Germs, Social Networks and Growth

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Motivation

Large literature explaining differences in output across countries:

- Political, legal, financial institutions
- Geography, climate and factor endowments
- Technological progress and technology diffusion

All abstract from the potential role of “social structure”

Social Structure

Definition: The pattern of social ties between people in an economy; a social network.

Our main questions:

- Do differences across countries in social structure matter for macroeconomic outcomes?
- How might they matter?
- Where do they come from?

Social Networks

- A social network: the set of all individuals in the economy (“nodes”) and their relationships (“ties” or “edges”).
- How individuals make friends determines the social network. Aggregate features of this network constitute social structure.
- The structure of a network affects the speed of technology diffusion: differences in social structure translate into differences in the speed of diffusion of ideas in the economy.

Key feature: Collectivism in networks

- Dimension of variation: tendency to create tightly knit groups (collectives).
- Collective: a set of 3 mutually connected nodes.
- Example: How collectives in networks can affect diffusion.

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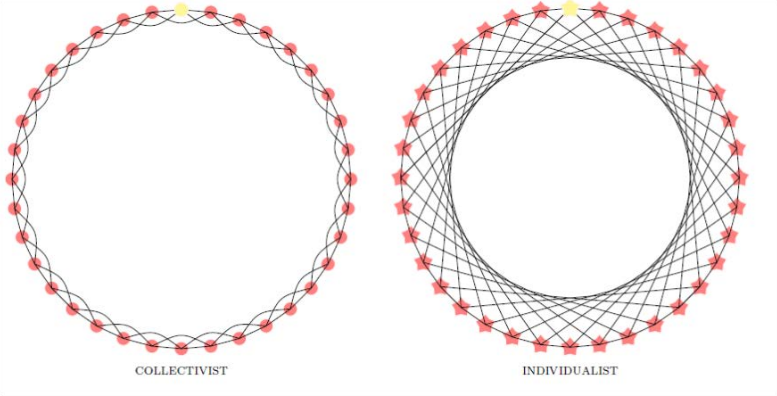

