Path Dependence

Bruno Barsanetti

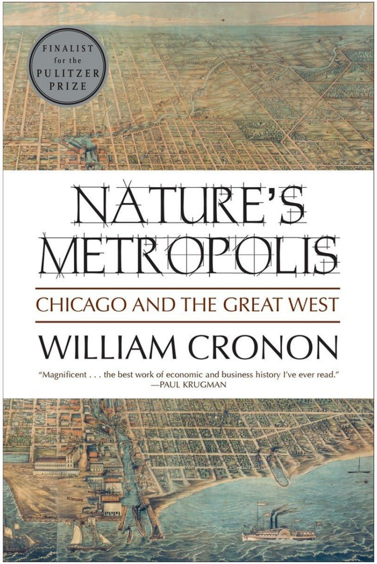
Economic Geography
FGV EPGE

Path dependence

- The core-periphery model predicts equilibrium indeterminacy
  - why one region would become the core, not the other?
  - it requires some sort of coordination
- Key idea: move to a dynamic perspective. Perhaps:
  - there are multiple steady-state
  - but the long-run equilibrium is determinate given *initial conditions*
  - history matters $\Rightarrow$ path dependence!
- Theoretical foundation: history vs. expectations models (Krugman 1991, Matsuyama 1991)
  - more recent quantitative spatial models (Allen and Donaldson 2024)
- Empirical evidence: turn to historical experiments
  - persistence literature, with clear theoretical underpinnings

First and second nature

- Geographic fundamentals: drive location decisions
- First nature: physical fundamentals
- Second nature: human built-fundamentals
  - includes capital and infrastructure
  - other self-reinforcing agglomerations



Bones, Bombs, and Break Points: The Geography of Economic Activity

Davis and Weinsten

American Economic Review

2002

Seminal paper

- Test between three economic theories about city size
    1. geographic fundamentals
    2. multiplicity of equilibria due to agglomeration economies
    3. random city growth

Great abstract!

Bones, Bombs, and Break Points: The Geography of Economic Activity

By DONALD R. DAVIS AND DAVID E. WEINSTEIN*

We consider the distribution of economic activity within a country in light of three leading theories—increasing returns, random growth, and locational fundamentals. To do so, we examine the distribution of regional population in Japan from the Stone Age to the modern era. We also consider the Allied bombing of Japanese cities in WWII as a shock to relative city sizes. Our results support a hybrid theory in which locational fundamentals establish the spatial pattern *of relative regional densities, but increasing returns help to determine the* degree *of spatial differentiation. Long-run city size is robust even to large temporary shocks.* (*JEL* D5, J1, N9, R1)

Spatial distribution of economic activity in Japan

- Hilly country, highly urbanized
- Good historical data:
  - number of arqueological sites per period and prefecture: Jomon (6,000-300 aC, hunter and gatherer) e Yayoi (-300 aC - 300 dC, neolithic)
  - population counts since 725
- Data aggregated at the prefecture levels
- Useful experiments: WW2 bombings

Year	Population in thousands	Share of five largest regions	Relative var of log population density	Zipf coefficient	Raw correlation with 1998	Rank correlation with 1998	History
−6000 to −300	125	0.39	2.46	−0.809 (0.217)	0.53	0.31	Hunter-gatherer society, not ethnically Japanese, no metal tools or agriculture.
−300 to 300	595	0.23	0.93	−1.028 (0.134)	0.67	0.50	First appearance of primitive agriculture and ethnically Japanese people. Some metallurgical skills, some coins, no writing or cloth.
725	4,511	0.20	0.72	−1.207 (0.133)	0.60	0.71	Creation of feudal regime, population censuses begin, writing well developed, farming is widespread. Capital is Nara.
800	5,506	0.18	0.75	−1.184 (0.152)	0.57	0.68	Capital moves to Kyoto. Property rights for peasant farmers continue to improve, leading to greater cultivation.
900	7,442	0.29	0.68	−1.230 (0.166)	0.48	0.65	Use of metallic farm tools doubles over average for previous 300 years. Improved irrigation and dry-crop technology.

