Trade and the End of Antiquity

A Quantitative Investigation of the Pirenne Thesis

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What caused the End of Antiquity?

- Antiquity: Roman and Greek civilizations centered around the Mediterranean
- End of antiquity circa 7th-8th Century AD:
  - Economic activity shifts away from the Mediterranean.
  - Rise of Northern Europe (Charlemagne).

$\hookrightarrow$ *Question*: What caused the End of Antiquity?

- Discussed, among others, by Montesquieu (1734), Voltaire (1756), Gibbon (1789)

Pirenne Hypothesis

Henri Pirenne (1937), *“Mahomet et Charlemagne”*

- Rise of the Islamic Caliphate disrupts Mediterranean trade/exchanges.
- Causes a shift of economic activity away from the Mediterranean.
- Rise of the Carolingian Empire in Northern Europe.

Political changes in the Mediterranean: 600 AD

Political changes in the Mediterranean: 600 AD

Political changes in the Mediterranean: 600 AD

Political changes in the Mediterranean: 600 AD

Political changes in the Mediterranean: 632 AD

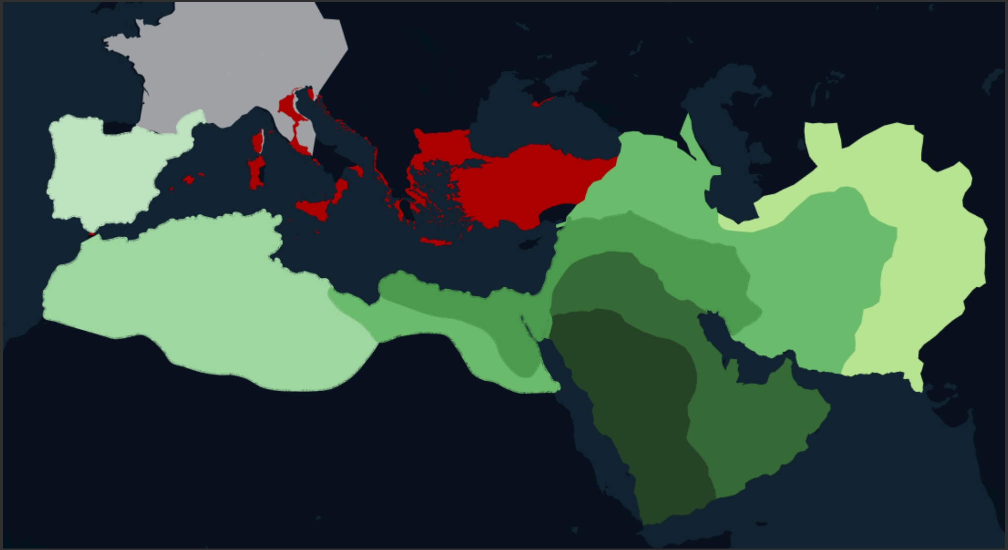
Political changes in the Mediterranean: 634 AD

Political changes in the Mediterranean: 644 AD

Political changes in the Mediterranean: 661 AD

Political changes in the Mediterranean: 661-700 AD

Political changes in the Mediterranean: 750 AD



This paper

We use data on the movement of coins to study the changing economic geography during Late Antiquity.

- Coins are the main medium of exchange during Late Antiquity, particularly for long-distance trade $\rightarrow$ informative about trade
- Coins are well studied & documented by historians and numismatists
- Coins have features that help solve econometric identification problems

Roadmap:

1. Data description
2. Stylized facts / reduced-form evidence
3. Quantitative Model
    - Identification of trade shares from coin stocks
    - Identification of trade cost changes from origin/destination "sizes"
4. (Preliminary) quantitative counterfactuals to investigate the economic relevance of trade cost changes in the Mediterranean ($\rightarrow$ Pirenne)

Outline

Data

Reduced form evidence

Model

Parameterization and Estimation

Data: Coins around the Mediterranean, AD 325 to AD 950

Assemble a large dataset of coin finds from around the Mediterranean

1. FLAME (2023) project:
   - "Framing the Late Antique and Early Medieval Economy."
   - Collaboration of >60 historians and numismatists.
   - $\sim$200,000 coins with complete records from $\sim$4,600 hoards
   - Pre AD 725.
2. Hand-coded records from numismatic / archaeological literature:
   - 797 coin finds.
   - 100,478 coins.
   - post AD 725.

