Core-Periphery Patterns

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The Core-Periphery Model

- Krugman (JPE 1991), “Increasing returns and economic geography”
  - foundational paper of New Economic Geography
  - we follow Fujita, Krugman and Venables (1999), ch. 5
- Core periphery patterns: concentration of activity in one region
  - about *symmetry breaking*
  - ideally, studied in a featureless space
  - trade-off between agglomeration and dispersion forces
  - agglomeration force: increasing returns in production
  - dispersion force: costly transportation

Setting

- Two sectors:
  - monopolistically competitive M
    - iceberg costs: $T > 1$ good ships $\rightarrow$ 1 good arrives
    - implicit assumption: CRS in transportation
  - perfectly competitive A
    - no transportation costs, numeraire
- Two factors:
  - mobile workers (in M), of mass L
    - increasing returns, Dixit-Stiglitz
  - immobile farmers (in A), of mass 1
    - constant returns, 1 farmer $\rightarrow$ 1 ag good
- Two regions: $r \in \{1, 2\}$
  - identical endowments of $\frac{1}{2}$ farmers

Wages and incomes

- w_r: nominal wages
- λ: share of workers in region $r = 1$
- Incomes are:

$$Y_1 = \frac{1}{2} + \lambda L w_1$$
$$Y_2 = \frac{1}{2} + \left(1 - \lambda\right) L w_1$$

Preferences over M

$$M_r = \left(\int_0^{n_r} m_r(i)^{\frac{\sigma-1}{\sigma}} di + \int_0^{n_{-r}} m_r(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$$

- n_r: number of varieties produced in region r
- $m_r(i)$ consumption in r of the variety i
- σ is the elasticity of substitution
  - $\sigma = 1$: isoelastic (Cobb-Douglas)
  - $\sigma \to 1$: perfect substitutes
  - $\sigma = 0$: perfect complementary (Leontief)
  - assume $\sigma > 1$

Demand for M

- Minimize expenditure holding M_r fixed
- $p(i)$ price of domestic good, $Tp(i)$ price of import
- The solution satisfies:

$$m_r(i) = \left(\frac{p(i)}{P_r}\right)^{-\sigma} M_r$$

$$P_r = \left(\int_0^{n_r} p(i)^{1-\sigma} di + T^{1-\sigma} \int_0^{n_{-r}} p(i)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$$

- add T to the price in first equation if an import

Price indexes – simplified

- In equilibrium, $p(i) = p_r$ for every variety produced in r
- This implies that the price indexes simplify as

$$P_1 = \left(n_1 p_1^{1-\sigma} + n_{-r} T^{1-\sigma} p_{-r}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

$$P_2 = \left(n_1 T^{1-\sigma} p_1^{1-\sigma} + n_2 p_2^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

Profit maximization condition

- M firms use labor to produce the final good
  - monopolistically behavior
  - marginal cost: w_r
  - fixed cost: Fw_r
- Firms choose prices to maximize profits:

$$p(i)^{1-\sigma}D(i) - w_r p(i)^{-\sigma}D(i) - w_r F$$

- Due to the constant elasticity assumption, price is a mark up of wages:

$$p(i) = p_r = \frac{\sigma}{\sigma - 1}w_r$$

Zero profit condition

- Let q be the production of the firm
- From the zero profit condition:

$$\begin{aligned} 0 &= \big(p(i) - w_r\big)q - w_r F \\ \Rightarrow q &= F(\sigma - 1) \end{aligned}$$

- Hence, each firm hires σF workers
- Note that firm size does not depend on wages, equal in both regions

Price indexes – further simplified

- Since firm employment is constant, the number of varieties are:

$$n_1 = \frac{\lambda L}{\sigma F}, \quad n_2 = \frac{(1-\lambda)L}{\sigma F}$$

- This implies that the price indexes further simplify as

$$P_1 = \frac{\sigma}{\sigma - 1}\left(\frac{L}{\sigma F}\right)^{\frac{1}{1-\sigma}}\left(\lambda w_1^{1-\sigma} + (1-\lambda)T^{1-\sigma}w_2^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$
$$P_2 = \frac{\sigma}{\sigma - 1}\left(\frac{L}{\sigma F}\right)^{\frac{1}{1-\sigma}}\left(\lambda T^{1-\sigma}w_1^{1-\sigma} + (1-\lambda)w_2^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