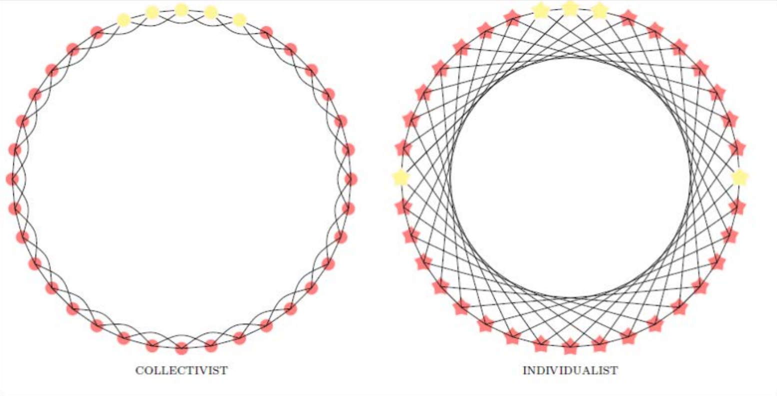
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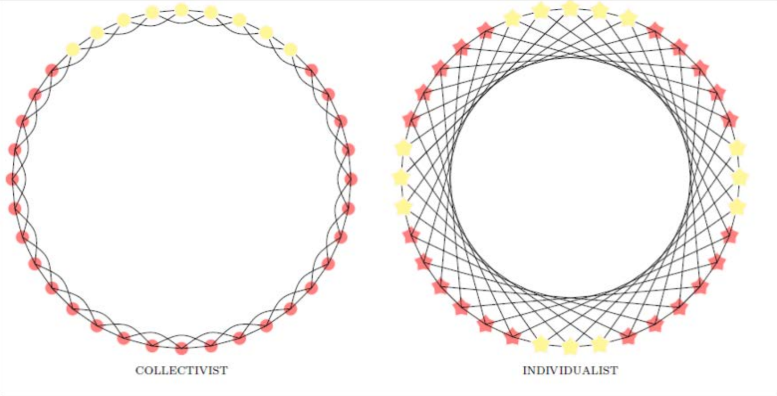
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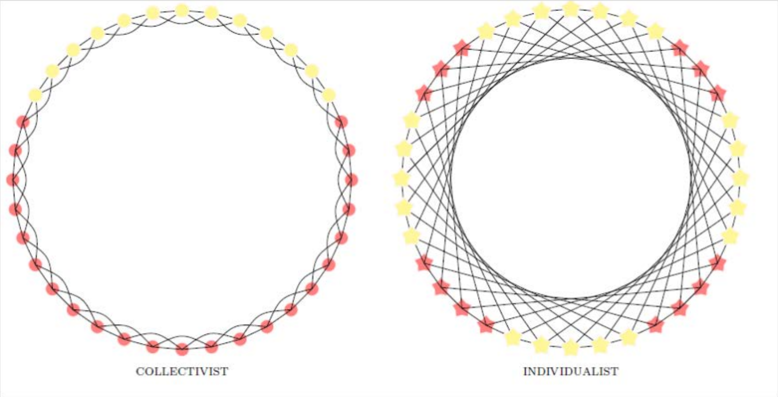
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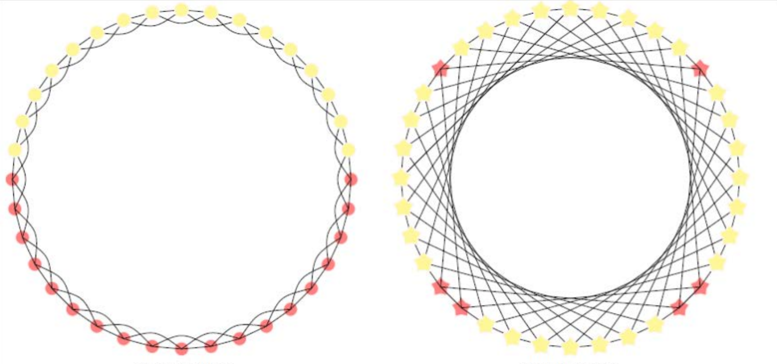

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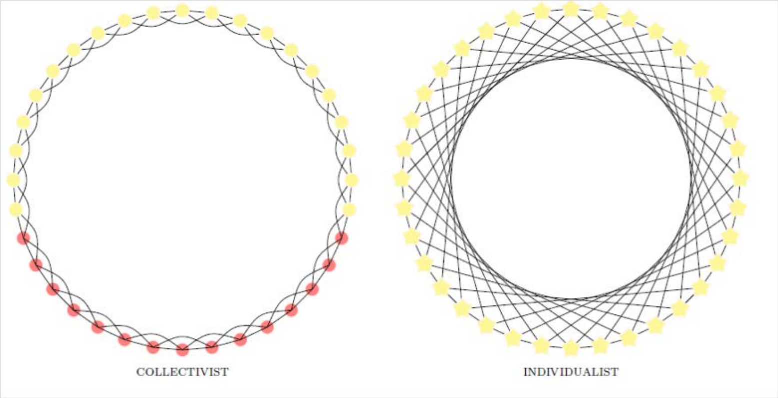

