Trade and the End of Antiquity

A Quantitative Investigation of the Pirenne Thesis

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Sciences Po Friday Seminar

22 March 2024

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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 (1939) 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

1. Coins and goods/services travel in opposite directions:

   $\hookrightarrow$ Ancient coins record traces of ancient trade flows.
2. Trade flows are shaped by gravity:

   $\hookrightarrow$ (*Reconstructed*) trade flows inform:
   (a) bilateral trade frictions
   (b) origin/destination "sizes"
3. Time-varying (*estimated*) trade frictions:

   $\hookrightarrow$ Test + quantify the Pirenne hypothesis.

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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  2. Mint date ("birthdate"): τ
  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*)

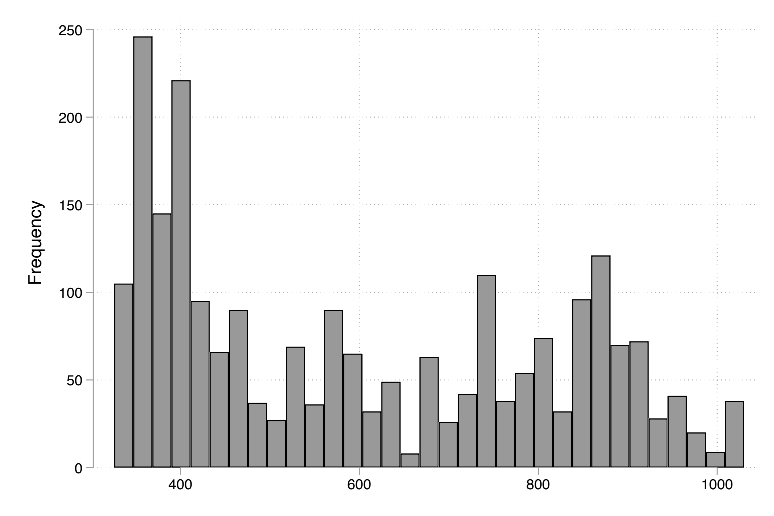

Figure 2: Terminus Post Quem (*tpq*) of hoards

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

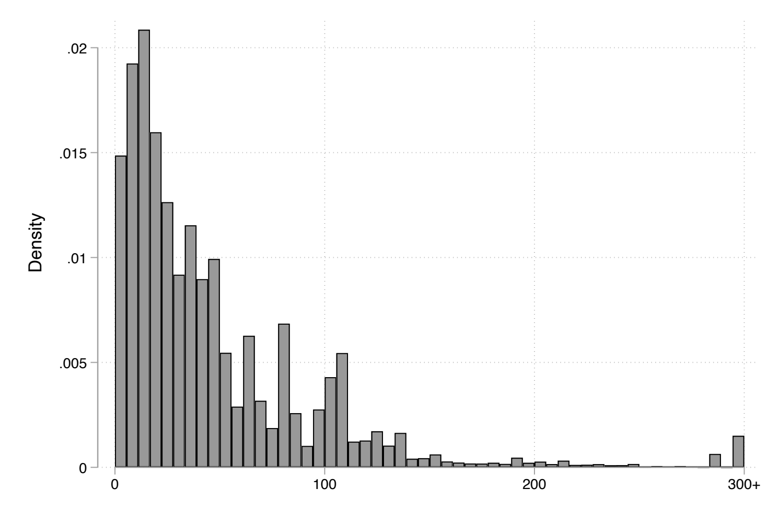

Figure 3: Coin age at time of deposit (*tpq*), in years

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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	0.162**	0.0982**	0.0910**	0.181**	0.0650**
	(0.050)	(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	0.767	0.865	0.871	0.783	0.901
Observations	282354	282136	281972	245252	244927

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 $1° \times 1°$ 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)
Log Distance	-1.138**	-0.984**	-0.740**	-0.707**
	(0.12)	(0.13)	(0.10)	(0.10)
Within border dummy		2.446**		1.608**
		(0.37)		(0.41)
Hoard Cell FE	Yes	Yes	Yes	Yes
Mint $\times$ Empire Cell FE	Yes	Yes	Yes	Yes
Sample			Int. Marg. only	Int. Marg. only
Estimator	PPML	PPML	PPML	PPML
R^2				
Observations	215984	215984	6222	6222

