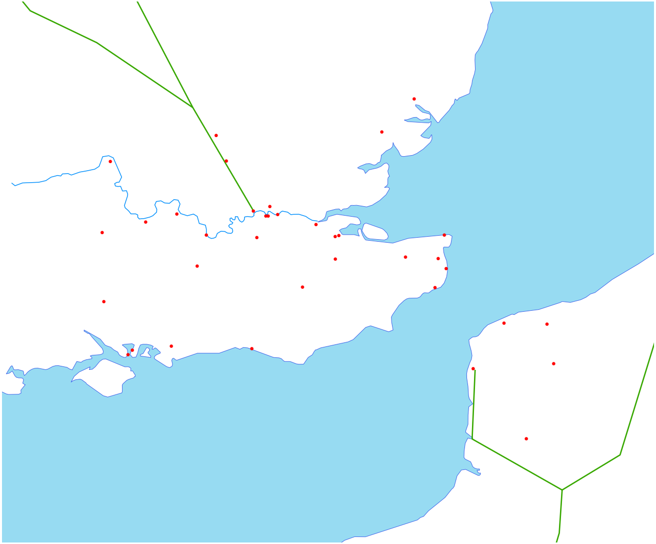
- Market Access for city j is defined as:

$$MA_j = \sum_{i=j} N_i \tau_{ji}^{-\sigma} \tag{1}$$

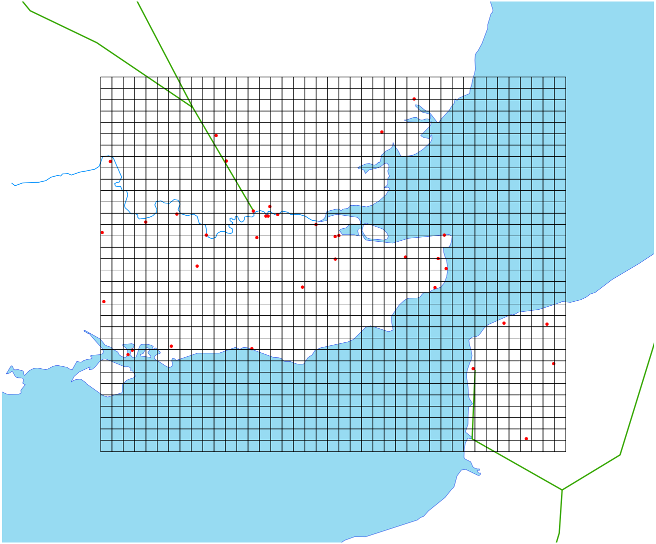
- where N_i is the population of city i, τ_{ji} is the cost of travel between cities j and i, and σ is a trade elasticity (from Donaldson & Hornbeck (2015) = 3.8).

- Where does τ_{ji}, or, 'travel cost' come from?

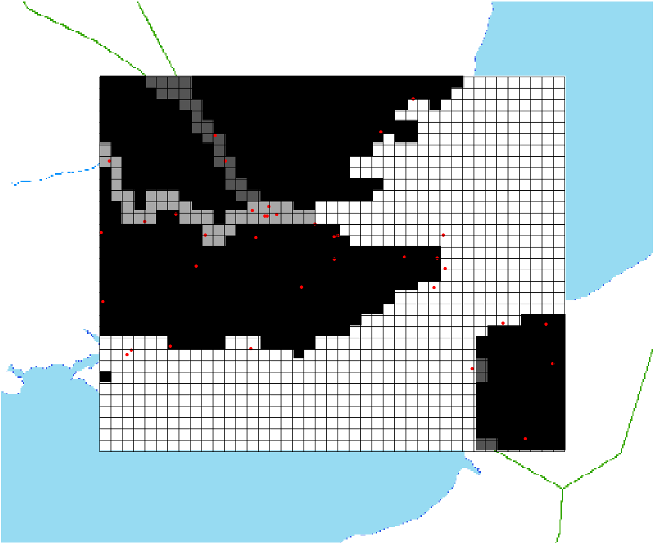
Start with vector data containing cities, rivers, seas, and trade routes…