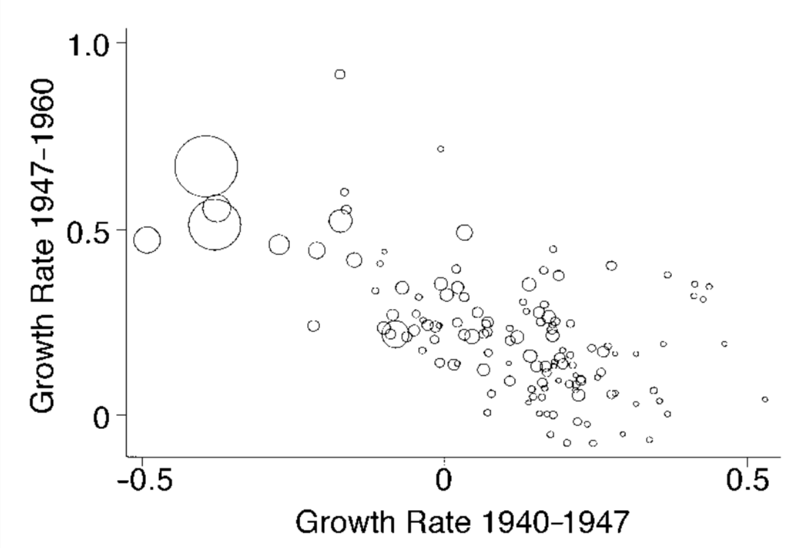
1150	6,836	0.20	0.66	−1.169 (0.141)	0.53	0.73	Multiple civil wars especially in (rice-rich) northern Japan. General political instability and rebellions.
1600	12,266	0.30	0.64	−1.192 (0.068)	0.76	0.83	Reunification achieved after bloody war, extensive contact with West. Japan is a major regional trading and military power.
1721	31,290	0.21	0.43	−1.582 (0.113)	0.85	0.84	Closure of Japan to trade with minor exceptions around Nagasaki. Capital moves to Tokyo. Political stability achieved.
1798	30,531	0.21	0.37	−1.697 (0.120)	0.83	0.81	Population is approximately 80 percent farmers, 6 percent nobility. Population stability attributed to infanticide, birth control, and famines.

1872	33,748	0.18	0.30	−1.877 (0.140)	0.76	0.78	Collapse of shogun's government, civil war, jump to free trade, end of feudal regime, start subsidized import of foreign technology.
1920	53,032	0.25	0.43	−1.476 (0.043)	0.94	0.93	Industrialization and militarization in full swing, but still 50 percent of labor force is farmers. Japan is a major exporter of silk and textiles.
1998	119,486	0.41	1.00	−0.963 (0.025)	1.00	1.00	Japan is a fully industrialized country. Tokyo, with a population of 12 million, is one of the largest cities in the world.

Long-run persistence

- “Bones” part of the paper
- “Bombs” part: what is the effect of WW2 bombings on city sizes?
- Seem to rebound pretty quickly

War losses and post-war growth



Econometric model

- City size $s_{i,t}$ is a fundamental plus an error:

$$s_{i,t} = \Omega_i + \epsilon_{i,t}$$

- error adjust over time, but also is subject to stochastic shocks

$$\epsilon_{i,t} = \rho \epsilon_{i,t-1} + \nu_{i,t}$$

Econometric model

- Hence, city sizes change according to

$$\begin{aligned} s_{i,t+1} - s_{i,t} &= \epsilon_{i,t+1} - \epsilon_{i,t} \\ &= \big(\rho - 1\big)\nu_{i,t} + \big[\nu_{i,t+1} + \rho(1-\rho)\epsilon_{i,t-1}\big] \end{aligned}$$

- The parameter of interest is ρ:
  - if $\rho = 1$, then shocks are permanent (random growth or NEG)
  - if $\rho < 1$, then shocks are transitory and there is a unique s.s. (fundamentals)
- Identification: instrument the 1940-47 population growth with bombing damages

First stage

TABLE 2—INSTRUMENTAL VARIABLES EQUATION (DEPENDENT VARIABLE = RATE OF GROWTH IN CITY POPULATION BETWEEN 1940 AND 1947)

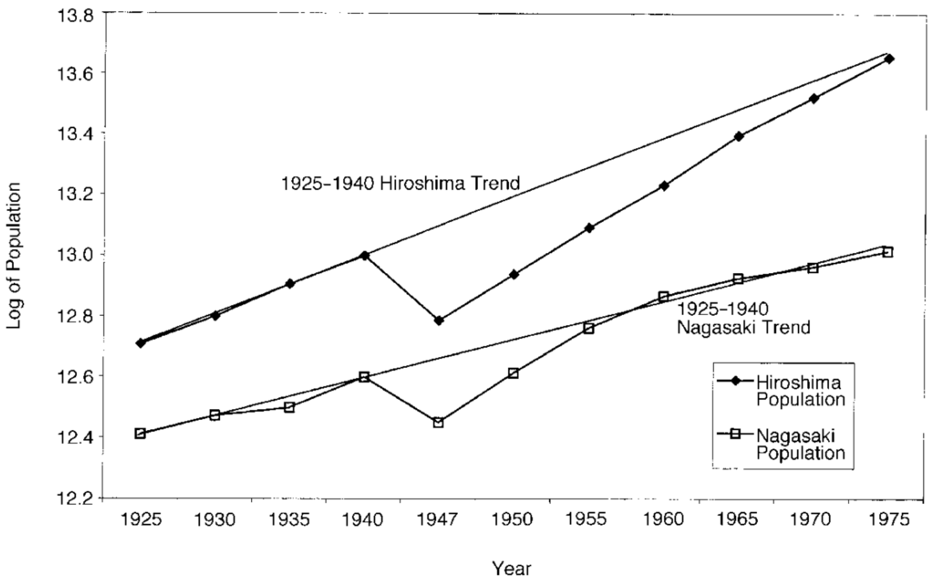
Independent variable	Coefficient
Constant	0.213
	(0.006)
Deaths per capita	−0.665
	(0.506)
Buildings destroyed per capita	−2.335
	(0.184)
R^2:	0.409
Number of observations:	303