Real wages

- Isoelastic preferences between the goods
  - μ: expenditure share on M
- Real wages are thus:

$$\omega_r = w_r P_r^{-\mu}$$

Wage equation

- Connects wages to income and aggregate price levels
- Derived through the demand for goods. Since each firm produces $q = F(\sigma - 1)$,

$$F(\sigma - 1) = p_r^{-\sigma} \mu P_r^{\sigma-1} Y_r + p_r^{-\sigma} T^{1-\sigma} \mu P_{-r}^{\sigma-1} Y_{-r}$$

- Since prices are a markup of wages, $p_r = \left(\frac{\sigma}{\sigma-1}\right) w_r$, we have:

$$w_r = \frac{(\sigma - 1)^{\frac{\sigma-1}{\sigma}}}{\sigma} \left(\frac{\mu}{F}\right)^{\frac{1}{\sigma}} \left(P_r^{\sigma-1} Y_r + T^{1-\sigma} P_{-r}^{\sigma-1} Y_{-r}\right)^{\frac{1}{\sigma}}$$

CP equilibrium

- Instantaneous: 8 equations, 8 unknowns, λ fixed
- Income, price, (nominal) wage, and real wage equations

$$Y_1 = \frac{1}{2} + \lambda L w_1, \quad Y_2 = \frac{1}{2} + \big(1-\lambda\big) L w_1$$

$$P_1 = \kappa_p \left(\lambda w_1^{1-\sigma} + \big(1-\lambda\big) T^{1-\sigma} w_2^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \quad P_2 = \kappa_p \left(\lambda T^{1-\sigma} w_1^{1-\sigma} + \big(1-\lambda\big) w_2^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

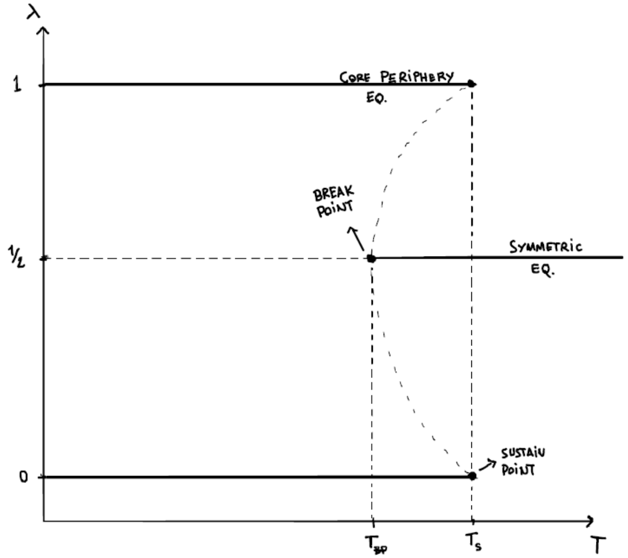
$$w_1 = \kappa_w \left(P_1^{\sigma-1} Y_1 + T^{1-\sigma} P_2^{\sigma-1} Y_2 \right)^{\frac{1}{\sigma}}, \quad w_1 = \kappa_w \left(T^{1-\sigma} P_1^{\sigma-1} Y_1 + P_2^{\sigma-1} Y_2 \right)^{\frac{1}{\sigma}}$$

$$\omega_1 = w_1 P_1^{-\mu}, \quad \omega_2 = w_2 P_2^{-\mu}$$

- Assumption on dynamics (we focus on stable equilibria):

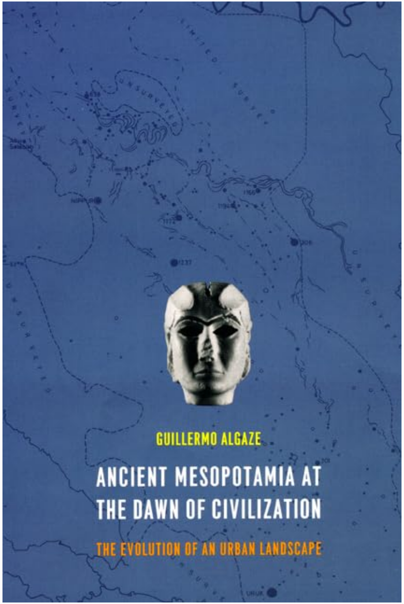
$$\dot{\lambda} \propto \omega_1 - \omega_2$$