Data covers most of published literature on hoard records (and more)

Coin hoard data: an example from al 'Ush (1972)

No.	MINT	DATE	DIAM.	WEIGHT	NUMB.
51	الأندلس	114	29.	2.93	4
52	"	115	29.5	2.92	1
53	"	116	26.5	2.92	3

Excerpt of an original publication on the Damascus silver hoard:

- record number (51)
- mint (al-Andalus) *
- mint date (year 114 of the Hijri calendar) *
- diameter (29mm)
- weight (2.93g)
- number of coins with these attributes (4) *

The issuing dynasty (Umayyad) is given in the table headings and the denomination and material (silver *dirham*) is stated in the text. * denotes required attributes

Coin dataset

- Each coin provides the following information:
    1. Mint location ("birthplace"): m
    2. Mint date ("birthdate"): τ
    3. Hoard location ("death place"): h
    4. Terminus post quem, *tpq* ("death date"): $T = \sup \tau$

Coin dataset

- Each coin provides the following information:
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  3. Hoard location ("death place"): h
  4. Terminus post quem, *tpq* ("death date"): $T = \sup \tau$
- 286,035 coins.
- Time:
  - Mint date > AD 325
  - *tpq* < AD 950.
- Space:
  - Western Europe.
  - Southern Europe.
  - Northern Africa.
  - Middle East++.

Spatial distribution: the (extended) Mediterranean

Figure 1: Region Definitions

Distribution of coin “death dates” (*tpq*)

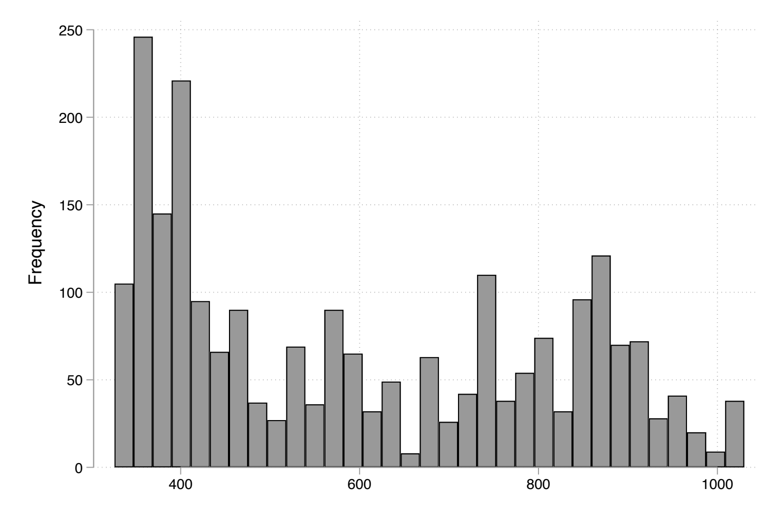

Figure 2: Terminus Post Quem (*tpq*) of hoards

Distribution of coin ages (*tpq* minus mint date)

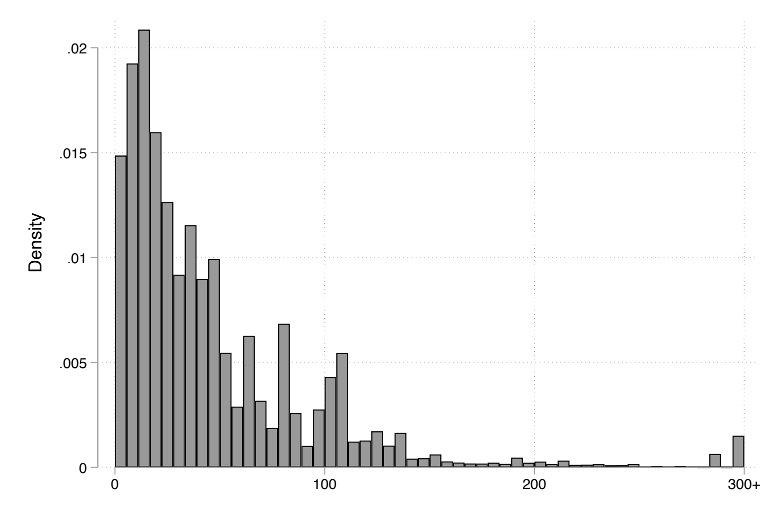

Figure 3: Coin age at time of deposit (*tpq*), in years

Outline

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Stylized facts

We document 3 main stylized facts:

1. Older coins travel further.
2. Distance *and* politics impede coin travels (gravity).
3. The Arab conquest disrupts Mediterranean crossings.

Fact #1: within a hoard, older coins have travel farther

Table 1: Within-hoard distance travelled and age of coin at deposit

	Dependent variable: Log Distance between Mint and Hoard				
	(1)	(2)	(3)	(4)	(5)
Log Age of Coin	0.163**	0.0981**	0.0912**	0.183**	0.0650**
	(0.051)	(0.026)	(0.031)	(0.050)	(0.021)
Sample				No non-hoards	No non-hoards
Hoard FE	Yes	Yes	Yes	Yes	Yes
Mint $\times$ 50-year-interval FE		Yes			
Mint $\times$ 25-year-interval FE			Yes		Yes
R^2	0.766	0.865	0.871	0.782	0.901
Observations	282466	282248	282085	245364	245040

Standard errors in parentheses, clustered at the hoard level.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Age of coin $= tpq -$ mint date

$\Rightarrow$ coins diffuse across space over time.