Main results

TABLE 3—TWO-STAGE LEAST-SQUARES ESTIMATES OF IMPACT OF BOMBING ON CITIES (INSTRUMENTS: DEATHS PER CAPITA AND BUILDINGS DESTROYED PER CAPITA)

	Dependent variable = growth rate of population between 1947 and 1960		Dependent variable = growth rate of population between 1947 and 1965
Independent variable	(i)	(ii)	(iii)
Growth rate of population between 1940 and 1947	−1.048	−0.759	−1.027
	(0.097)	(0.094)	(0.163)
Government reconstruction expenses	1.024	0.628	0.392
	(0.387)	(0.298)	(0.514)
Growth rate of population between 1925 and 1940		0.444	0.617
		(0.054)	(0.092)
R^2:	0.279	0.566	0.386
Number of observations:	303	303	303

Nuclear strikes



Comparing theory with data

Stylized fact	Increasing returns	Random growth	Locational fundamentals
Large variation in regional densities at all times	−	+	+
Zipf's Law	−	+	+
Rise in variation with Industrial Revolution	+	−	−
Persistence in regional densities	?	?	+
Mean reversion after temporary shocks	?	−	+

Portage and Path Dependence

Bleakley e Lin

Quarterly Journal of Economics

2011

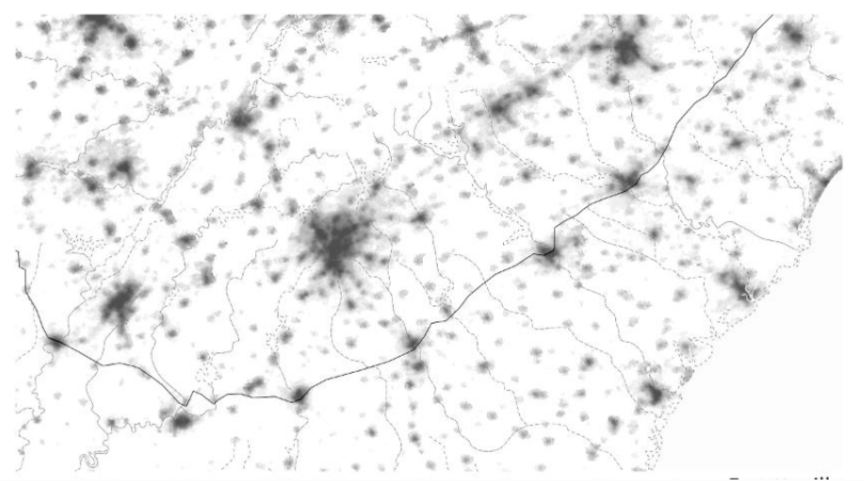
Relevance of this paper

- This paper: first convincing evidence of path dependence in economic geography
- What is the idea?
  - use a geographic fundamental that mattered in the past: *portage sites*
  - these sites led to employment in the transportation sector
  - but this fundamental should not matter today (obsolete): river transportation lost relevance, no more need for portages
  - if there is urban activity next to portage sites today, it is not due to modern fundamentals
  - conclusion: path dependence!

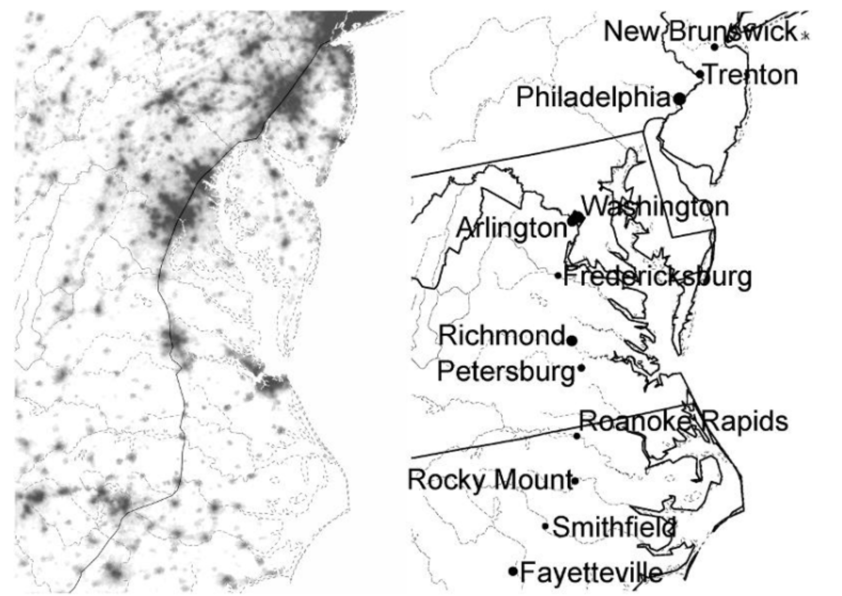
Historical setting

- East coast: settled during the 18 century, when river transportation was common
- US rivers usually allowed navigation deep into the interior of the country
- At some point, they crossed with a fault line: portage site
- Several portage cities: Philadelphia, Richmond, Augusta
- Portage sites connecting the Great Lakes to the Mississipi basin: Chicago, South Bend