CP bifurcation: low transportation costs break symmetry



Historical evidence for the CP model

- Sumerian takeoff in the Uruk period (4000-3100 BC)
- Symmetry: similar settlement sizes across Mesopotamia
- Growth of Sumer, especially Uruk, and decline of other regions
- Lower trade costs: domestication of donkey
- Trade of manufacturing from Sumer



The dawn of civilization: Metal trade and the rise of hierarchy

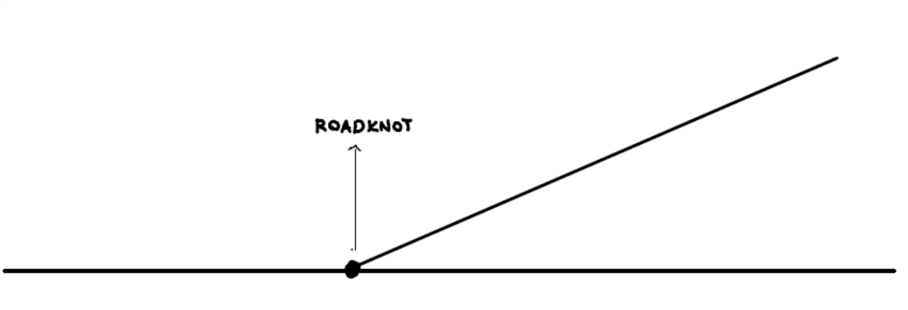
Fluckiger, Larch, Ludwig, Pascali

working paper

2024

Urban revolution

- Urban revolution: explosion of cities, trade, states, hierarchies
- In Eurasia, it occurred during the Bronze Age (3,300-1,200 BC)
- What is the role of trade? Hypothesis: road knots (Ramsay 1890)
- Similar argument as in Fujita and Mori (JDE 1996)



This paper

- Idea: use the location of copper and tin mine to find these road knots
- Combine several georeferenced datasets
- Identification: use deposits to build an IV, show lack of pre-trends in panel
- Main finding: grid cells near road knots more likely to concentrate cities and arch. sites in the Bronze Age
- Suggest a political economy mechanism: ability to tax merchants

Data and sample

- Sample: Old World, 1×1 degree grid
- Main outcome variables:
  1. presence of any pre-1300 cities: > 10 k inhabitants, from Reba et al (2016) and HYDE 3.1
  2. archaeological sites: Atlas of World Archaeology (Bahn 2000) and Pleiades
- Other important data sources:
  - cropland in different historical periods (Klein et al 2010)
  - land productivity: net primary production (NPP, amount of biomass supported by geoclimate)
  - based on arch. data, location of Bronze Age copper and tin mines
  - location of mineral deposits (US Geological Survey)

Identifying road knots

- Step 1: find transport costs for the Bronze Age period
  - use archaeological artifacts to measure trade flows
  - split grids according to being land, river, or sea, and assume transport costs $\alpha = (\alpha_s, \alpha_r, \alpha_l)$
  - for each α, estimate a gravity equation by Poisson pseudo-maximum likelihood:

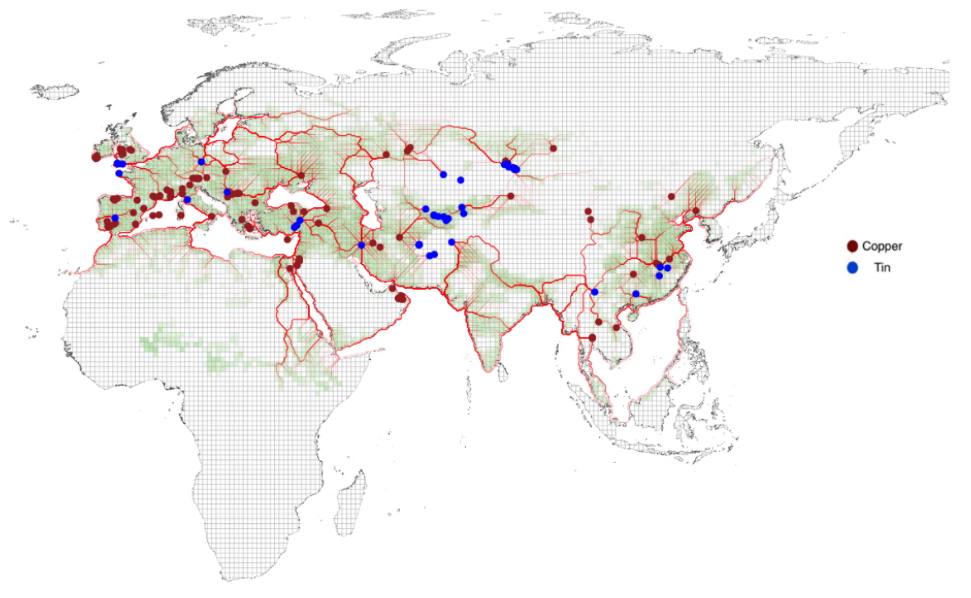
$$x_{od} = e^{\delta logLC_{od}(\alpha)+\beta_o+\beta_d+\epsilon_{od}}$$

    where $logLC_{od}$ is the least-cost between grids o and d
  - choose α that maximizes the log-likelihood

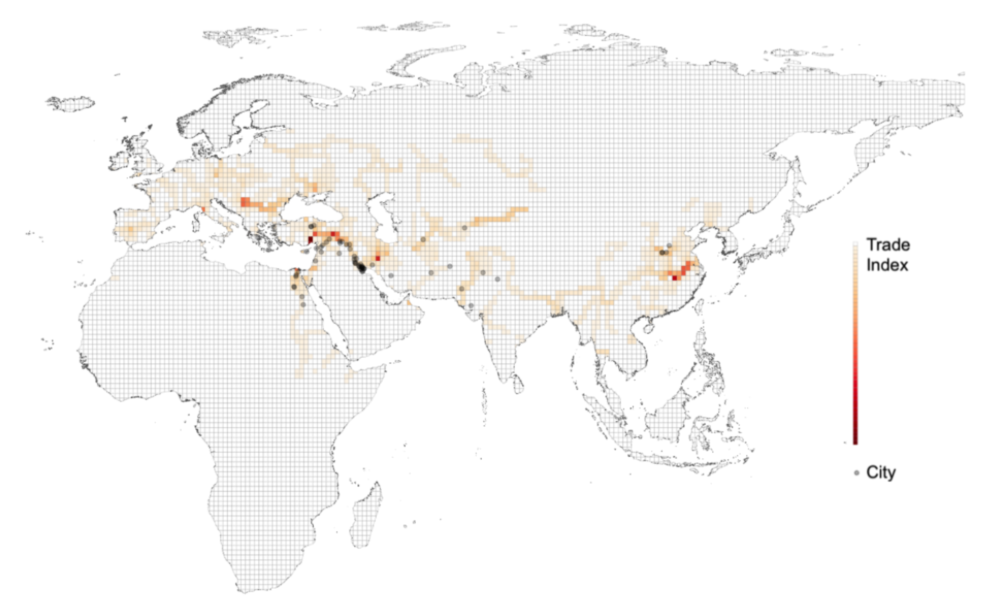
$$\hat{\alpha} = (1, 2, 6)$$

- Step 2: calculate LCPs between each mine and cropland grid up to 10,000 km (by sea) away
- Step 3: find weighted (by cropland area) sum of LCPs crossing the cell
- Use NPP and deposits in steps 2–3 to construct an IV