Fact #2: distance and political borders impede coin travels

Construct $1^\circ \times 1^\circ$ cells for mint and hoard locations and calculate flows count_{mdh}

Table 2: Gravity and Border Effects in Coin Flows

	Dependent variable: # Coins_{mdh}					
	(1)	(2)	(3)	(4)	(5)	(6)
Log Distance	-1.138**	-0.984**	-0.740**	-0.707**	-1.139**	-0.955**
	(0.12)	(0.13)	(0.10)	(0.10)	(0.10)	(0.077)
Within border dummy		2.444**		1.605**		2.074**
		(0.37)		(0.42)		(0.47)
Hoard Cell FE	Yes	Yes	Yes	Yes	Yes	Yes
Mint $\times$ Empire Cell FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample			Int. Marg. only	Int. Marg. only	Gold only	Gold only
Estimator	PPML	PPML	PPML	PPML	PPML	PPML
R^2						
Observations	215461	215461	6223	6223	57457	57457

Standard errors in parentheses, clustered at mint cell $\times$ empire and hoard cell level.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Estimating eqn: $\text{count}_{mdh} = \exp\left(\gamma_1 \log \text{distance}_{mh} + \gamma_2 \text{withinBorder}_{dh} + \alpha_{md} + \alpha_h + \varepsilon_{mhd}\right)$