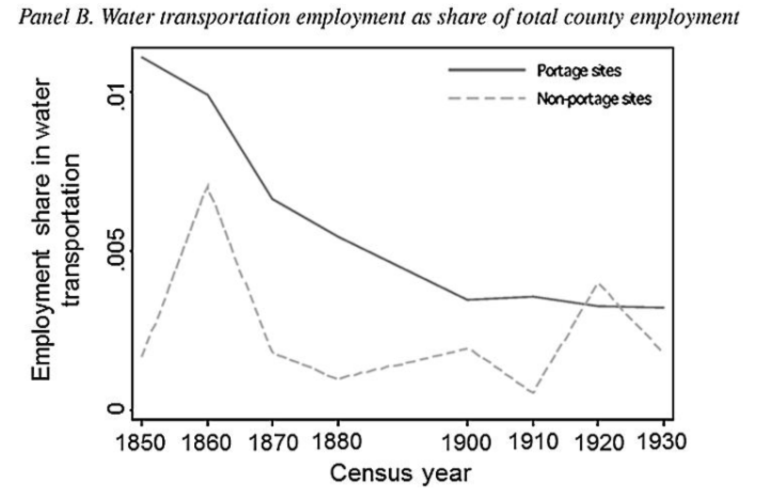
Cartographic evidence



Cartographic evidence



But there is hardly any more portage



Empirical framewwork

- Difference-in-differences:

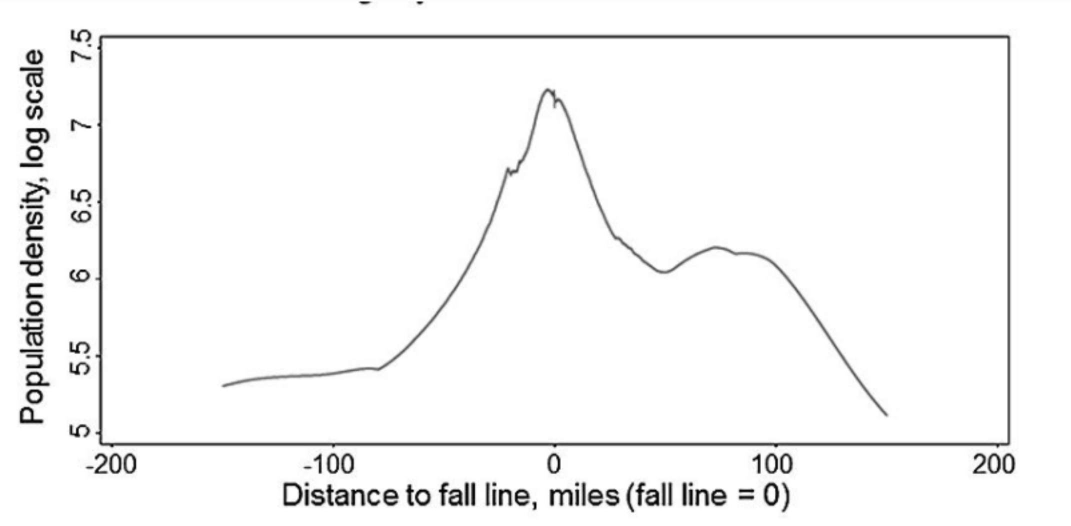
$$log(density_i) = \alpha Portage_i + \beta_1 River_i + \beta_2 FaultLine_i + X_i\theta + u_i$$

  where $Portage_i = River_i \times FaultLine_i$
- Proximity dummy: se $\leq$ 15 mi
- Data:
  - population density per *census tract*
  - nightlights intensity

Main results

Specifications:	(1) Basic	(2) Other spatial controls: State fixed effects	(3) Other spatial controls: Distance from various features
Explanatory variables:			
Panel A: Census Tracts, 2000, N = 21452			
Dummy for proximity	1.113	1.009	1.118
to portage site	(0.340)***	(0.321)***	(0.243)***
Distance to portage	–0.617	–0.653	–0.721
site, natural logs	(0.134)***	(0.128)***	(0.118)***
Panel B: Nighttime Lights, 1996–97, N = 65000			
Dummy for proximity	0.504	0.445	0.490
to portage site	(0.144)***	(0.127)***	(0.161)***
Distance to portage	–0.188	–0.159	–0.151
site, natural logs	(0.065)***	(0.065)**	(0.090)

