Relatedness and technological change

The Emergence of New Technologies in U.S. Cities from 1975 to 2010

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Our aim

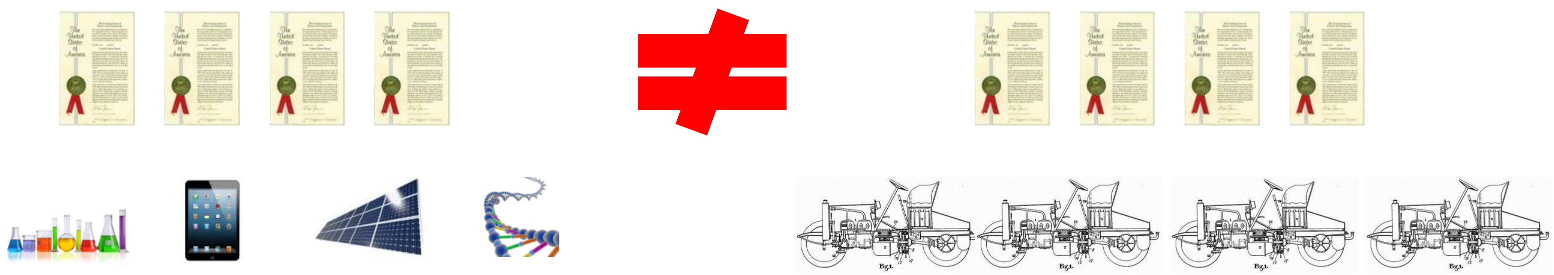
- Question: explain **technological change** in cities, i.e. why cities diversify into some technologies and not others?
- Main idea: the (evolutionary) process of technological change is driven by the specific **knowledge structure** of cities
- Methods: **patents** statistics indicate the diversity of knowledge in cities and allow to precisely characterize their knowledge structure
- Interest for decision makers: the method presented in the paper can be used as a **twofold diagnostic tool** (city & technological level)

