Technological Waves and Local Growth

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[1] The views expressed in this presentation are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of Chicago or the Federal Reserve System.

We Study Frictional Knowledge Diffusion as Determinant of Local Growth

- Changes in the technological landscape often coincide with transformations in the economic geography.
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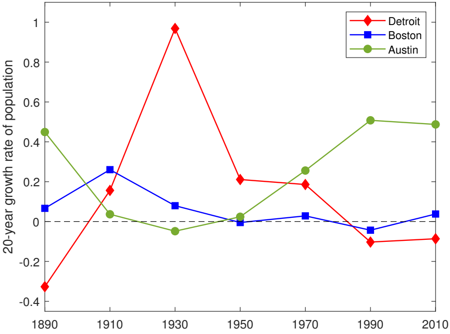
- Changes in the technological landscape often coincide with transformations in the economic geography.
- As new technological opportunities emerge, some cities grow and other decline.
- Our Hypothesis:

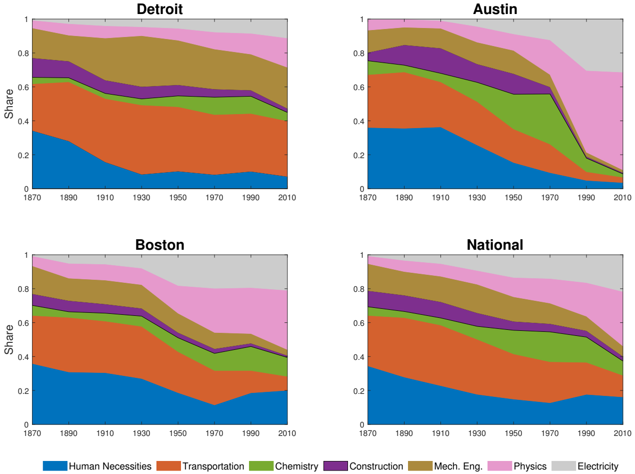
  Frictions to knowledge diffusion make cities sensitive to "technological waves."

Cities alternate periods of growth and decline



Notes: Residuals of a regression of population growth on Census Division × decade fixed effects

Cities differ in the composition of their patenting output



This paper: Frictions to knowledge diffusion make cities sensitive to "technological waves"

- Frictions to knowledge diffusion across cities and fields of knowledge $\implies$
  - A city's ability to embrace new technological opportunities ("technological waves") depends on local availability of complementary ideas

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- Develop a theory combining elements from
  - Quantitative spatial equilibrium
  - Endogenous growth with innovation and idea diffusion

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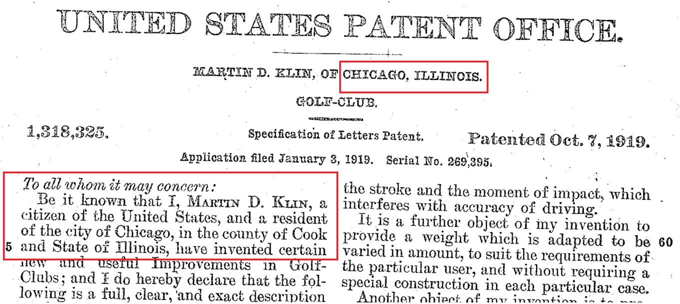
- Quantify the model using historical geo-located data on population and patents, 1870-present
- Assess the role of technological waves in city dynamics (historically and under plausible future scenarios)

Comprehensive Universe of US Patents (CUSP)

- Near-universe of US patents since 1836 (Berkes, 2018)
- Information on location (city) of inventors, technology class, filing and award date, assignee



UNITED STATES PATENT OFFICE.

MARTIN D. KLIN, OF CHICAGO, ILLINOIS.

GOLF-CLUB.

1,318,325. Specification of Letters Patent. Patented Oct. 7, 1919.

Application filed January 3, 1919. Serial No. 269,395.

To all whom it may concern:

Be it known that I, Martin D. Klin, a citizen of the United States, and a resident of the city of Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Golf-Clubs; and I do hereby declare that the following is a full, clear, and exact description

the stroke and the moment of impact, which interferes with accuracy of driving.