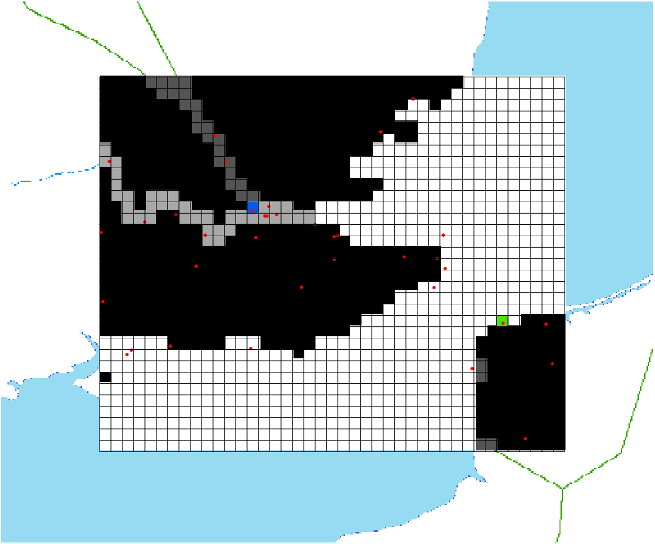
Superimpose a 5km x 5km grid...



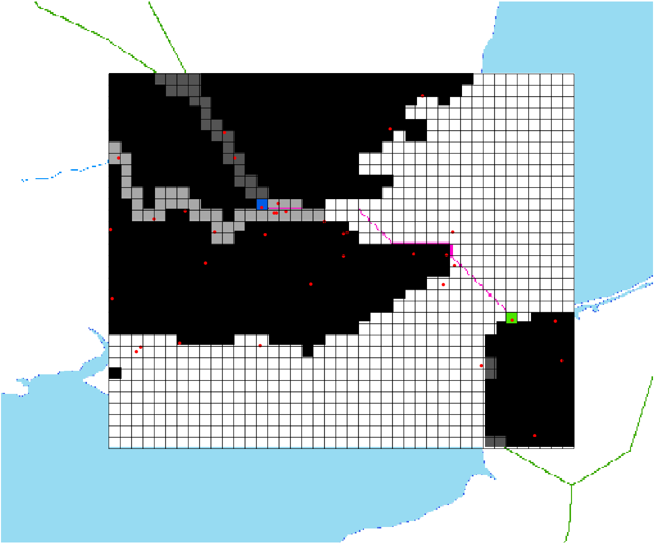
Transform into a raster taking value of least cost transport for each grid…



Choose two cities: London and Calais. . .



Apply Dijkstra's Algorithm to identify least cost path and cost of taking least cost path (τ)...



Rinse and repeat 1,603,840 times. . .

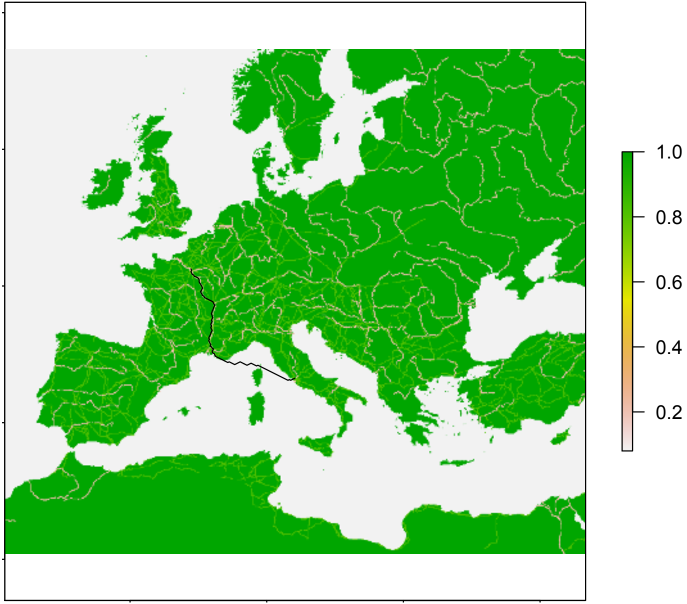


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Table 3: MORTALITY AND CITY GROWTH, INVESTIGATION OF CAUSALITY