Fact #3: Arab conquests disrupt Mediterranean trade

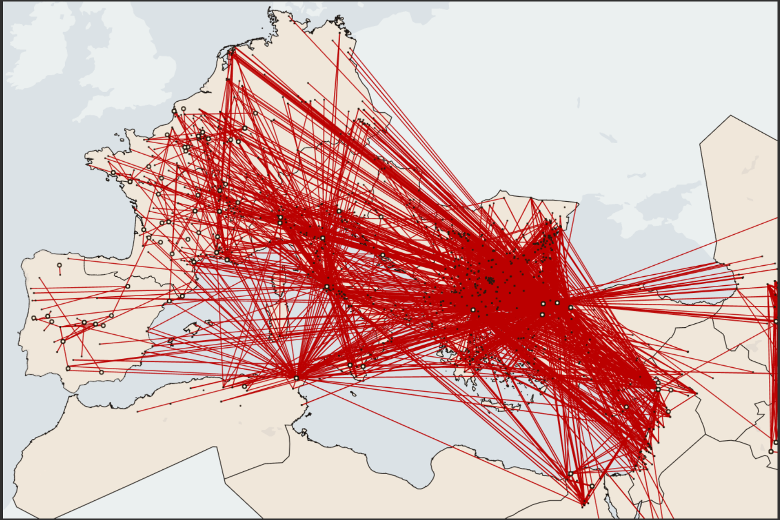

Figure 4: Before the Arab conquests: 450-630 AD

Fact #3: Arab conquests disrupt Mediterranean trade

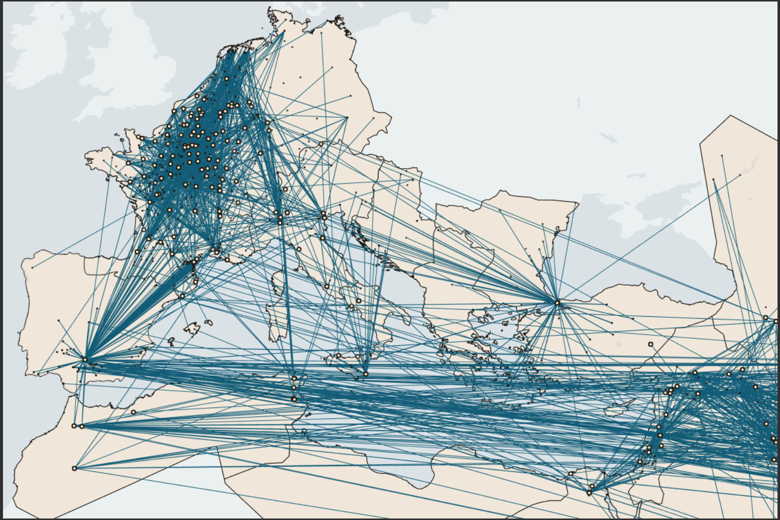

Figure 5: After the Arab conquests: 713-900 AD

Fact #3: Arab conquests disrupt Mediterranean trade

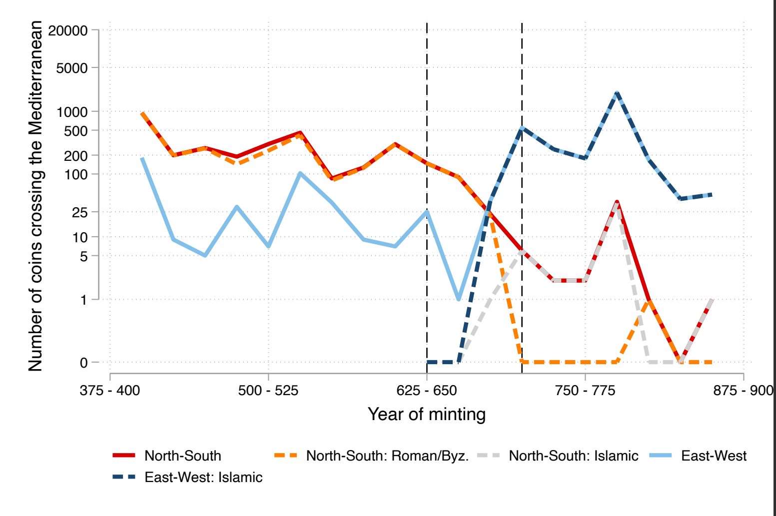

Figure 6: Number of coins flowing across the Mediterranean

Fact #3: Arab conquests disrupt Mediterranean trade

Table 3: The Mediterranean Before and After the Arab Conquest

	Dependent variable: Number of Coins			
	(1)	(2)	(3)	(4)
Crossing Mediterranean × After Conquests	-1.837**	-3.203**	-0.768	-1.780
	(0.46)	(0.54)	(0.66)	(1.27)
Crossing Mediterranean × After Conquests × Islamic Coin		7.114**	4.745**	8.496**
		(0.91)	(0.98)	(1.17)
Crossing Mediterranean × After Conquests × Roman Coin			-3.114**	-3.012**
			(0.79)	(0.71)
Mint Cell × Empire FE	Yes	Yes	Yes	Yes
Mint Cell × Hoard Cell FE	Yes	Yes	Yes	Yes
After Conquests FE	Yes	Yes	Yes	
Mint Cell × After Conquests FE				Yes
Hoard Cell × After Conquests FE				Yes
Estimator	PPML	PPML	PPML	PPML
Observations	10188	10188	10188	5880

Standard errors in parentheses, clustered at the hoard × era and mint × era level.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Estimating eqn: $\text{count}_{mdht} = \exp\left(\gamma_1 \text{mediterranean}_{mh} \times \text{after}_t + \cdots + \alpha_{md} + \alpha_{mh} + \varepsilon_{mhdt}\right)$

▸ Gold

Outline

Data

Reduced form evidence

Model

Parameterization and Estimation

Model ingredients

- Coins-in-advance economy
- Minting: coin birth
- Ricardian model of trade.
  (Eaton and Kortum, 2002)
- Coins-in-advance economy.
- Endogenous trade imbalances
  (Dekle, Eaton and Kortum, 2007)

Setup

Location n, period t: homog. mass $L_n(t)$ of workers. Four sub-periods $t_{sub1}, t_{sub2}, t_{sub3}, t_{sub4}$

t_{sub1} Start with $S_n(t)$ coins saved from period $t-1$

t_{sub2} A fraction $\lambda_n(t)$ of those saved coins is lost

$M_n(t) \geq 0$ fresh new coins are minted

t_{sub3} $X_n(t)$, expenditure on consumption

Budget constraint:

$$X_n(t) \leq (1-\lambda_n(t))\, S_n(t) + M_n(t)$$

t_{sub4} $L_n(t)$ workers produce and sell goods in exchange for coins

$w_n(t)$, competitive wage, $w_n(t)\, L_n(t)$, aggregate labor income

$S_n(t+1)$ coins saved for $t+1$

$$\underbrace{(1-\lambda_n(t))\,\overbrace{S_n(t)}^{t_{sub1}} + M_n(t)}_{t_{sub2}} - \underbrace{X_n(t)}_{t_{sub3}} + \underbrace{w_n(t)\, L_n(t)}_{t_{sub4}} = \underbrace{S_n(t+1)}_{(t+1)_{sub1}}$$

Intra-temporal allocations

- Fraction π_{ni} of expenditure X_n allocated to goods from i:

$$\pi_{ni}(t) = \frac{T_i(t)\left(w_i(t)\, d_{ni}(t)\right)^{-\theta}}{\sum_k T_k(t)\left(w_k(t)\, d_{nk}(t)\right)^{-\theta}}, \tag{1}$$

as in Eaton and Kortum (2002).

Intertemporal preferences

- Intertemporal utility U_n, within period welfare W_n, ,

$$U_n(t) = \mathbb{E}\left[\sum_{\tau \geq t} \beta^{\tau - t} \ln\left(\frac{X_n(t)}{p_n(t)}\right)\right],$$

$$\text{with } p_n(t) = \gamma\left(\sum_k T_k(t)\left(w_k(t)\, d_{nk}(t)\right)^{-\theta}\right)^{1/\theta}$$

Dynamic optimization

- Optimal coin savings dynamics,

$$\max_{\{S_n(\tau)\}_{\tau\geq t}} \left[\sum_{\tau\geq t} \beta^{\tau-t} \ln\left(\frac{X_n(\tau)}{p_n(\tau)}\right)\right]$$

$$X_n(\tau) = w_n(\tau) L_n(\tau) + M_n(\tau) + (1-\lambda_n(\tau)) S_n(\tau) - S_n(\tau+1),$$

$$S_n(\tau+1) \geq w_n(\tau) L_n(\tau), \forall \tau \geq t,$$

$$\lim_{\tau\to\infty} \beta^{\tau} S_n(\tau+1)/X_n(\tau) = 0$$

- Dynamic equilibrium wages clear markets,

$$w_i' L_i' = \sum_n \pi_{ni}(\mathbf{T}, \mathbf{d}; \mathbf{w}) \left[w_n L_n + M_n + (1-\lambda_n) S_n - S_n'\right]$$

Savings $S_n(\mathbf{T}, \mathbf{d}, \boldsymbol{\delta}, \mathbf{L}, \mathbf{M}; \mathbf{w})$ depend on parameters and wages, which depend on wages etc.