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

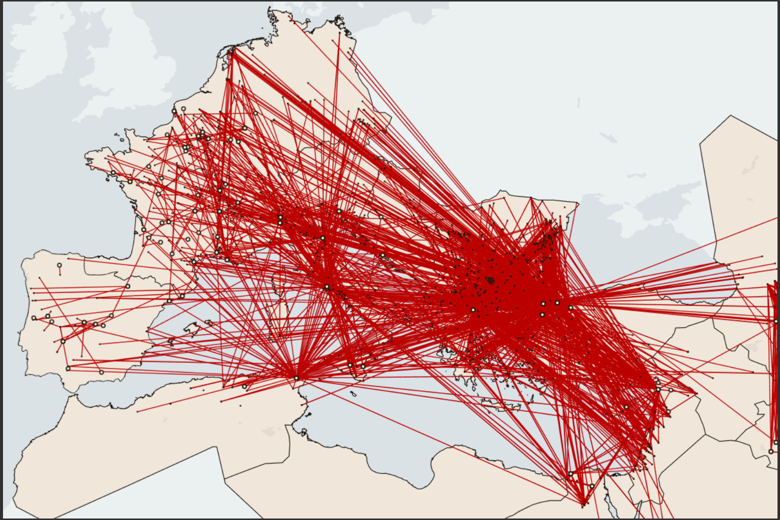


Figure 4: Before the Arab conquests: 450-630 AD

Fact #3: Arab conquests disrupt Mediterranean trade

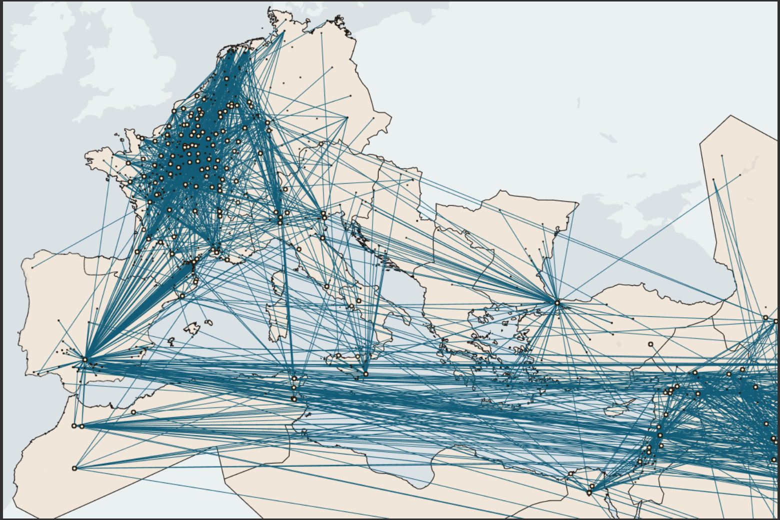


Figure 5: After the Arab conquests: 713-900 AD

Fact #3: Arab conquests disrupt Mediterranean trade

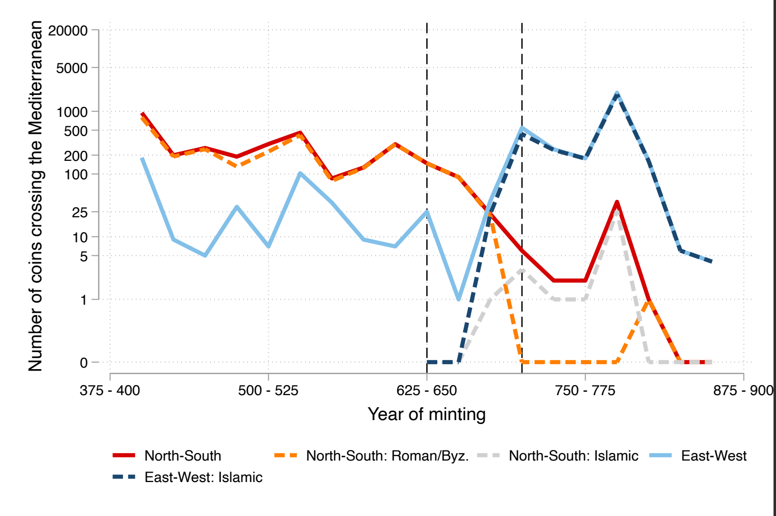


Figure 6: Number of coins flowing across the Mediterranean

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	-1.878**	-3.186**	-0.820	-2.283
	(0.48)	(0.55)	(0.68)	(1.59)
Crossing Mediterranean × After Conquests × Islamic Coin		6.748**	4.435**	7.614**
		(0.86)	(0.94)	(0.96)
Crossing Mediterranean × After Conquests × Roman Coin			-3.048**	-3.061**
			(0.78)	(0.69)
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	9246	9246	9246	4884

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

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

Outline

Model ingredients

- Ricardian model of trade.
  (Eaton and Kortum, 2002)
- Coins-in-advance economy.
- Minting: coin birth.
- Hoarding: coin death.
- Optimal coins saving.
  (Dekle, Eaton and Kortum, 2007)