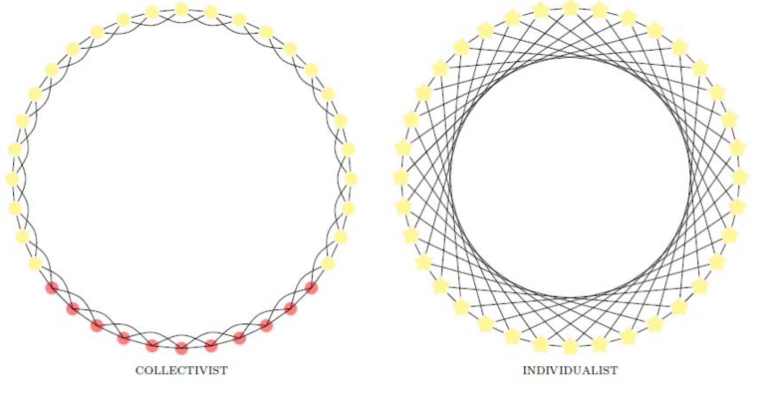
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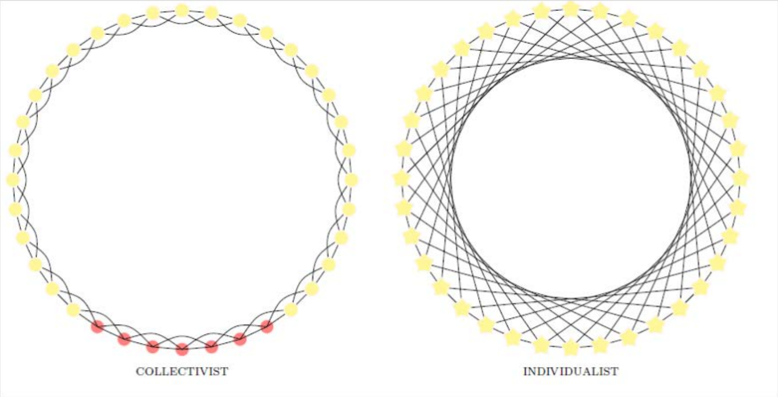
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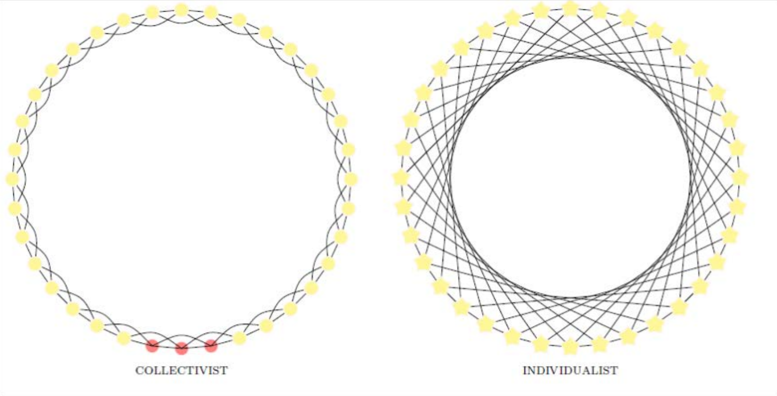
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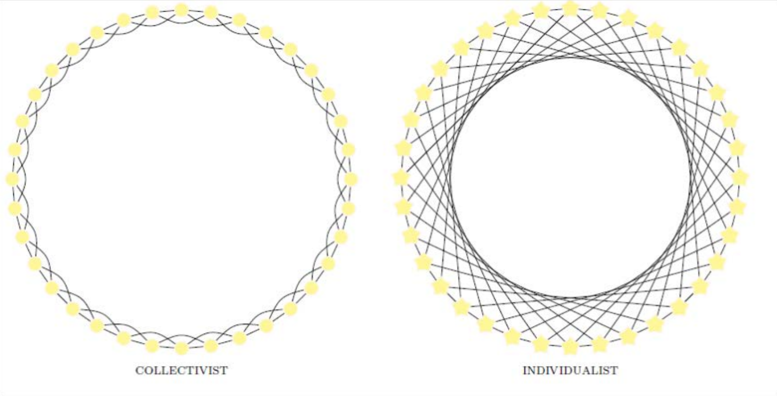


Key Ideas

- If some social structures slow down the diffusion of ideas,

Why do they emerge in the first place?

- Two factors that affect development and spread through human contact:

Germs and Ideas

- Social networks that inhibit the diffusion of ideas also protect people from diseases.