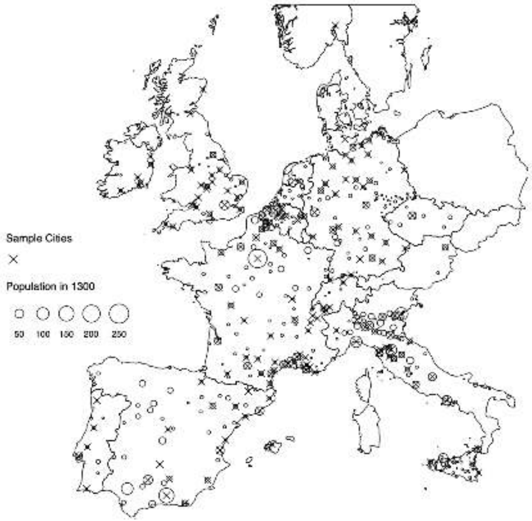
Dependent Variable: Percentage Change in City Population (%) in Period t						
Regression:	(1) t = 1300-1400			(2) t = 1300-1600		
1. Baseline (See Columns (1) and (3) of Table 1)	-0.87***	[0.28]	165	0.36	[0.80]	164
2. Controls: Locational Fundamentals	-0.79***	[0.26]	165	0.24	[0.64]	164
3. Controls: Increasing Returns	-0.68***	[0.24]	165	-0.03	[0.55]	164
4. Controls: Institutions	-0.61**	[0.23]	165	0.66	[0.75]	164
5. Controls: All	-0.59***	[0.21]	165	-0.37	[0.70]	164
6. Dropping Top and Bottom 5% in Mortality	-0.67**	[0.29]	145	1.36	[1.12]	144
7. Dropping Top and Bottom 10% in Mortality	-0.67*	[0.38]	136	1.10	[0.92]	135
8. Dropping More Hygienic Cities	-0.89***	[0.30]	161	0.59	[0.90]	160
9. 13 Country (2018) FE	-0.62**	[0.26]	165	0.03	[0.76]	164
10. 7 States (1300) FE (for States >= 5 Cities)	-0.82**	[0.35]	105	-0.29	[0.68]	104
11. Ctrls for Dummy & Num. Plague Reocc. 50km	-0.87***	[0.27]	165	0.41	[0.81]	164
12. Ctrls for Dummy & Num. Battles 50km	-0.84***	[0.28]	165	0.77	[0.78]	164
13. Ctrls for Jewish Pres., Pers., Pogr. 1347-1352	-0.83***	[0.30]	165	0.28	[0.81]	164

Including controls for city characteristics, dropping outliers, including spatial fixed effects, including controls for contemporaneous shocks (incl. plague reoccurences).

Return

Sample Selection?

Figure A.5: Main Sample of 165 Cities vs. Location of the 466 Cities in 1300.



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Counterfactual Paths of Infection