Optimal consumption/saving

Under log utility:

- price level $p_n(t)$ dynamics irrelevant (i.e. separates out)
- when unconstrained, consumption declines exponentially:

$$\frac{X_n(t+1)}{X_n(t)} = \beta(1-\lambda_n(t)) < 1$$

- when constrained, consume as much as you can:

$$S_n' = w_n(t)L_n$$

Define *net* saving:

$$s_n(t) = \frac{(1-\lambda_n(t))S_n(t) + M_n(t) - X_n(t)}{(1-\lambda_n(t))S_n(t) + M_n(t)}$$

Steady state: zero net savings, $S_n(t+1) = S_n(t), \forall t$

- No motive for extra savings, $S_n = w_n L_n$. Hence $s_n(t) = 0$.
- Wages and trade shares jointly determined,

$$w_i L_i = \sum_n \pi_{ni} \left((1 - \lambda_n) w_n L_n + M_n \right)$$

$$\pi_{ni} = \frac{T_i \left(w_i d_{ni} \right)^{-\theta}}{\sum_k T_k \left(w_k d_{nk} \right)^{-\theta}}$$

- Constant aggregate stock of coins in circulation,

$$\sum_n M_n = \lambda_n \sum_n w_n L_n$$

- *Note*: trade deficits as in Dekle, Eaton and Kortum (2007),

$$D_n = X_n - Y_n = M_n - \lambda_n S_n$$

Introducing and tracking coins of different vintages

Coin stocks $S_n(\tau)$ consist of coins of different vintage:

$$S_n(\tau) = \sum_{m=1}^{N} \sum_{t<\tau} S_{mn}(t,\tau)$$

Coins start their life when minted: $S_{mm}(t,t) = M_m(t)$.

Traders are ‘blind’ to coin types, draw coins with equal probability:

$$S_{mi}(t,\tau+1) = \sum_{n=1}^{N} (1-\lambda_n(\tau))(1-s_n(\tau)) S_{mn}(t,\tau)\pi_{ni}(\tau) + (1-\lambda_i(\tau)) s_i(\tau) S_{mi}(t,\tau), \forall \tau \geq t$$

In compact matrix form:

$$\mathsf{S}(t,T) = \boldsymbol{M}(t)\left(\prod_{\tau=t}^{T-1} (\boldsymbol{I} - \boldsymbol{\lambda}(\tau))\Big((\boldsymbol{I} - \boldsymbol{s}(\tau))\boldsymbol{\Pi}(\tau) + \boldsymbol{s}(\tau)\Big)\right)$$

Pitfall #1: medium of exchange vs store of value

- Dynamics with 'saving-augmented' trade shares,

$$\mathsf{S}(t,T) = \boldsymbol{M}(t)\left(\prod_{\tau=t}^{T-1}\Big(\boldsymbol{I}-\boldsymbol{\lambda}(\tau)\Big)\tilde{\boldsymbol{\Pi}}(\tau)\right)$$

- Separate origin, destination, and bilateral terms,

$$\tilde{\pi}_{ni}(\tau) = \alpha_n(\tau)\,\beta_i(\tau)\,\delta_{ni}(\tau)$$

$$\alpha_n = \frac{1}{\sum_k T_k\left(w_k d_{nk}\right)^{-\theta}},\ \beta_i = T_i\left(w_i\right)^{-\theta}$$

$$\delta_{ni} = \left(d_{ni}\right)^{-\theta}$$

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$$\tilde{\pi}_{ni}(\tau) = \alpha_n(\tau)\,\beta_i(\tau)\,\delta_{ni}(\tau)$$

$$\alpha_n = \frac{1}{\sum_k T_k\,(w_k d_{nk})^{-\theta}},\ \beta_i = T_i\,(w_i)^{-\theta}$$

$$\delta_{ni} = (d_{ni})^{-\theta} \times \begin{cases}(1-s_n) & \text{if } n \neq i\\ (1-s_n) + \dfrac{s_n\sum_k T_k\,(w_k d_{nk})^{-\theta}}{T_n\,(w_n d_{nn})^{-\theta}} & \text{if } n = i.\end{cases}$$

- $\frac{\delta_{nj}}{\delta_{ni}} = \frac{(d_{nj})^{-\theta}}{(d_{ni})^{-\theta}}, \forall n \neq i, j, \forall s_n \geq 0$: no impact on external trade
- $\frac{\delta_{nn}}{\delta_{ni}} > \frac{(d_{nn})^{-\theta}}{(d_{ni})^{-\theta}}, \forall s_n > 0$: net saving mimics home bias in trade!