Setup

Period t, location n: homogeneous mass $L_n(t)$ of workers

- Start with $S_n(t)$ coins saved from period $t-1$ to t.
- Beginning of period t:
    - Fraction $\lambda_n(t)$ of saved coins $S_n(t)$ is lost (turned into hoards $H_n(t) = \lambda_n(t) S_n(t)$)
    - $M_n(t) \geq 0$, fresh new coins minted
- Middle of period t: divide coins into consumption and saving
    - $X_n(t)$, expenditure on consumption
    - $S_n(t+1)$, saving for period $t+1$.
- End of period t:
    - Workers produce and sell goods in exchange for coins.
    - $w_n(t)$, competitive wage, in coins.
    - $Y_n(t) = w_n(t) L_n(t)$, aggregate labor income.

Inter- and intra-temporal allocations

- Intertemporal budget constraint:

$$S_n[t+1] = w_n[t]\,L_n[t] + M_n[t] + (1-\lambda_n[t])\,S_n[t] - X_n[t]\,. \tag{1}$$

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

$$\pi_{ni}(t) = \frac{T_i(t)\,(w_i(t)\,d_{ni}(t))^{-\theta}}{\sum_k T_k(t)\,(w_k(t)\,d_{nk}(t))^{-\theta}}, \tag{2}$$

as in Eaton and Kortum (2002).

Intertemporal preferences

- Intertemporal utility U_n, within period welfare W_n, ,

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

$$\text{with } W_n(t) = \frac{X_n(t)}{p_n(t)},$$

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

Dynamic optimization and equilibrium

- Optimal dynamic savings decision,

$$V\left(S_n; (\mathsf{T}, \mathsf{d}, \boldsymbol{\delta}, \mathsf{L}, \mathsf{M}; \mathsf{w})\right) =$$

$$\max_{S_n'} \ln \left(\frac{w_n L_n + M_n + (1-\lambda_n) S_n - S_n'}{\gamma L_n \left(\sum_k T_k (w_k d_{nk})^{-\theta}\right)^{1/\theta}} \right)$$

$$+ \beta \mathbb{E}\left[V_n\left(S_n'; (\mathsf{T}, \mathsf{d}, \boldsymbol{\delta}, \mathsf{L}, \mathsf{M}; \mathsf{w})'\right)\right]$$

- Dynamic equilibrium wages clear markets,

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

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

Optimal consumption/saving

Under log utility:

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

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

- when constrained, consume as much as you can:

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

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

- No motive for extra savings, $S_n = w_n L_n$.
- Wages and trade shares jointly determined,

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

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

- 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 $S_n(t)$ consist of coins of different vintage:

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

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 steady state, $s_n = 0$, and the diffusion equation becomes:

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

Outline

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:

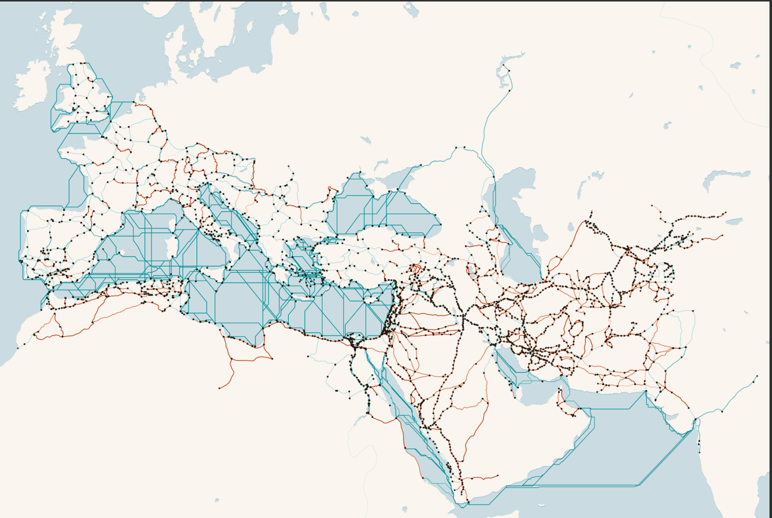
$$\hat{\lambda}_{20y} = 0.3$$

- 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).

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).