Outline

- Related work
- Compare diffusion in 2 exogenous networks: 1 individualist and 1 collectivist (isolate this dimension)
- Endogenize the network: Evolutionary model with high and low disease explains why networks form.
- Data: Collectivism, pathogens, tech diffusion
- IV estimation: Use the difference between socially transmittable and zoonotic disease to instrument for social structure. Estimate effect on technology.

Related work

- Technology diffusion: Lucas and Moll (2011), Perla and Tonetti (2011) use random matching.
- Technology spillovers: Eeckhout and Jovanovic (2002). Our network puts more structure on matches or spillovers.
- Political structure and growth: Acemoglu, Johnson and Robinson (2002). Related empirical strategy.
- Collectivism, culture and norms: Gorodnichenko and Roland (2011), Bisin and Verdier (2000,01), Fernandez and Fogli (2005), Greif (1994).

> *While mass media play a major role in alerting individuals to the possibility of an innovation, it seems to be personal contact that is most relevant in leading to its adoption. Thus, the diffusion of an innovation becomes a process formally akin to the spread of an infectious disease.*

(Kenneth Arrow, 1969 AEA presidential address)

Fixed Network Model

- Time discrete and infinite.
- N agents, located on a circle, are indexed by their location i. 2 states:
  - health status: healthy ($\psi_i(t) = 0$) or sick ($\psi_i(t) = 1$)
  - technology level: $A_i(t)$
- Network: A matrix N of 1's and 0's. $n_{ij} = 1$ means that i, j connected.
- A collective: When friends i and j have a mutual friend k. $n_{ij} = n_{ik} = n_{jk} = 1$

Fixed Network Model: Disease

- Healthy agents produce A_{it}. They survive to the next period with probability ξ.
- Sick agents have zero productivity ($A_i(t) = 0$) and die at end of period.
- Initial fraction S of sick people.
- Each sick person transmits the disease to each friend with probability π.
- An agent who dies is replaced. The new agent i, born at date t, has same network and $A_{i(t-1)} = 0$.

Fixed Network Model: Technology

Technology advances in 2 ways:

- Poisson arrival of new ideas. At the start of each period, with probability λ agent j advances his technology by one step:

$$ln(A_j(t+1)) = ln(A_j(t)) + \delta$$

- Agents can also learn from others in their networks. If person j is connected to person k and $A_j(t) > A_k(t)$ then with probability ϕ, k will learn what j knows:

$$A_k(t+1)) = A_j(t)$$

Fixed Network Model:

We compare diffusion in 2 networks.

- **Collectivist network** (N1): Hold the number of connections fixed (4). Everyone connected. Maximize collectives.
- **Individualist network** (N2): The minimal deviation from collectivist network that achieves zero collectives.

Key result: Collectives slow diffusion

- Collectives increase network diameter.
- Agents are more likely to infect friends that have already been infected by other friends.

Fixed Network Model: Diffusion Results

Let $\Psi_j(t) = min\{s \geq t : \psi_j(s) = 1\}$ and $\alpha_j(t) = min\{s \geq t : A_j(s) > A(t)\}$.

Result

If $\pi = 1$ and $\sum_j \psi_j(0) = 1$, then the average lifetime $E_j[\Psi_j(0)]$ is longer in the collectivist network (1) than in the individualist network (2).

If $\phi = 1$, then the average discovery time $E_j[\alpha_j(0)]$ is slower in the collectivist network (1) than in the individualist network (2).

Collectivist networks prolong lifetimes, but slow technology diffusion.