Pitfall #2: stocks vs flows (steady state math)

- SS: no net saving ($\mathbf{s} = 0$), only age (a) matters, not time (t),

$$\mathsf{S}(t, t+a) = \mathsf{S}(a) = \boldsymbol{M}\Big((\boldsymbol{I} - \boldsymbol{\lambda})\,\boldsymbol{\Pi}\Big)^{a}, \forall t$$

- Sum of different vintages (stocks by origin-destination),

$$\sum_{a=0}^{A} \mathsf{S}(a) = \boldsymbol{M}\left(\sum_{a=0}^{A}\Big((\boldsymbol{I} - \boldsymbol{\lambda})\,\boldsymbol{\Pi}\Big)^{a}\right) \underset{A \to +\infty}{=} \boldsymbol{M}\left(\boldsymbol{I} - (\boldsymbol{I} - \boldsymbol{\lambda})\,\boldsymbol{\Pi}\right)^{-1}$$

- Naive gravity on stocks gives Leontief inverse of trade shares!
  $\Rightarrow$ inconsistent estimates of trade elasticities/border effects due to model misspecification

Outline

Data generating process

- In n at t, a fraction $\eta_n(t)$ of the coins in circulation $S_n(t)$ is lost and subsequently found by archaeologists

  Assumption: η small enough, does not affect model choices.

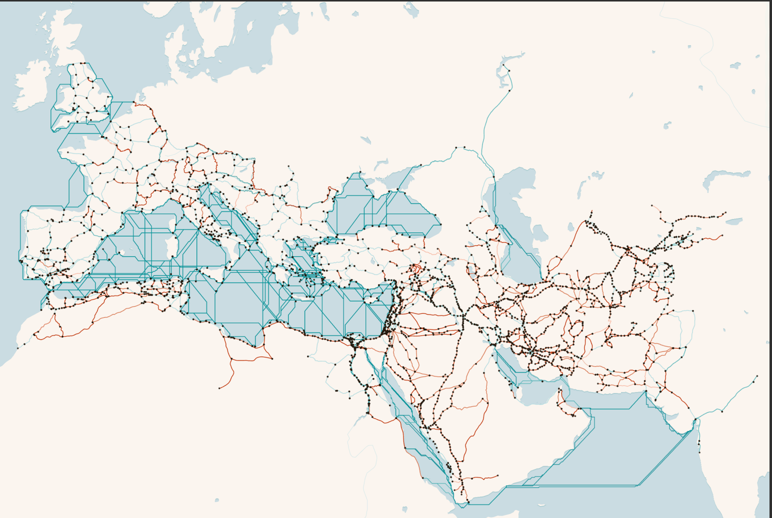
  $\Rightarrow$ For coin shares within a hoard, the η's cancel out. $\eta_n(t)$ not used in our identification!

Taking the model to the data

- 21 regions around the Mediterranean ▸ details
- 20-year time intervals
- Assume constant λ and estimate as exponential decay parameter in within-hoard age distribution:
$$\hat{\lambda}_{20y} = 0.3$$
- Parameterize trade frictions,
$$d_{ni}(t)^{\theta} = \exp\left(\beta_0 + \beta_1 \ln\left(\text{TravelTime}_{ni}\right) + \beta_3 \text{PoliticalBorder}_{ni}(t) + \beta_4 \text{ReligiousBorder}_{ni}(t)\right)$$
- Assume (for now) that we're in steady state for savings: $s_n(t) = 0$.
- For counterfactuals, assume $\theta = 4$ (Simonovska and Waugh, 2014).

▸ Unsolved problems (as of yet)

Trade costs *only* depend on travel times (and politics/religion)



Note: Combined geospatial models from Orbis (Scheidel, 2015) and al-Ṯurayyā (Romanov and Seydi, 2022). ▸ al-Maqdisi

Maximum likelihood estimation

Assume coins in our data are a random sample of coin types in each location $\times$ time.

- Multinomial distribution of coin types,

$$P\left(\cdots, X_i^{(m,\tau)}(T) = x_i^{(m,\tau)}, \ldots\right) = \frac{N_i(T)!}{\prod_{(m,\tau)} x_i^{(m,\tau)}!} \prod_{(m,\tau)} \left[p_i^{(m,\tau)}(T)\right]^{x_i^{(m,\tau)}}$$