Maximum likelihood estimation

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

- Multinomial distribution of coin types,

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

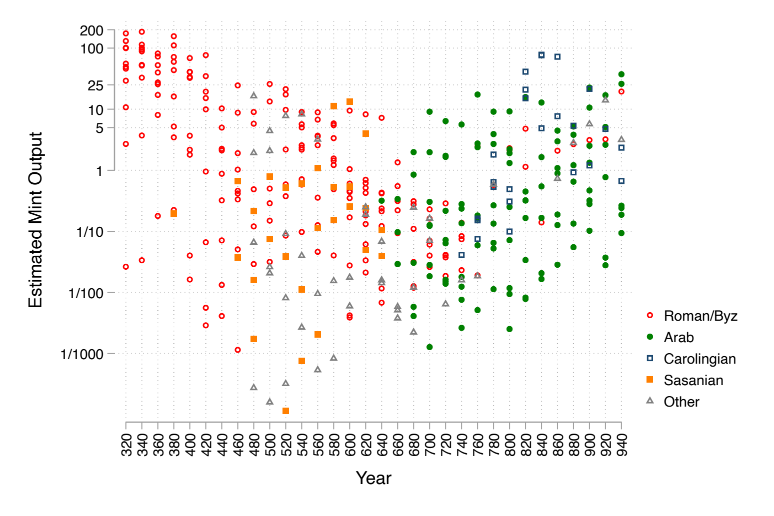
  with the probability of drawing a coin of type (m, τ),

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

- 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

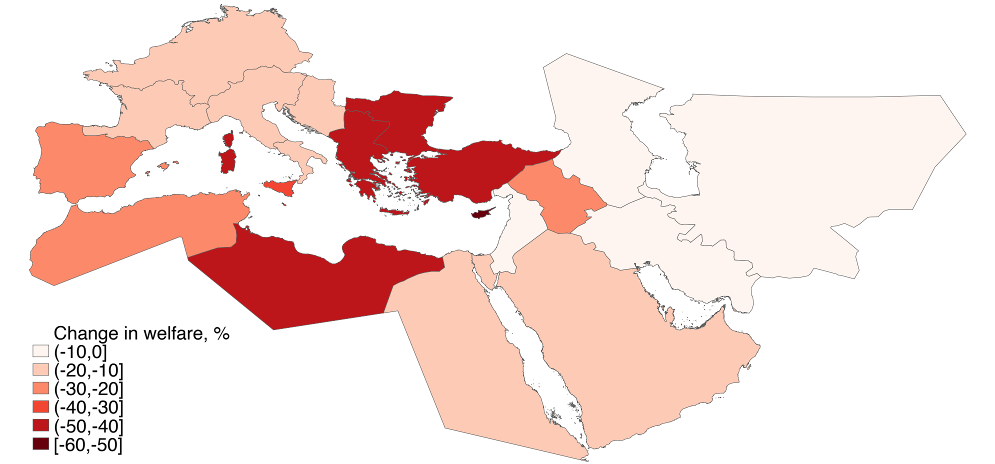
$$\begin{aligned}\theta \ln\left(\lambda_{ni}(t)\right) = -1.81 + 2.22 \ln\left(TravelTime_{ni}\right) \\ + 1.28\, PoliticalBorder_{ni}(t) + 2.09\, ReligiousBorder_{ni}(t)\end{aligned} \quad (3)$$

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: $(d_{ni}^{-\theta})^{pre} \rightarrow (d_{ni}^{-\theta})^{post}$

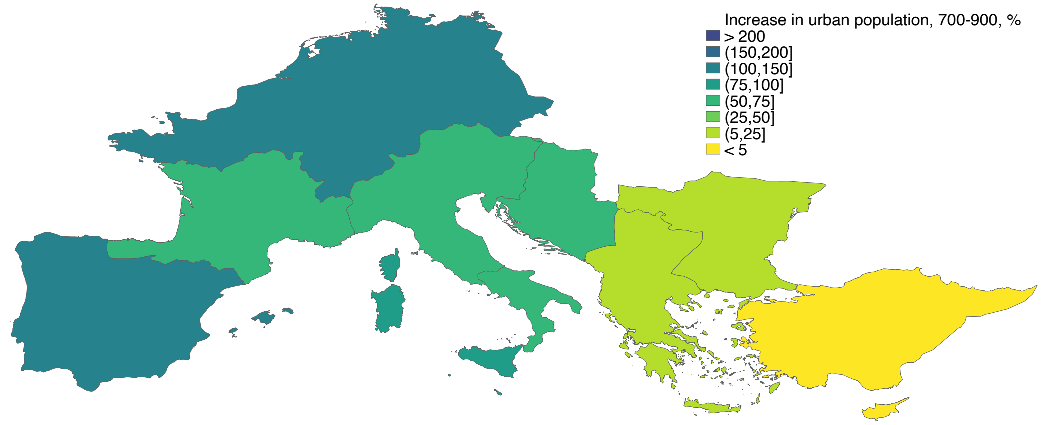
Holding fixed technology T_i wages w_i, and mint output M_i at pre-conquest levels, and assume $\theta = 4$.



Counterfactual from changing pre-conquest trade costs to post-conquest trade costs. Counterfactual holds wages constant.

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!

BACKUP SLIDES

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Regions