It is a further object of my invention to provide a weight which is adapted to be varied in amount, to suit the requirements of the particular user, and without requiring a special construction in each particular case.

Another object of my invention is to pro-

Local exposure to technological wave is correlated with city growth

- Shift-share measure of exposure to technological wave:

$$Exp_{n,t} = \sum_{s \in S} Share_{n,s,t-1} \times g_{-n,s,t}.$$

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- Estimate relationship between 20-year population growth and exposure to the technological wave, 1910-2010:

$$\Delta \log(Pop_{n,t}) = \sum_{j=1,2} \delta_j \log(Pop_{n,t-j}) + \beta Exp_{n,t} + \gamma X_{n,t} + \mu_{d,t} + \epsilon_{n,t}$$

Local exposure to technological wave is correlated with city growth

	Growth rate of population			
	(1)	(2)	(3)	(4)
Exposure to tech. wave	0.424***	0.396***	0.367***	0.276***
	(0.082)	(0.067)	(0.071)	(0.070)
Human capital (ranking)			0.082*	0.035
			(0.047)	(0.046)
Industry composition				0.657***
				(0.116)
Log-population (lags 1 and 2)	Yes	Yes	Yes	Yes
Fixed effects	T	CD$\times$T	CD$\times$T	CD$\times$T
# Obs.	2,238	2,238	2,238	2,228
R^2	0.393	0.507	0.509	0.528

Notes: CZ level regression, 1910-2010. Dependent variable defined as growth rate of population over 20 years. "T" denotes time fixed effects, and "CD$\times$T" denotes Census Division-time fixed effects. Standard errors clustered at the CZ level in parenthesis. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Model Setting

- Consider an economy with N locations and S sectors.
- Newborn agents choose location (n) and sector (s) to maximize lifetime utility:

$$U_{n,s,i,t} = u_n \, x_{n,s,i} \, c_{n,s,i,t}$$

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- Every location-sector (n, s) has distribution of productivity $F_{n,s,t}$

Productivity: An imitate or innovate decision

- After moving, each agent receives draws from local (l) and external (x) distributions of ideas:

$$\boldsymbol{z}_{n,s,i} = \left\{ z^l_{n,s,i}, \{z^x_{m,r,i}\}_{m,r \in N \times S} \right\}$$

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- Two options:
  - Keep the local draw, $z^l_{n,s,i}$, and use it in production (**imitation**):

$$q_{n,s,i,t} = z^l_{n,s,i}$$

  - Convert one of the external draws, $z^x_{m,r,i}$, into an **innovation**:

$$q_{n,s,i,t} = \frac{\epsilon_{n,s,t} \alpha_{r,t} z^x_{m,r,i}}{d_{(m,r) \to (n,s)}}$$

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$$q_{n,s,i,t} = \max\left\{ z^{I}_{n,s,i},\ \left\{ \frac{\epsilon_{n,s,t}\, \alpha_{r,t}\, z^{x}_{m,r,i}}{d_{(m,r)\to(n,s)}} \right\}_{m,r \in N \times S} \right\}$$

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- $F_{n,s,t}$ remains Fréchet for all $t > 0$. Scale $\lambda_{n,s,t}$ ("productivity of (n, s)") has law of motion:

$$\lambda_{n,s,t} = \underbrace{\lambda_{n,s,t-1}}_{\text{Imitation}} + \underbrace{\sum_{m \in N} \sum_{r \in S} \lambda_{m,r,t-1} \left(\frac{\epsilon_{n,s,t}\alpha_{r,t}}{d_{(m,r)\to(n,s)}} \right)^{\theta}}_{\text{Innovation}}.$$

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- Perron-Frobenius theorem guarantees A_t has a unique (up to scale) positive eigenvector $\vec{\lambda}^*$ and a unique corresponding eigenvalue $(1 + g^*_\lambda)$:
    - For any set of stable exogenous variables (A^*), the model has a unique Balanced Growth Path (BGP)