Fixed Network Model: Technology Frontier Results

Result

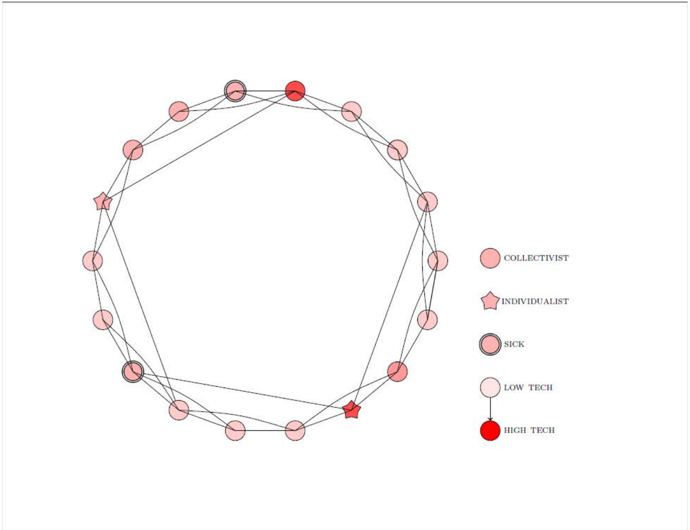
Suppose that at t, a collectivist network (N1) and an individualist network (N2) have the same $A_j(t)$ $\forall j$. Then the probability that the next new idea arrival will increase the technological frontier is larger in N2 than N1.

This is why an individualist network can achieve a higher rate of growth and a higher income in the long-run.

An evolutionary model of network formation

Same structure as before, except

- Individuals can be of two types: collectivist $\tau_j(t) = 0$ and individualist $\tau_j(t) = 1$.
  - Collectivist in location j is linked to $j-1$, $j+1$ and $j+2$
  - Individualist in location j is linked to $j-1$, $j+1$ and $j+4$
  - They can both be linked to $j-2$ and/or $j-4$ depending on types of agents in those locations.
- When agents die (from disease or old age), new agents inherit the type and technology of the friend in their parent's network with highest A. $\Rightarrow$ Successful types are passed on.


COLLECTIVIST
INDIVIDUALIST
SICK
LOW TECH
HIGH TECH

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Introduction

Related Work

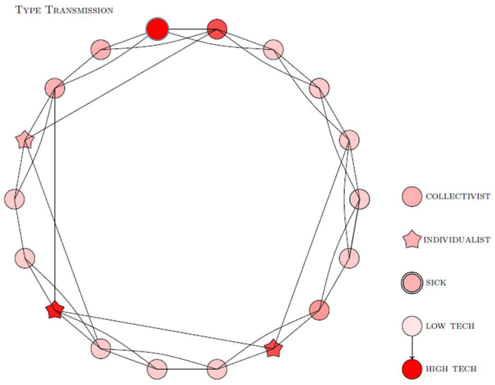
Fixed Network Model

Evolutionary Network Model

Calibration

Estimation

Conclusion



Long run results

Result

With probability 1, the network becomes homogeneous: $\exists T$ *s.t.* $\tau_j(t) = \tau_k(t)$ $\forall k$ *and* $\forall t > T$.

Result

With probability 1, the disease dies out: $\exists T$ *s.t.* $\psi_j(t) = 0 \quad \forall j$ *and* $\forall t > T$.

- If individualist$= 0 \Rightarrow$ Stay collectivist forever
- If individualist$> 0 \Rightarrow$ Likely converge to individualist

(learns faster and pass on type more often but not certain b/c random death)

Calibrate the model

- Does higher disease $\Rightarrow$ collectivism?
- How much can networks affect growth?

	Parameter	Value	Target
Initial disease prevalence	$E[\psi_j(0)]$	0.5%	TB death rate in China
Disease transmission probability	π	32%	Disease disappears in 150 years (indiv avg)
Innovation productivity increase	δ	30%	2.6% growth rate in individualist country
Technology transfer probability	ϕ	50%	Half-diffusion in 20 years (Comin et. al. '06)
Technology arrival rate	λ	0.25%	1 arrival every 2 years (Comin et. al. '06)
Exogenous death rate	ξ	1/70	average lifespan

Illustrative example: Diffusion in fixed networks

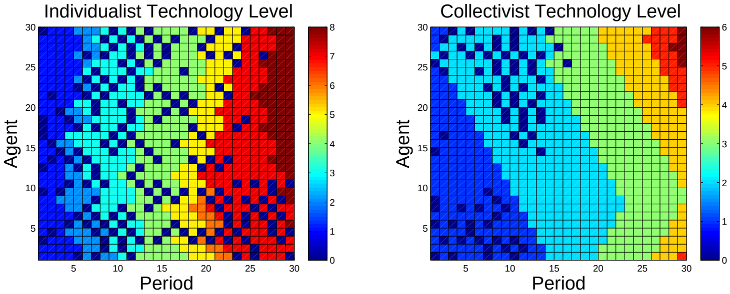


Figure: How disease and technology spread through networks.