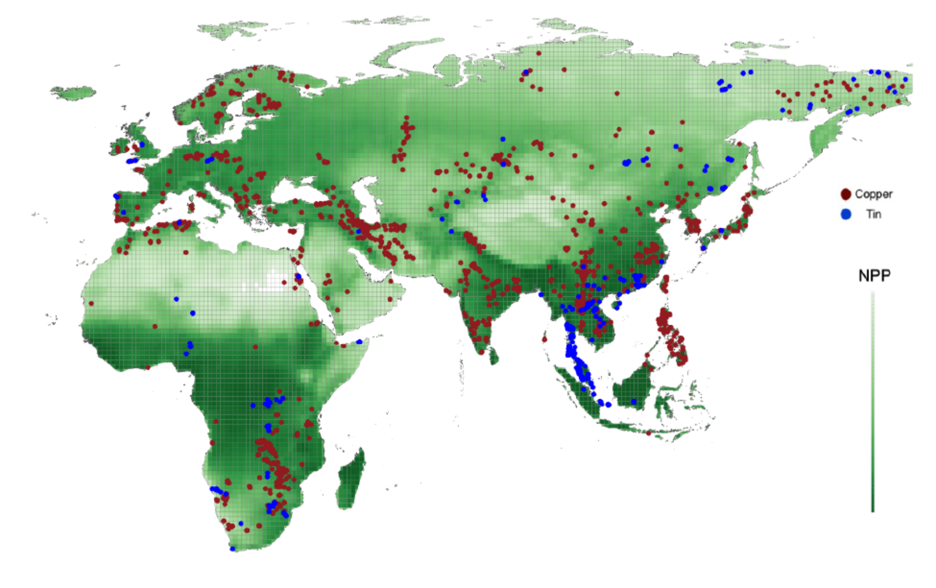
Least cost paths between mines and cropland



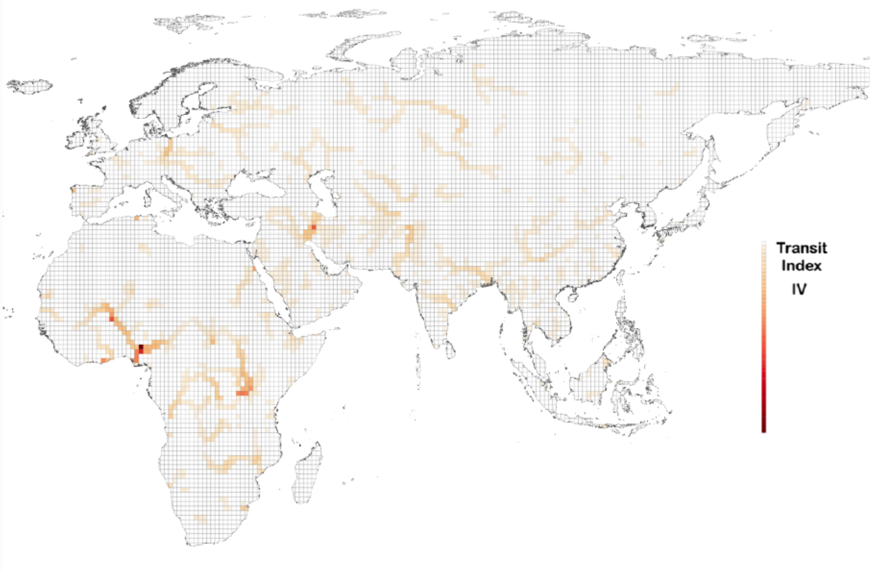
Roadknots and Bronze Age Cities



Instrumental variable construction



Instrumental variable distribution



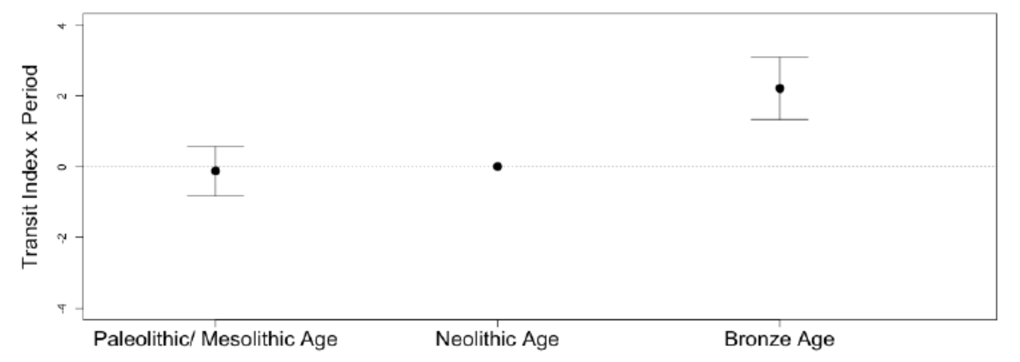
Empirical Strategy

- Cross-section: compare presence of cities with road knots
  - why could the OLS be biased?
  - use the IV to rely only on physical variation
- Panel: archaeological sites by period
  - sample period: Paleolithic, Neolithic, Bronze Age
  - interact road knots with the Bronze Age
  - IV: also interacted
  - allows cell (and time) fixed effects
  - event study estimates: evaluate pre-trends