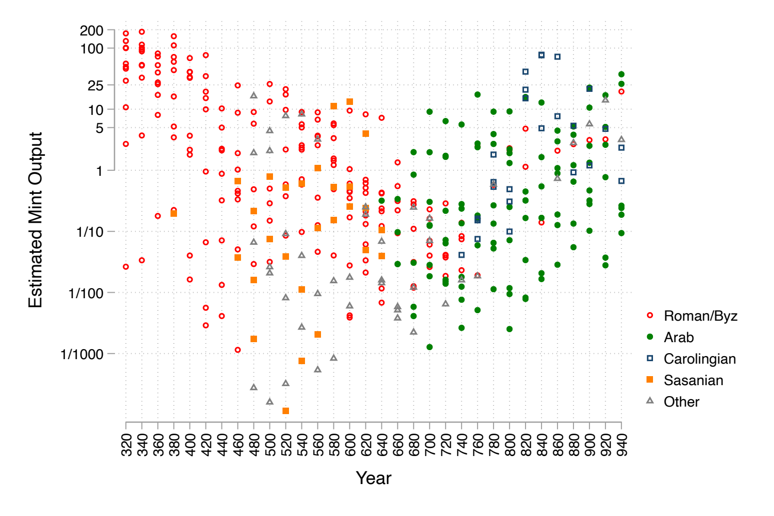
  with the probability of drawing a coin of type (m, τ),

$$p_i^{(m,\tau)}(T) = \frac{S_i^{(m,\tau)}(T)}{\sum_{(m',\tau')} S_i^{(m',\tau')}(T)} = \frac{S_i^{(m,\tau)}(T)}{S_i(T)}.$$

- Likelihood of observing a sample of coins given parameters $\boldsymbol{\theta}$,

$$\ell(X; \boldsymbol{\theta}) = \sum_i \sum_T \sum_{(m,\tau)} x_i^{(m,\tau)} \left[\log S_i^{(m,\tau)}(T; \boldsymbol{\theta}) - \log S_i(T; \boldsymbol{\theta})\right] + \text{constant}$$

Estimation results: Mint output



Estimation results: Determinants of trade costs

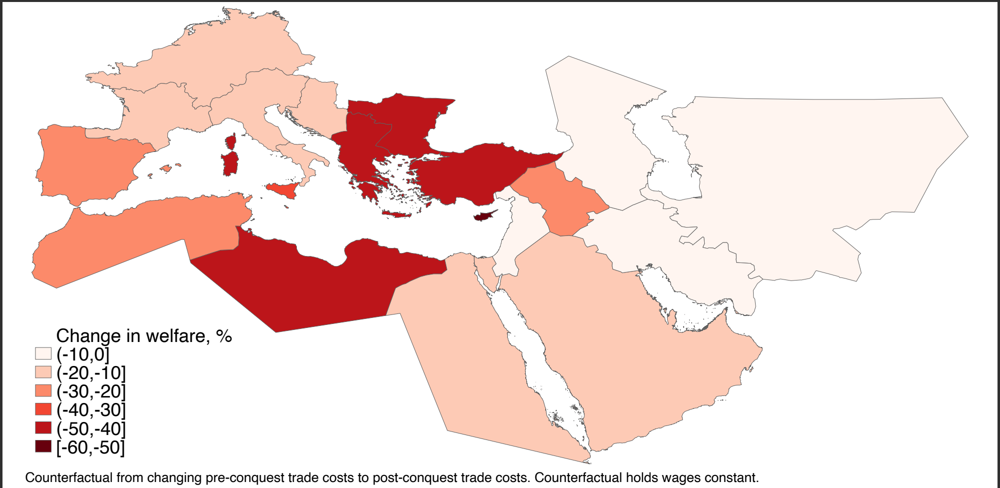
$$\theta \ln\left(\lambda_{ni}\left(t\right)\right) = -1.81 + 2.22 \ln\left(TravelTime_{ni}\right) + 1.28\, PoliticalBorder_{ni}\left(t\right) + 2.09\, ReligiousBorder_{ni}\left(t\right) \quad (2)$$

Holding fixed multilateral resistance term:

- removing a political border would increase a bilateral trade share by $\exp(1.28) - 1 \approx 260\%$
- removing a religious border would increase the same trade share by $\exp(2.09) - 1 \approx 710\%$

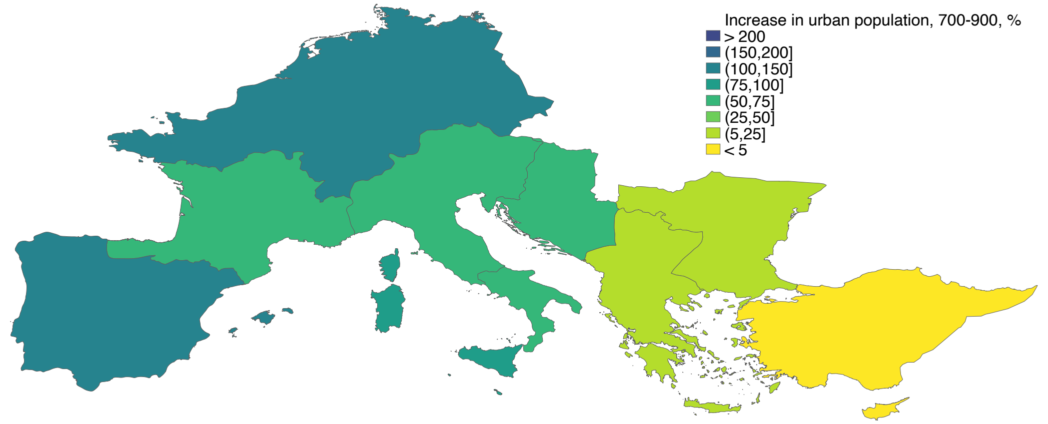
Changing pre-conquest trade costs to post-conquest: $(d_{ni}^{-\theta})^{pre} \rightarrow (d_{ni}^{-\theta})^{post}$

Holding fixed technology T_i wages w_i, and mint output M_i at pre-conquest levels, and assume $\theta = 4$.