The darkest boxes indicate individuals who acquired the disease in period *t* and therefore have zero time-*t* productivity. Warmer colors indicate higher levels of technology. Note: these are not calibrated levels of disease or tech arrival.

Calibration results: Comparing fixed networks

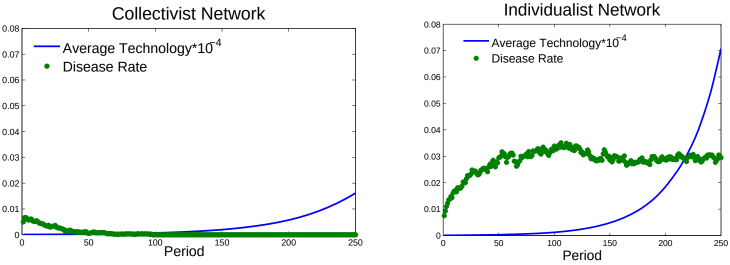


Figure: Average disease prevalence and productivity

- Avg growth rate in individualist network: 2.6%
- Avg growth rate in collectivist network: 2.0%

Numerical example: Network Evolution

Long run network structure depends on whether disease or individualist trait dies out first.
Example with 1 run:

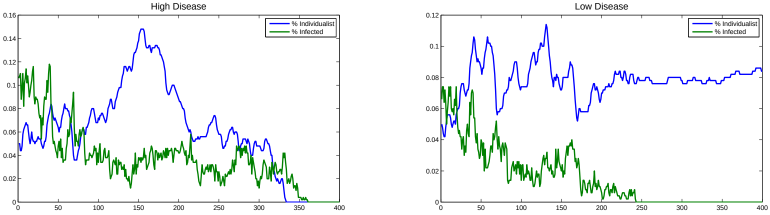


Figure: Long run network structure

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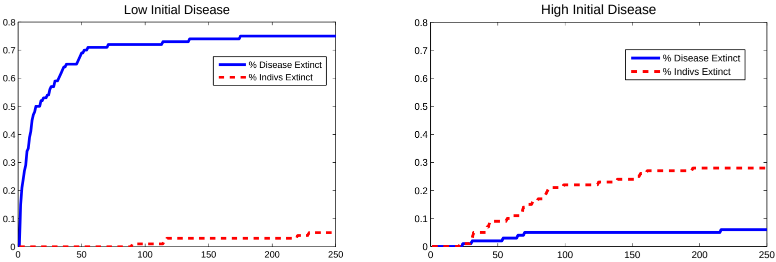
Calibration results: Disease and network evolution

Evolutionary model: Higher disease prevalence makes collectivist network more likely.



The probability that the economy converges to a zero-disease or purely collectivist steady-state at each date.

Theory summary

- Initial differences in disease govern social structure, which persists even after diseases disappear.
- The collectivist economy grows .6% less per year. A large quantitative effect over the long-run.
- Next step: Can we find causal evidence of an effect of social structure on income? How big?

Empirical strategy

- Instrument suggested by theory: historical prevalence of pathogens. But pathogens depend on technology and disease directly affects productivity.

$$A = \alpha_1 + \alpha_2 S + \epsilon$$
$$S = \gamma_1 + \gamma_2 A + \gamma_3 G_H + \gamma_4 G_Z + \eta$$
$$G_i = \delta A + \varepsilon_i \qquad i \epsilon \{H, Z\}$$

  Problem: G_i's show up in residual ϵ.
- Identifying assumption: $E[(G_H - G_Z)\epsilon] = 0$
- Our instrument: human$-$zoonotic pathogens.
  Idea: Both have the same relationship with A, but only human-to-human pathogens affect S.