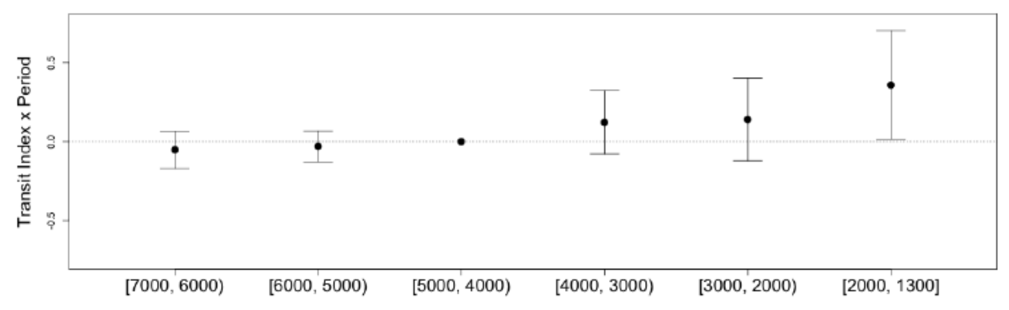
Cross-sectional results

	Any City by 1300 BC (×100)							IHS #Cities
	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	**Panel A: Second stage**						
Transit index	0.379	0.437	0.440	0.406	0.397	0.411	0.403	0.005
	(0.090)***	(0.137)***	(0.157)***	(0.143)***	(0.123)***	(0.132)***	(0.148)***	(0.002)**
	[0.141]***	[0.203]**	[0.225]*	[0.204]**	[0.176]**	[0.191]**	[0.203]**	[0.003]*
Proximity mines			-0.009				-1.178	-0.014
			(0.077)				(0.484)**	(0.007)**
			[0.095]				[0.691]*	[0.010]
Proximity croplands				0.118			1.510	0.018
				(0.070)*			(0.553)***	(0.008)**
				[0.096]			[0.810]*	[0.011]
Sea					0.220		0.222	0.002
					(0.183)		(0.176)	(0.002)
					[0.184]		[0.179]	[0.002]
River					0.285		0.189	0.004
					(0.289)		(0.292)	(0.003)
					[0.377]		[0.346]	[0.004]
Mountains					-0.377		-0.405	-0.005
					(0.190)**		(0.260)	(0.003)
					[0.246]		[0.351]	[0.004]
Centrality						-0.045	-0.045	-0.001
						(0.026)*	(0.026)*	(0.000)
						[0.037]	[0.035]	[0.000]
		Panel B: First stage						
IV Transit index		0.714	0.616	0.648	0.623	0.689	0.518	0.518
		(0.047)***	(0.045)***	(0.046)***	(0.049)***	(0.048)***	(0.048)***	(0.048)***
		[0.073]***	[0.069]***	[0.070]***	[0.074]***	[0.074]***	[0.072]***	[0.072]***
Continent fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area grid cell	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,970	10,970	10,970	10,970	10,970	10,970	10,970	10,970
Mean dependent variable	0.419	0.419	0.419	0.419	0.419	0.419	0.419	0.004
First-stage F-stat (5×5 grids)		228.2	186.1	198.8	159	205.9	115.6	115.6
First-stage F-stat (Conley 1000km)		94.31	79.31	84.67	70.40	86.39	51.60	51.60

Panel results: Archaeological Atlas



Panel results: Pleiades data



- Note: it is not the Uruk expansion!
- Illustrative example: Assur

Taking stock

- Economic geography is very spiked!
  - unlike physical geography, which is not so much
  - hence, there must be some break of symmetry
- The core-periphery explains well how this occurs
  - very deep model, mechanisms are nuanced
  - reinforcing patterns which depend on increasing returns to scale
  - trade costs play a crucial role here
- There is great historical evidence supporting it
  - but we still lack more tightly connected econometric evidence
  - but it is a hard problem, due to identification and data