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- Dynamics of local population:

$$\hat{\pi}_{n,t} \propto \sum_{s \in S} \left\{ (1 - \pi^*_n) \pi^*_{s|n} \hat{\lambda}_{n,s,t} - \sum_{m \neq n} \pi^*_{m,s} \hat{\lambda}_{m,s,t} \right\}$$

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Technological wave shocks and local population dynamics

- Local population dynamics:

$$\hat{\pi}_{n,t} \propto \sum_{(r,s)\in S\times S} \left\{ (1-\pi_n^*)\pi_{s|n}^*\eta_{r\to(n,s)}^* - \sum_{m\neq n} \pi_{m,s}^*\eta_{r\to(m,s)}^* \right\} \hat{\alpha}_{r,t}$$

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- Now, to gain intuition, decompose local population dynamics

Decomposing local population dynamics

1. Assume individual cities are negligible in size, i.e. $\pi_n^* \approx 0$
2. Assume knowledge flows across fields are negligible, i.e. $\eta^*_{s\rightarrow(n,s)} \approx 1$

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- Because of frictions across fields, productivity growth is higher in expanding fields ($\hat{\alpha}_{s,t} \uparrow$)
- If expanding fields are more prevalent in the local economy, average local productivity and hence population grows faster ("Bartik" effect)

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- Because of frictions across cities, $\eta_{r\to(n,s)}^*$ is higher in cities where r is more prevalent
- If expanding fields are more prevalent in the local economy, productivity in all sectors (and hence population) grows faster

Decomposing local population dynamics

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City growth and technological waves: Data and Model

	Population growth		
	Data	Model	
	(1)	(2)	(3)
	1910-1950		
Exposure to tech. wave	.878***		
	(.201)		
	1970-2010		
Exposure to tech. wave	.397***		
	(.098)		
Idea flows across fields	-		
Structural residuals	-	Fixed at BGP	
# Obs.	373		

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- One s.d. increase in Exposure leads to 0.16 (1910-1950) and 0.20 (1970-2010) s.d. increase in population growth

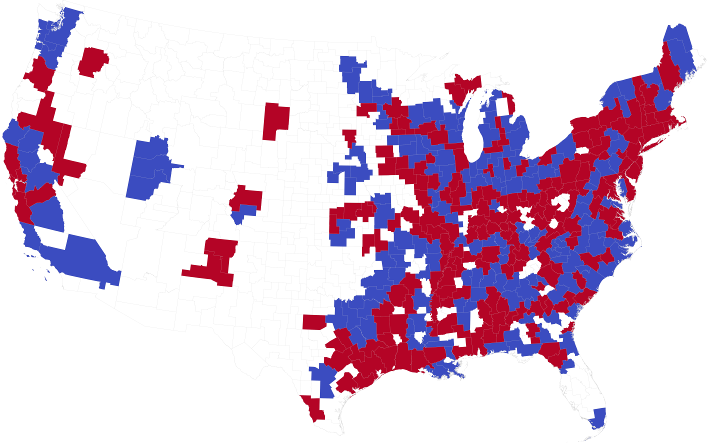
Additional quantitative results

- Local diversification makes growth trajectory less volatile:
  1. Frictions across fields $\Longrightarrow$ Tech wave makes some sectors expand (or decline) more than others $\Longrightarrow$ Cities specialized in expanding (declining) sectors grow (shrink)
  2. Frictions across cities $\Longrightarrow$ local productivity growth in *all sectors* is less volatile in more diversified cities

- Study the effects of future technological scenarios on the economic geography

Future Scenario: Autonomous vehicles

- Fall in diffusion frictions between (to and from) “Physics” - “Electricity” and ”Transportation”



Blue: Net population gain. Red: Net population loss.

Conclusions and Discussion

- The growth and decline of cities over time is correlated with their exposure to technological waves
- Developed a tractable quantitative model of innovation with frictional knowledge diffusion across space and tech. fields:
  - Mechanism accounts for most of this correlation ($\sim 16\% - 20\%$ of total variation in city growth)
- Innovation via frictional knowledge diffusion implies heterogeneous geographical effects of possible future scenarios
- Implications for benefits from local diversification in fostering cities' resilience to technological waves

Comments or Questions?

ruben.gaetani@utoronto.ca

Thank you!