Empirical measures

- Social structure
  - individualism index: constructed by sociologists to measure dependency of individuals from the group (varies between 0 and 100).
- Innovation
  - speed of technology diffusion from Comin and Mestieri (2012).
- Germs
  - prevalence of 9 of the deadliest communicable diseases: leishmanias, leprosy, trypanosomes, malaria, schistosomes, filariae, dengue, typhus and tuberculosis, from 1930 atlases of infectious diseases (on a 4 points scale).

Measuring Collectivism

- Two observable characteristics of collectivism
  1. An aversion to severing social ties
     Difficult to sustain collectives with changing ties.
  2. Cooperation and social influence
     Common friends enforce cooperation and social norms.

- Key factors that determine Hofstede's individualism index
  1. Group cooperation (C)
  2. Importance of freedom (I)
  3. Importance of job satisfaction and location(I)
     Collectivists don't change jobs or location much.

Constructing Disease Instruments

- Instrument 1: Difference in reservoir (diff_res)
  1. Reservoir is the long-term host of a pathogen.
  2. Human: leprosy, filariae
  3. Zoonotic: schistosomes, typhus
  4. Multi-host: leishmanias, trypanosomes, malaria, dengue, tuberculosis

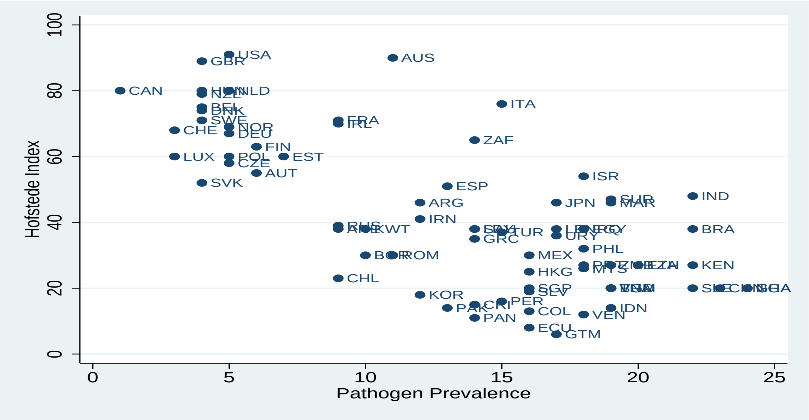
$$diff\_res = \text{human} + \text{multi} - \text{zoonotic}$$

- Instrument 2: Standardized difference

$$std\_res = (human + multi) - zoonotic \frac{std(\text{human} + \text{multi})}{std(\text{zoonotic})}$$

- Robustness: Split by vector (diff and std)

Individualism and Germs



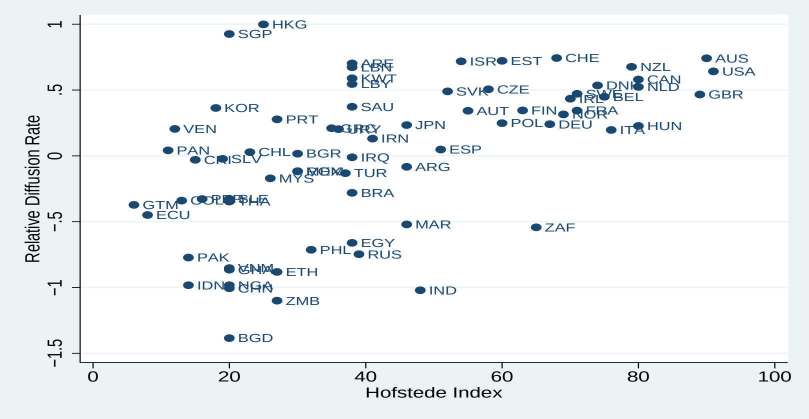
Total pathogen prevalence is a sum of all nine diseases.