Average density along rivers



Cities on Pre-Columbian Paths

Barsanetti

Journal of Urban Economics

2020

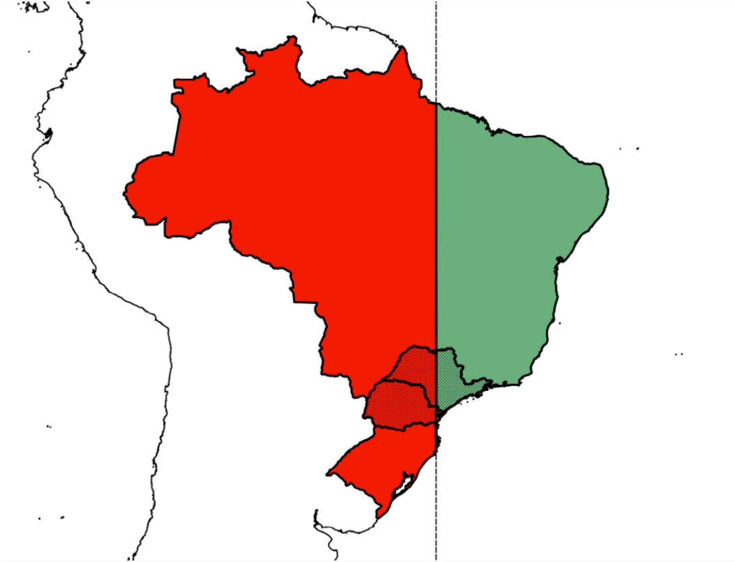
Motivation

- How strong is the influence of the distant past on city location?
- The settlement of the Americas is a great laboratory to think about it:
  1. most towns emerged only after the European arrival
  2. the European conquest changed the importance of geographic fundamentals: new technologies, population losses, overseas trade
- Reversal of Fortune? How did pre-colonial geography affect modern city location?
- Anedotal evidence for persistence (e.g. Mexico City)
- But two challenges:
  - **identification**
  - what was the spatial distribution of economic activity before 1500?

This paper

- City location around a pre-colonial path
  - Peabiru
  - used by both Portuguese and Spanish settlers
  - colonial towns were built along it: São Paulo, Ciudad Real del Guairá
- Natural experiment to identify the persistent effects of history (continuous settlement around the path):
  - abandonment of the Guairá by the spaniards after a bandeirante raid in 1628
  - western Paraná

Tordesillas Treaty



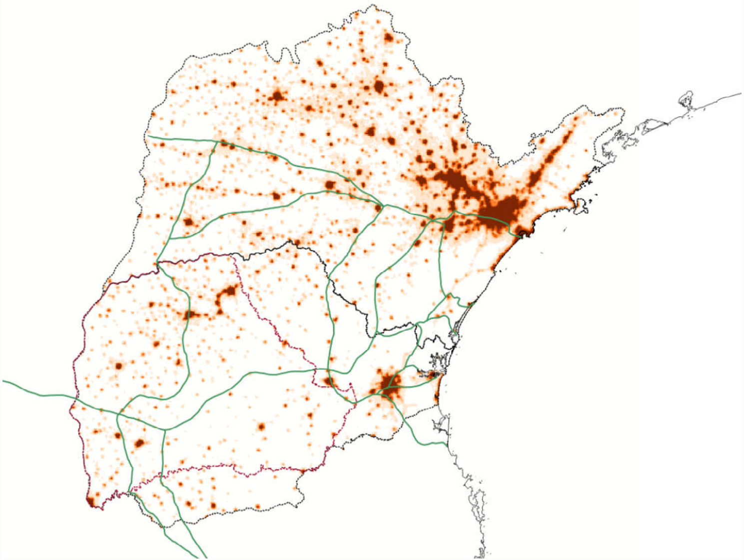
Peabiru


Tietê
São Paulo
São Paulo
Paranapanema
Ivaí
Tibagi
Paraná
Paraná
Curitiba
Iguazu

Data

- Peabiru: Reinhard Maack (1959)
- Guairá: natural borders (rivers)
- City location:
  - population density by setor censitário (2010)
  - rural or urban block
  - nightlights

Nightlights around the Peabiru



Empirical strategy

$$y_i = \beta Peabiru_i \times Portug_i + \beta^S Peabiru_i \times Spain_i + \alpha Spain_i + X_i'\theta + u_i$$

- Differences-in-differences: $\beta - \beta^S$
  - proximity to the Peabiru in the Spanish region: correlated geographic fundamentals
  - proximity to the Peabiru in the Portuguese region: correlated fundamentals + **effect of historical settlement**
- Identification assumption: correlation of Peabiru with fundamentals is the same in both regions