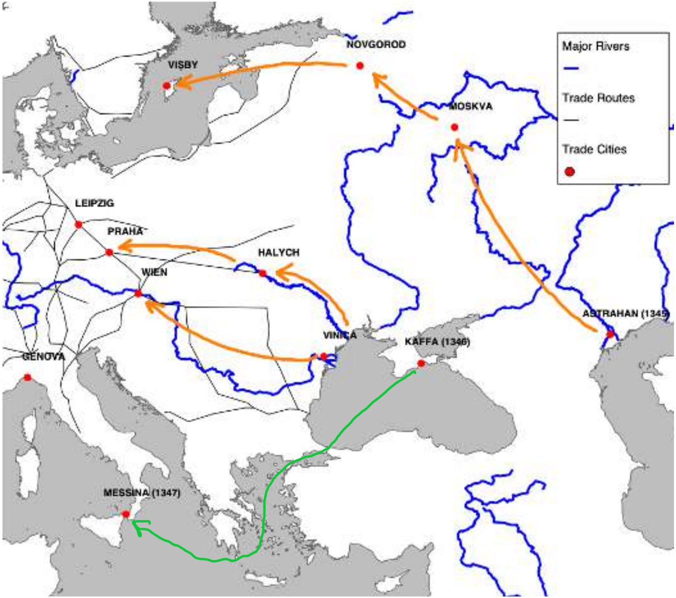

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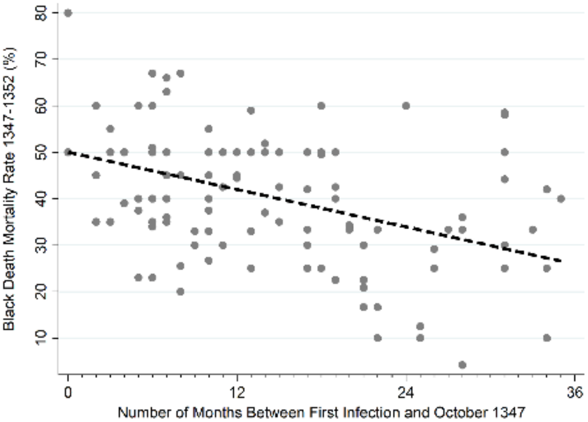
Table 5: MORTALITY AND CITY GROWTH, ROBUSTNESS CHECKS

Dependent Variable: Percentage Change in City Population (%) in Period t						
Regression:	(1) t = 1300-1400			(2) t = 1300-1600		
1. Baseline (See Columns (1) and (3) of Table 1)	-0.87***	[0.28]	165	0.36	[0.80]	164
2. Add Pct. Change in Pop. 1200-1300 as Control	-1.07***	[0.36]	93	0.83	[1.04]	93
3. Absolute ΔPop. 1300-1400 & Mortality 1347-52	-0.86**	[0.42]	162	0.83	[0.99]	161
4. SEs Clustered at State ca 1300 Level (N = 64)	-0.87***	[0.27]	165	0.36	[0.68]	164
5. Conley Standard Errors (500 km)	-0.87***	[0.17]	165	0.36	[0.58]	164
2. Dummies for Type of Mortality Data	-0.94***	[0.30]	165	0.27	[0.84]	164
3. Excl. Description-Based Mortality Data (N = 25)	-0.83***	[0.32]	140	0.37	[0.97]	139
4. Excl. Desertion-Based Mortality Data (N = 21)	-0.98***	[0.31]	144	0.31	[0.86]	143
5. Excl. Clergy-Based Mortality Data (N = 5)	-0.86***	[0.28]	160	0.38	[0.80]	158
6. Use Only Number-Based Mortality Data	-0.96***	[0.36]	114	0.35	[1.06]	113
7. Keeping Top and Bottom 10% in Mortality	-0.99**	[0.39]	34	-0.21	[1.01]	34
8. City Population Data: Bairoch Only	-0.78*	[0.41]	151	0.47	[0.80]	150
9. City Population Data: Chandler Only	-0.85**	[0.36]	59	1.37	[1.10]	60
10. Use Mortality of Nearest Avail. City w/i 50 km	-0.60***	[0.22]	290	0.41	[0.59]	286
11. Use Mortality of Other Cities in Same State	-0.70***	[0.17]	380	0.33	[0.63]	374
12. Extrapolated Rates Based on 274 Cities in 1300	-0.68***	[0.21]	464	0.43	[0.54]	457
13. Reweighting to Match Full City Size Dist.	-0.74***	[0.24]	165	-0.06	[0.65]	164