First stage estimation

Dependent variable	Individualism (S)				
	(1)	(2)	(3)	(4)	(5)
Total pathogens	-2.73				
	(0.31)				
H+MH - zoonotic		-3.46	-2.15		
diff_res		(0.44)	(0.45)		
H+MH - zoonotic				-5.26	
std_res				(2.04)	
diff by vector					-4.39
std_vec					(2.16)
English			25.33	28.48	26.55
Pronoun			-19.17	-28.33	-30.17
Constant	77.10	67.53	69.71	59.86	61.16
R^2	0.52	0.47	0.71	0.64	0.63
Observations	72	72	62	62	62

The table reports OLS estimates of the γ coefficients in $S = \gamma_1 + \gamma_3 x + \eta$,

Technology Diffusion and Individualism



Comin and Mestieri's technology diffusion measure (vertical axis) plotted against Hofstede's individualism index (horizonal axis).

Social Structure and Technology (main result)

Dependent variable:	Technology Diffusion Rate			
Instruments:	diff_res	diff_res_std	diff_vec_std	none
		pronoun and english		(OLS)
Individualism	1.63	1.31	1.36	1.40
	(0.33)	(0.34)	(0.35)	(0.28)
Over-ID p-val	0.12	0.21	0.77	
	Accept	Accept	Accept	
R^2	0.27	0.28	0.28	0.27
N	62	62	62	72

1 std dev increase in individualism (23.0) results in 16 more technologies, (34% of average tech level).

Controlling for other variables

Dependent variable			Technology Diffusion			
	(1)	(2)	(3)	(4)	(5)	(6)
Individualism	1.46*	0.69	1.23*	1.35*	1.02*	1.24*
	(0.31)	(0.39)	(0.30)	(0.36)	(0.27)	(0.36)
Population Density	0.040* (0.010)					
Social Infrast		112.2* (30.17)				
Ethno-lingu fractionalz			−1.08* (0.21)			
Latitude				0.21 (0.26)		
Disease-adj life expect					−0.0030* (0.0006)	
Capitalist (EcOrg)						5.89 (4.44)
R^2	0.43	0.47	0.52	0.33	0.63	0.34
Observations	62	60	55	61	61	61

Estimating Effects on Output

Dependent var:	Solow Residual	Output per capita
Instruments:	diff_res_std	diff_res_std
	pronoun, eng	pronoun, eng
Individualism	0.99	2.10
	(0.40)	(0.45)
Over-ID p-val	0.78 0.87	
	Accept	Accept
R^2	0.20	0.42
N	58	59

1 std dev increase in individualism (23.0) results in 23 higher Solow residual (23% of US level) and 48 higher output per capita (48% of US level). Solow residual and output per capita come from the Penn World Tables mark 5.6. All estimates are significant at 5% level.

Conclusions

- If ideas and germs spread in similar ways, disease prevalence can rationalize social networks that inhibit technology diffusion and growth.
- Differences in social networks persist, even after disease disappears. Large income effects over time.
- IV analysis finds evidence of the effect of social networks on technology.
- More generally we offer a theory of endogenous social institutions and show how to measure and test for their effects.

Backup

Variable	Obsv	Mean	Std Dev	Min	Max
Technology	75	47.84	21.33	4	95
Solow Resid	64	81.94	6.47	62.8	90.2
GDP/capita	65	92.87	8.97	70.2	104.8
Individualism	75	42.27	22.98	6	91
Pronoun	65	0.68	0.47	0	1
% english	70	0 .077	0.24	0	0 .974
hum_res	75	1.28	1.16	0	3
zoo_res	75	2.87	1.49	0	6
hum_multi_res	75	10.25	5.33	1	19
diff_res	75	7.39	4.76	-1	16
diff_res_std	75	0.0011	0.995	-2.04	2.63
Life Exp	73	62.44	9.69	35.95	74.65
Soc Infra	67	0.549	0.262	0.113	1
pathcontemp	73	32.33	6.50	23	47