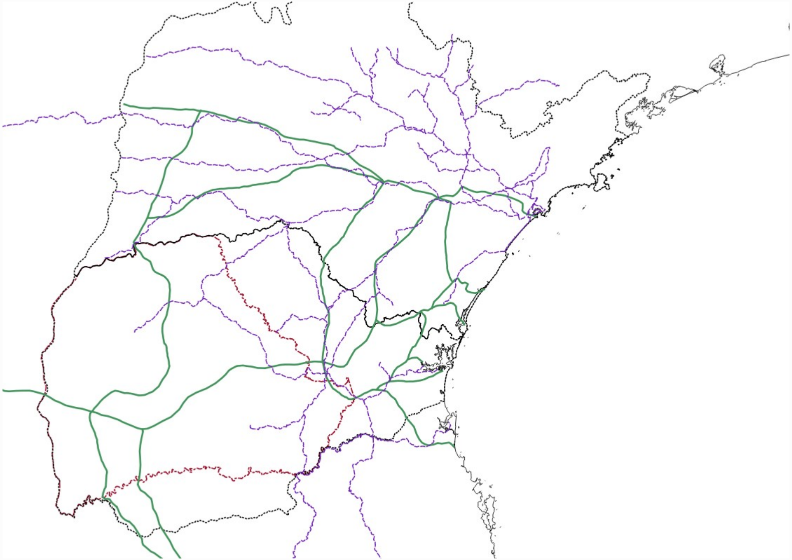
Main results

	Pop. Density (1)	IHS Pop. Density (2)	Urban Area (3)	Lights (4)	IHS Lights (5)	City (Lights $\geq$ 32) (6)
Panel A: no controls						
Dist. to Peabiru $\leq 10km$ $\times$ Portuguese	154.303*	0.396***	0.050***	3.424***	0.442***	0.045**
	(77.385)	(0.108)	(0.017)	(1.179)	(0.127)	(0.019)
Dist. to Peabiru $\leq 10km$ $\times$ Spanish	12.222	-0.202	0.007	0.046	-0.051	0.004
	(22.929)	(0.155)	(0.010)	(0.855)	(0.129)	(0.011)
Spanish	-111.524	0.256	-0.045*	-3.310**	-0.436**	-0.045*
	(89.525)	(0.197)	(0.024)	(1.536)	(0.191)	(0.023)
$\beta - \beta^S$	142.081	0.598	0.043	3.378	0.494	0.040
p-value $\beta = \beta^S$	0.083	0.003	0.030	0.024	0.008	0.070

Mechanisms

- Two main explanations:
  - Direct effect: towns that emerged during the colonial period
  - Indirect effect: through modern transportation infrastructures
    - railroads: older and less dense network
    - roads: newer and more dense network
- Evidence for both effects

Clear effects on railroads



but not so clear on roads

History versus expectations models

History versus expectations (HvE) models

- Self-reinforcing agglomerations lead to equilibrium indeterminacy
- QWERTY idea: history may select the equilibrium
- But how to formalize this idea?
  - “loose” connection
- Paradox: self-reinforcing processes may break the tie of history
  - theoretical foundations: frictions that make change costly
  - seminal papers: Krugman (1991), Matsuyama (1991)
  - capital as alternative anchor: Barsanetti (2024)

A “representative” HvE model

- Small open economy with a measure 1 of workers
- Discrete time: $t = 0, 1, 2, ...$
- Two sectors: A and M
  - γ_t: share of workers in M
- Revenue of labor in each sector: ϕ^A (constant) and $\phi^M(\gamma_t)$ (non-decreasing)
- In each t, each worker decides where to work. If moving to M, pay a one-time cost $\kappa > 0$
- Discount future at rate $\delta < 1$
- A fraction λ of workers die in each period and are replaced by new workers, who act as if they were in sector A

Law of Movement

- Each workers is in one of the conditions:
  - in $t-1$, was in A (or just born)
  - in $t-1$, was in M
- σ_t^A and σ_t^M: probability of working in M given the initial sector
  - note: $\sigma_t^A > 0 \Rightarrow \sigma_t^M = 1$
  - note: $\sigma_t^M < 1 \Rightarrow \sigma_t^A = 0$
- The share in M changes as:

$$\gamma_t = \gamma_{t-1}\left[\lambda\sigma_t^A + (1-\lambda)\sigma_t^M\right] + (1-\gamma_{t-1})\sigma_t^A$$

Payoffs and equilibrium

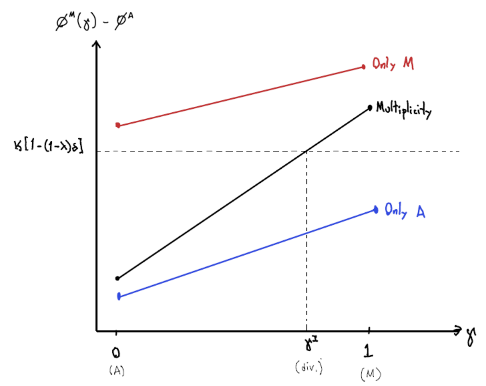
- We can define payoffs recursively as

$$U_t^A = max\left\{\phi^A + (1-\lambda)\delta U_{t+1}^A, \quad \phi^M(\gamma_t) + \delta(1-\lambda)U_{t+1}^M - \kappa\right\}$$
$$U_t^M = max\left\{\phi^A + (1-\lambda)\delta U_{t+1}^A, \quad \phi^M(\gamma_t) + \delta(1-\lambda)U_{t+1}^M\right\}$$

- We consider an initial condition γ_0: this is what history is!
- An equilibrium is a list $\left(\gamma_t, \sigma_t^A, \sigma_t^M, U_t^M, U_t^A\right)_{t=0}^{\infty}$
- A steady-state is an equilibrium where none of these variables depend on t