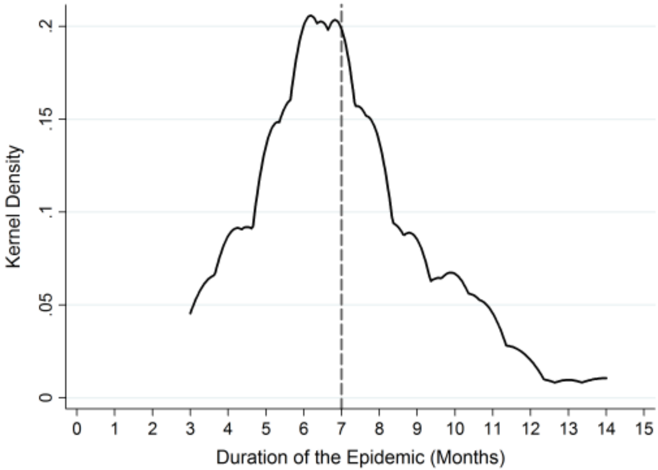
Return

(a) Timing of Black Death Onset and Mortality



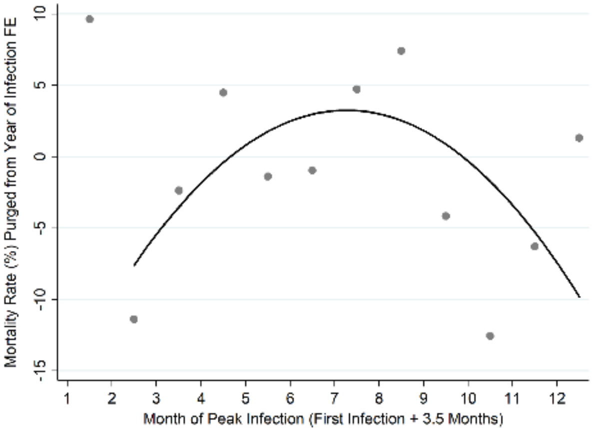
Mortality higher in first months due to epidemiological reasons (virulent pathogens eventually replaced by benign ones). IV1: Number of months since Oct 1347

Average duration of the plague $\approx$ 7 months.



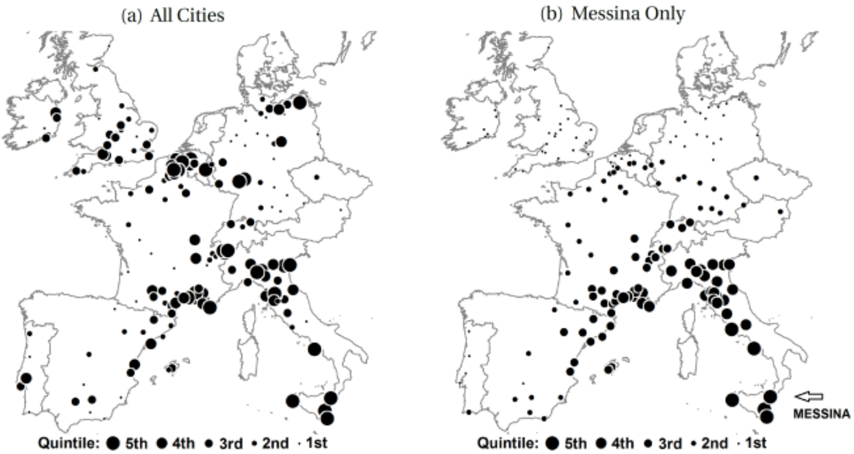
The Black Death usually stays in a city for 7 months, monthly mortality usually peaks after 3.5 months (qualitative evidence in Christakos et al 2005).

(b) Month of Black Death Onset and Mortality



Mortality higher if first infected in months leading to summer (fleas reproduce fast). IV2: Month of first infection FE, conditional on year of infection FE

Figure 5: Market Access to All Cities vs. Market Access to Messina Only, 1300.



Specific connectedness to Messina, not connectedness overall, mattered for mortality.
IV3: Log market access to Messina, controlling for log total market access

Table 4: MORTALITY AND CITY GROWTH, IV REGRESSIONS

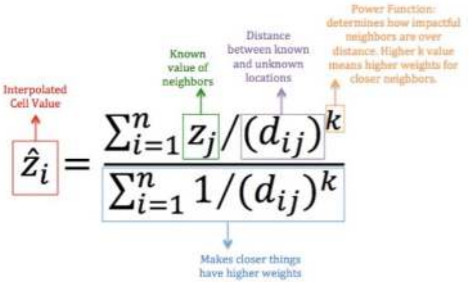
Dependent Variable: Percentage Change in City Population (%) in Period t						
Regression:	(1) t = 1300-1400			(2) t = 1300-1600		
1. Baseline (See Columns (1) and (3) of Table 1)	-0.87***	[0.28]	165	0.36	[0.80]	164
2. IV1: Timing w/ Controls (IV F-stat = 11.8)	-1.07**	[0.50]	124	0.05	[1.32]	124
3. IV2: Month w/ Controls (IV F-stat = 7.1)	-0.92***	[0.35]	114	-0.17	[0.68]	114
4. IV3: Messina w/ Controls (IV F-stat = 23.0)	-0.93**	[0.46]	164	-1.67	[1.72]	163
5. IV1 + IV3 w/ Controls (IV F-stat = 14.6)	-1.16***	[0.45]	123	-0.26	[1.21]	123