Compare to relative urbanization rates, 700–900 AD

Change in total urban population (urban: > 1k inhabitants), data from Buringh (2021)



Taking stock

- Clear pattern of change in economic geography before vs after conquest
- Trade disruption can account for the relative decline in the eastern Mediterranean
- Change in trade cost *alone* not able to account for urbanization in Muslim Spain, or in Carolingian empire
- Potentially in conjunction with changes in technology T_i ($\rightarrow$ Spain) or mint output ($\rightarrow$ Carolingian empire).

Conclusion

“Simply looking at the Mediterranean cannot of course explain everything about a complicated past created by human agents, with varying doses of calculation, caprice and misadventure. But this is a sea that patiently recreates for us scenes from the past, breathing new life into them, locating them under a sky and in a landscape that we can see with our own eyes, a landscape and sky like those of long ago. A moment’s concentration or daydreaming, and that past comes back to life.”

Fernand Braudel, Les Mémoires de la Méditerranée

THANK YOU!

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BACKUP SLIDES

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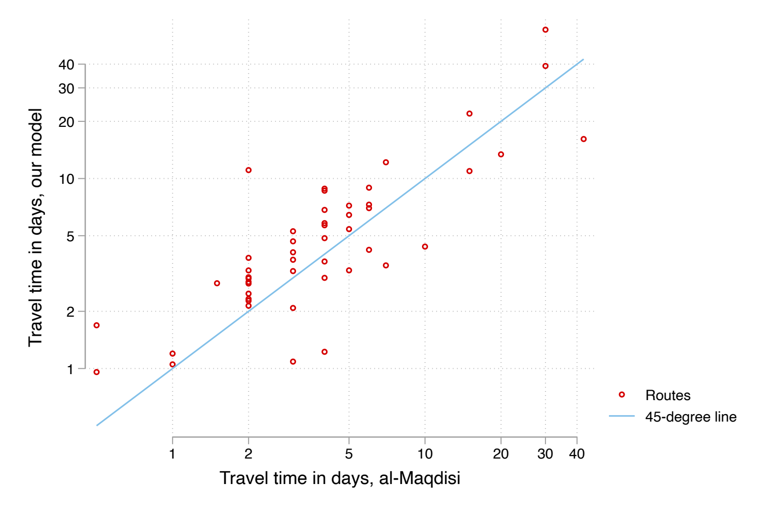
Regions

▸ Back

Validating Travel Times

Al-Maqdisi (c. 945–991): *The Best Divisions for Knowledge of the Regions*



Back

Unsolved problems (as of yet)

- *Lucas critique #1*: cost function does not minimize costs

$$\ln\left(\delta_{ni}\left(t\right)\right) = \min_{p \in paths(i \to n)} \Big(\gamma_0 + \gamma_1 \ln\left(TravelTime_p\left(t\right)\right) + \sum_{pb\text{: all political borders along } p} \gamma_2 PoliticalBorder_{pb}\left(t\right) + \sum_{rb\text{: all religious borders along } p} \gamma_3 ReligiousBorder_{rb}\left(t\right) \Big)$$

- *Lucas critique #2*: net saving (in δ_{nn}) depends on parameters.
- *Fix for #2*: location-specific intercepts ($\gamma_{0,n}$) and δ_{nn}'s.

For now: constant γ_0, and $\delta_{nn} = 1$...

Back

Fact #3: Arab conquests disrupt Mediterranean trade: Gold only

	Dependent variable: Number of Coins				
	(1)	(2)	(3)	(4)	(5)
Log Distance	-1.511**	-1.540**	-1.544**	-1.164**	-1.169**
	(0.13)	(0.12)	(0.12)	(0.16)	(0.16)
Crossing Mediterranean	0.209	0.220	0.238	-0.118	-0.105
	(0.37)	(0.38)	(0.37)	(0.29)	(0.29)
Crossing Mediterranean × After Conquests	-1.582*	-2.909**	-1.672*	-2.270*	-3.059**
	(0.71)	(0.74)	(0.70)	(0.98)	(1.13)
Crossing Mediterranean × After Conquests × Islamic Coin		3.106**	1.846*		2.857*
		(0.78)	(0.78)		(1.24)
Crossing Mediterranean × After Conquests × Roman Coin			-1.830		
			(1.13)		
Mint Cell × Empire FE	Yes	Yes	Yes	Yes	Yes
Hoard Cell × After Conquests FE	Yes	Yes	Yes	Yes	Yes
Sample				Gold only	Gold only
Observations	167042	167042	167042	28895	28895

Standard errors in parentheses, clustered at the hoard × era and mint × era level.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Before: 400–630; after: 713–950

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