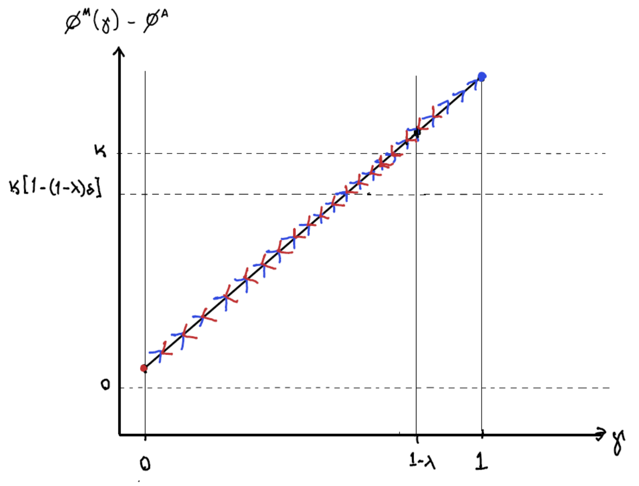
Steady-states

- There are three steady-states:
  1. A steady-state: $\gamma = 0$. It exists if $\kappa\left[1-\left(1-\lambda\right)\delta\right] \geq \phi^M(0) - \phi^A$
  2. M steady-state: $\gamma = 1$. It exists if $\kappa\left[1-\left(1-\lambda\right)\delta\right] \leq \phi^M(1) - \phi^A$
  3. Diversified steady-state. It exists if there are M and A steady-states.



The M steady-state may be anchored

- If $\phi^M(0) > \phi^A$ and $\phi^M(1-\lambda) - \phi^A > \kappa$, then for a sufficiently high γ_0, all equilibria converge to the M-steady-state



Natural amenities, neighbourhood dynamics, and persistence in the spatial distribution of income

Lee and Lin

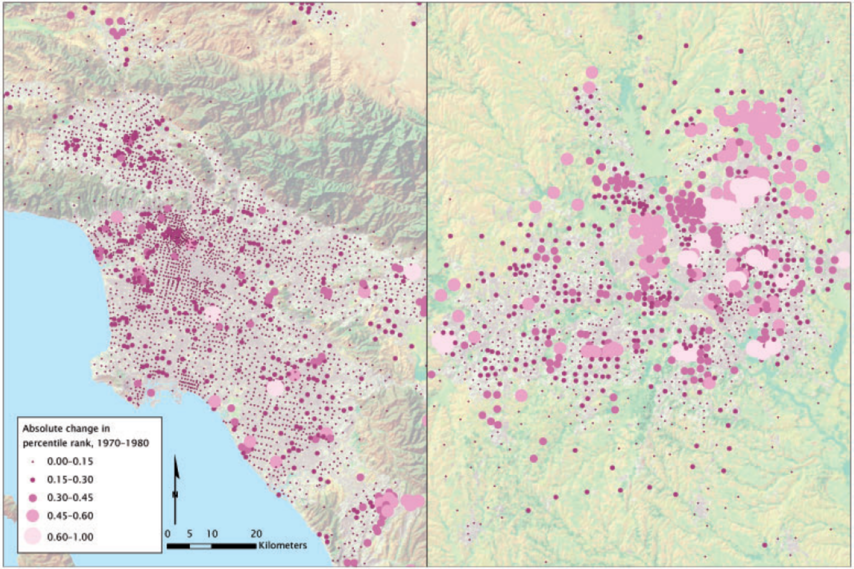
Review of Economic Studies

2018

What anchors economic geography?

- Geographic characteristics may induce uniqueness, but sometimes there is still multiplicity
- Does it mean that they do not matter for anchoring? No
- This paper: natural amenities + within-city income distribution

Two contrasting cases: LA and Dallas



Persistence of neighborhood income rankings

- Two neighborhoods, beach b and desert d, with amenities $\alpha_b > \alpha_d$
- Endogenous aggregate amenities follow

$$A_{j,t} = \alpha_j + E[\theta|j,t] + m_t + \epsilon_{j,t}$$

  - $E[\theta|j,t]$: average income of neighborhood (endogenous component)
  - m_t: aggregate city shock
  - ϵ_t: i.i.d. shock
- Closed city, workers sort into neighborhoods by income: high income half inhabits the higher aggregate amenity neighborhood
- Two equilibria:
  - S_d: high-income live in desert
  - S_b: high-income live in beach
- There may be multiple equilibria
  - assume that the equilibrium remains the same as last period if multiple

Transition probabilities

- The equilibrium changes when the shocks lead to a different unique equilibrium
- This leads to a Markov chain. It depends on S_d (S_b) no longer being an equilibrium:

$$Pr(S_b|S_d) = Pr(\alpha_d + \overline{\theta}_H + \epsilon_{d,t+1} < \alpha_b + \overline{\theta}_L + \epsilon_{b,t+1})$$
$$Pr(S_d|S_b) = Pr(\alpha_b + \overline{\theta}_H + \epsilon_{b,t+1} < \alpha_d + \overline{\theta}_L + \epsilon_{d,t+1})$$