IV1: Number of months since Oct 1347. IV2: Month of first infection dummies, conditional on year of first infection dummies. IV3: Market access to Messina, conditional on market access to all cities. Controls: City characteristics.

Return

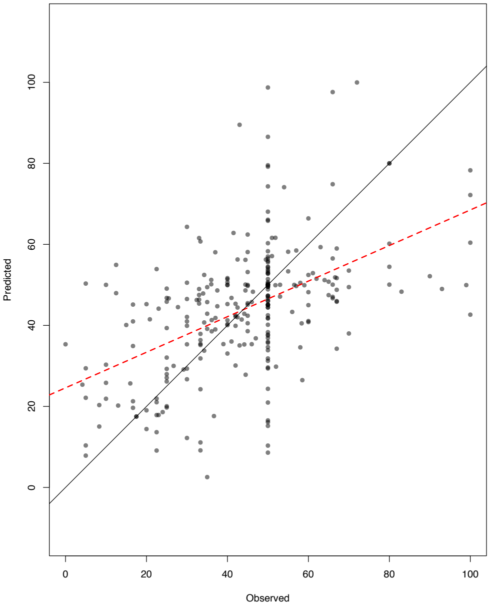
Inverse Distance Weighted Interpolation (IDW)

- Tobler's First Law of Geography: "Everything is related to everything else. But near things are more related than distant things."
- Can interpolate unknown values using known values, giving less weight to further away known values...

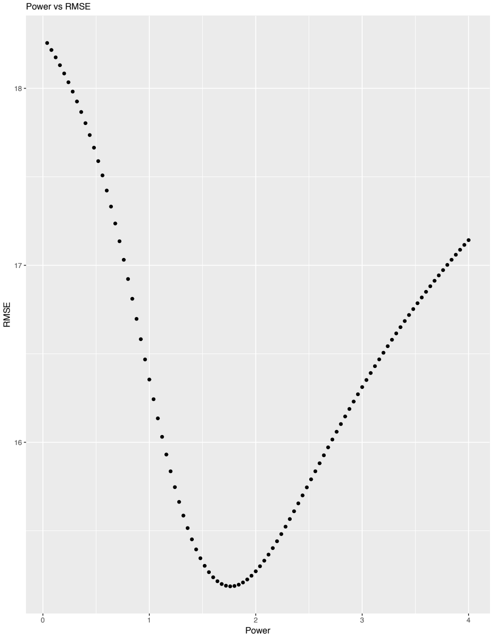


- But what power (k) to use?

Leave One Out Cross-Validation and Calculate Root Mean Square Error…



Repeat for Many Power Values (k's) and Plot…



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Related Literature

- Wars and bombings, as studied by Davis and Weinstein (2002), Bosker et al. (2008), and Glocker and Sturm (2014) killed people but also led to massive physical destruction and resulted in government reconstruction programs.
- Genocides, as studied by Acemoglu et al. (2011) and Rogall and Yanagizawa-Drott (2013) killed a large number of people but also resulted in physical destruction and disproportionately targeted intellectual elites or minority groups.
- Famines, as studied by Meng et al. (2015), killed large numbers of people but the poor died at higher rates.
- Disasters such as earthquakes and fires, as studied by Hornbeck and Keniston (2017) and Ager et al. (2018), tend to kill far less people but also lead to massive physical destruction.
- Expulsions, as studied by Waldinger (2010, 2012), Chaney and Hornbeck (2015), and Johnson and Koyama (2016) targeted specific subpopulations.
- Finally, other diseases such as malaria, HIV, or the 1918 influenza pandemic, as studied by Bleakley (2010), Young (2005), and Almond (2006) and Beach et al. (2018), disproportionately kill subgroups of the population