- Since $\alpha_b > \alpha_d$, then $Pr(S_b|S_d) > Pr(S_d|S_b)$

Main prediction: amenities anchor neighborhood income ranking

- Two income percentiles: $r_L = 0.5$ and $r_H = 1$
- Conditional on initial income rankings:

$$E(\Delta r | j = b, r = r_L) = 0.5Pr(S_b|S_d) > 0.5Pr(S_d|S_b) = E(\Delta r | j = d, r = r_L)$$
$$E(\Delta r | j = b, r = r_H) = -0.5Pr(S_d|S_b) > -0.5Pr(S_b|S_d) = E(\Delta r | j = d, r = r_H)$$

- Empirical test: rank census tracts (1880-2010)
  - 1880–1920: occupational score; 1930, 1940: housing rents; 1950–.: income
- Test if $\beta_1 > 0$ in the equation:

$$\Delta r_{i,t} = \beta_0 + \beta_1 1(\alpha_i) + \beta_2 r_{i,t} + \delta_{m,t} + \epsilon_{i,t}$$

- Main amenity measure: < 500 m from waterfront

Coastal proximity anchors neighbourhoods to high incomes

	μ [σ]	(1)	(2)	(3)	(4)	(5) $r_{i,t} > 0.9$	(6) Names
1(Coast)^{a,b,c}	0.05	−0.004	0.013***	0.007*	0.014***	0.045***	0.031***
	[0.22]	(0.004)	(0.004)	(0.004)	(0.003)	(0.005)	(0.005)
Initial Percentile rank	0.50	−0.161***	−0.169***	−0.184***	−0.202***	−0.204***	−0.203***
by income ($r_{i,t}$)	[0.29]	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
Log distance to	5.02		0.028***		−0.004	−0.004*	−0.004*
nearest seaport^{d}	[4.83]		(0.004)		(0.002)	(0.002)	(0.002)
Log distance to	7.51			0.035***	−0.008***	−0.008***	−0.008***
city centre	[1.95]			(0.003)	(0.002)	(0.002)	(0.002)
Log population	9.74				−0.036***	−0.036***	−0.036***
density	[1.04]				(0.001)	(0.001)	(0.001)
Log average	3.00				−0.019***	−0.019***	−0.019***
house age	[0.53]				(0.004)	(0.004)	(0.004)
Metro–year f.e.		✓	✓	✓	✓	✓	✓
R^2		0.081	0.090	0.116	0.202	0.202	0.202
Neighbourhoods		298,776	298,776	297,518	281,321	281,321	281,321
Metro–years		1,357	1,357	1,313	1,263	1,263	1,263

Notes: Each numbered column displays estimates from a separate regression. Column titled "μ [σ]" shows sample means and standard deviations. Regressions use pooled observations of 60,872 consistent-boundary neighbourhoods over 10 census years, 1910–2000. Dependent variable is 10-year forward change in percentile rank by income ($\Delta r_{i,t}$); mean, 0, standard deviation, 0.16. All regressions include metropolitan area–year effects. Standard errors, clustered on metropolitan area–year, in parentheses; *p<0.10, ***p<0.01. [a]Neighbourhood centroid is within 500 m of an ocean, the Gulf of Mexico, or a Great Lake. [b]Explanatory variable in column (5) is neighbourhood centroid is within 500 m of an ocean, the Gulf of Mexico, or a Great Lake, *and* neighbourhood initial rank is in top income decile. [c]Explanatory variable in column (6) is neighbourhood centroid is within 500 m of an ocean, the Gulf of Mexico, or a Great Lake *and* neighbourhood name includes "beach", "coast", "bay", "cove", "lagoon", "ocean", or "shore." [d]Log distance to nearest seaport times metropolitan indicator for coastal proximity.

Using other amenity measures

Coast	Lakes	Rivers	Hills	Temp. & dry	Pr(flood) < 1%	Nat'l val. > p(95)
A. Indicator for natural feature						
−0.004	0.044**	0.004**	0.050**	−0.033**	−0.025**	0.013*
(0.004)	(0.006)	(0.002)	(0.004)	(0.013)	(0.003)	(0.005)
B. With controls for historical factors						
0.014**	0.031**	−0.003*	0.008*	0.015	−0.001	0.028**
(0.003)	(0.005)	(0.001)	(0.003)	(0.010)	(0.002)	(0.004)
C. Indicator for natural feature and $r_{i,t} > 0.9$[a]						
0.045***	0.057***	0.026***	0.034***	0.031***	0.042***	0.040***
(0.005)	(0.014)	(0.005)	(0.004)	(0.009)	(0.003)	(0.005)
D. Place names[b]						
0.031***	0.030**	−0.004	−0.005	0.025***	0.005*	0.019**
(0.005)	(0.007)	(0.003)	(0.003)	(0.007)	(0.002)	(0.005)
E. Sample means of natural amenity indicator, 1910–2000						
0.053	0.006	0.093	0.063	0.073	0.640	0.053

Taking stock

- There is now strong evidence for path dependence in economic geography
  - Lin and Rauch (2020) survey
- Unlike other persistence papers, there is very solid theory behind
- A bit less understood: the exact anchors connecting past and present
- Useful to go back to Cronon's first and second natures
- More recently, a class of quantitative models ignore multiplicity with strong first nature
  - Allen and Donaldson (2024): incorporate the mechanisms of HvE models