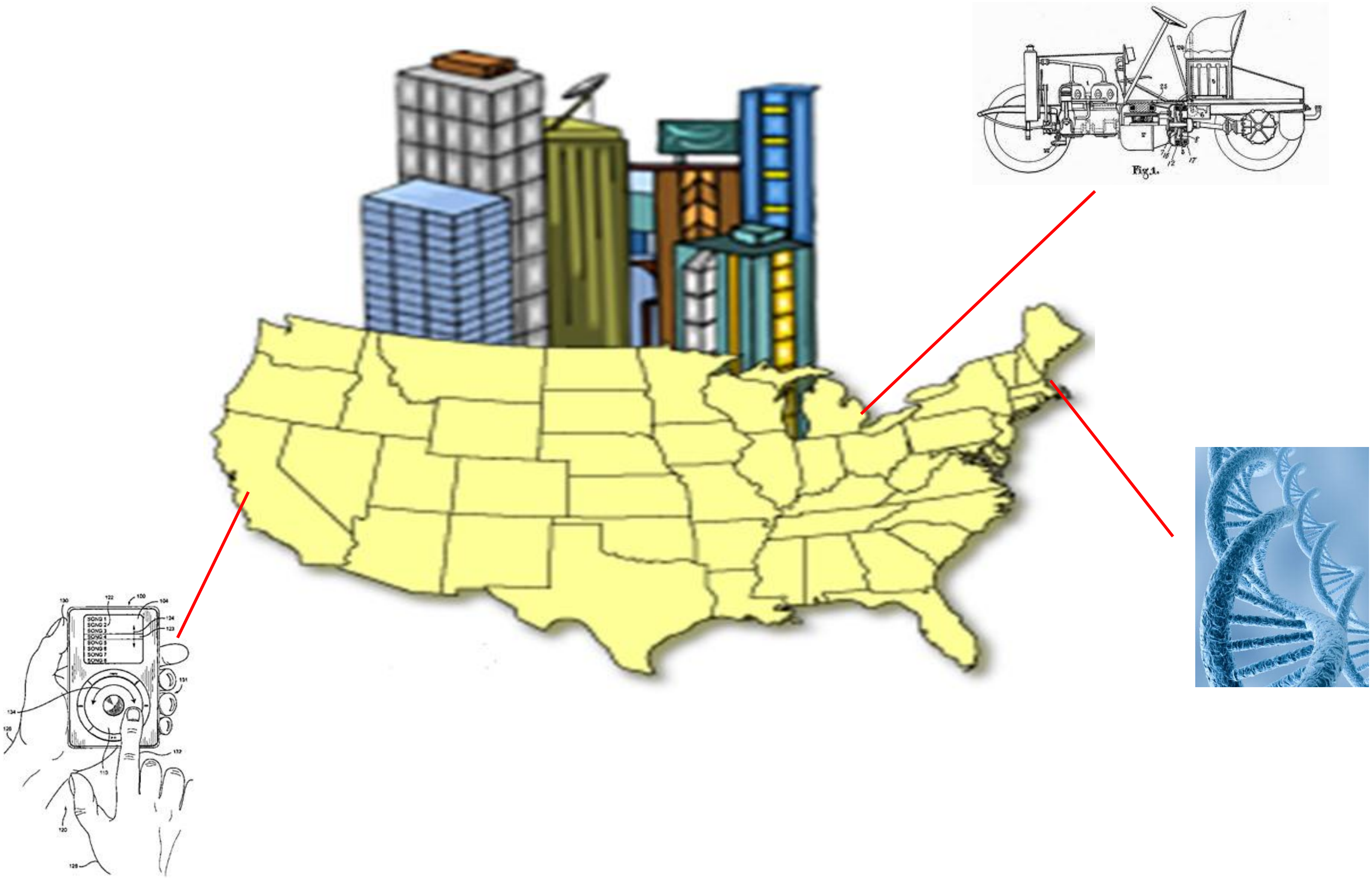
Theoretical background

- Economic Geography
  - ✓ Cities as knowledge incubators (geographical proximity matters)
  - ✓ Spatial dynamics of technologies as a path/place dependent process, emerging out of a branching process (Frenken and Boschma, 2007)
- The product space framework
  - ✓ Network representation of the economy, outcome-based measure of relatedness among products/tech (Hidalgo et al., 2007)
  - ✓ Increasing interest in economic geography & innovation studies: Neffke et al. (2011), Boschma et al. (2012), Rigby (2012) …

Patent Statistics

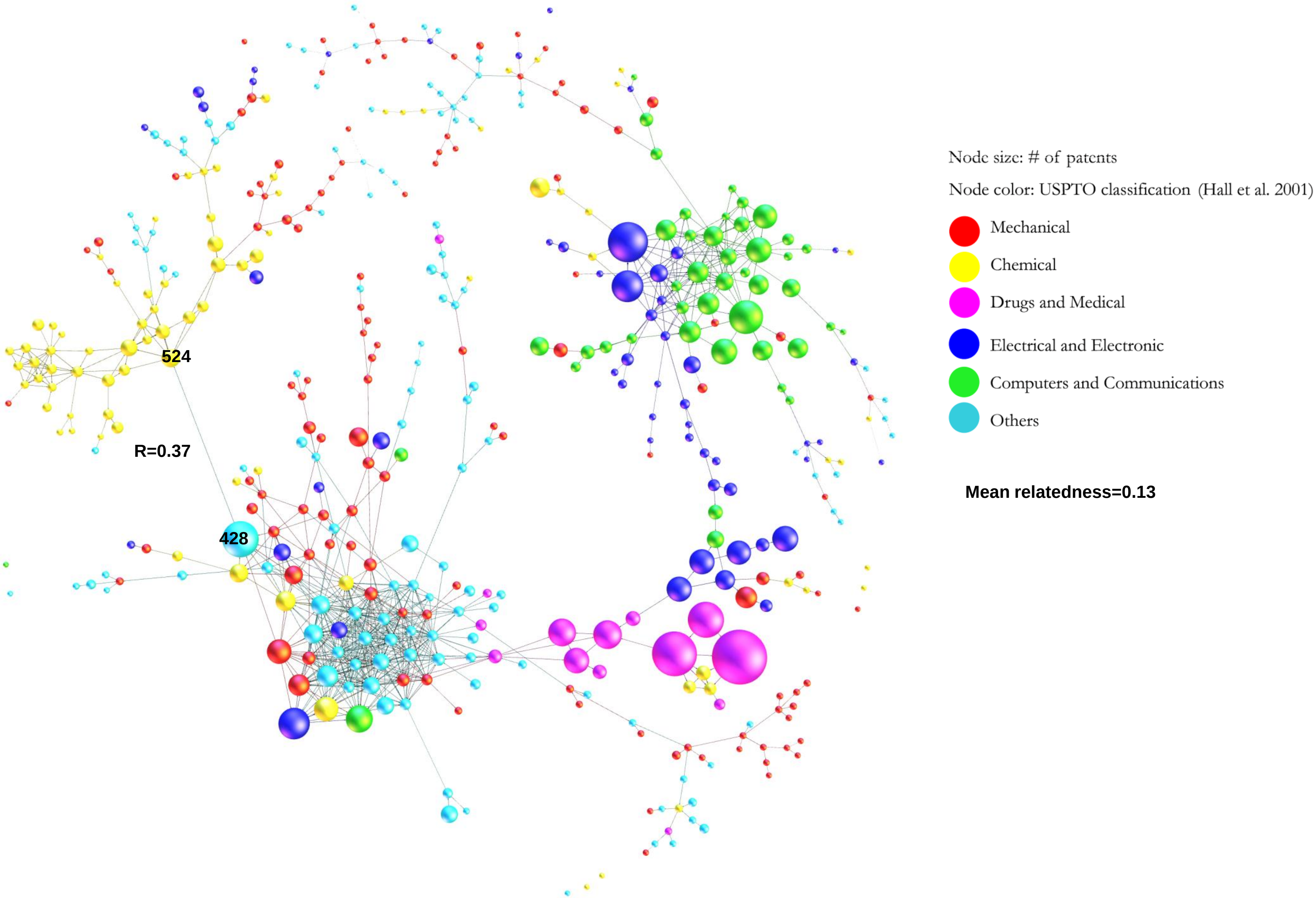
- Patents can be used to quantify the inventive capacity of individuals, firms, cities, countries… (count the number of new patents)
- But also to characterize their knowledge structure





*We analyze **technological change** in U.S. Cities*
(438 patent classes; 366 MSA; 1976 to 2010)

Measuring relatedness: the U.S. technology space



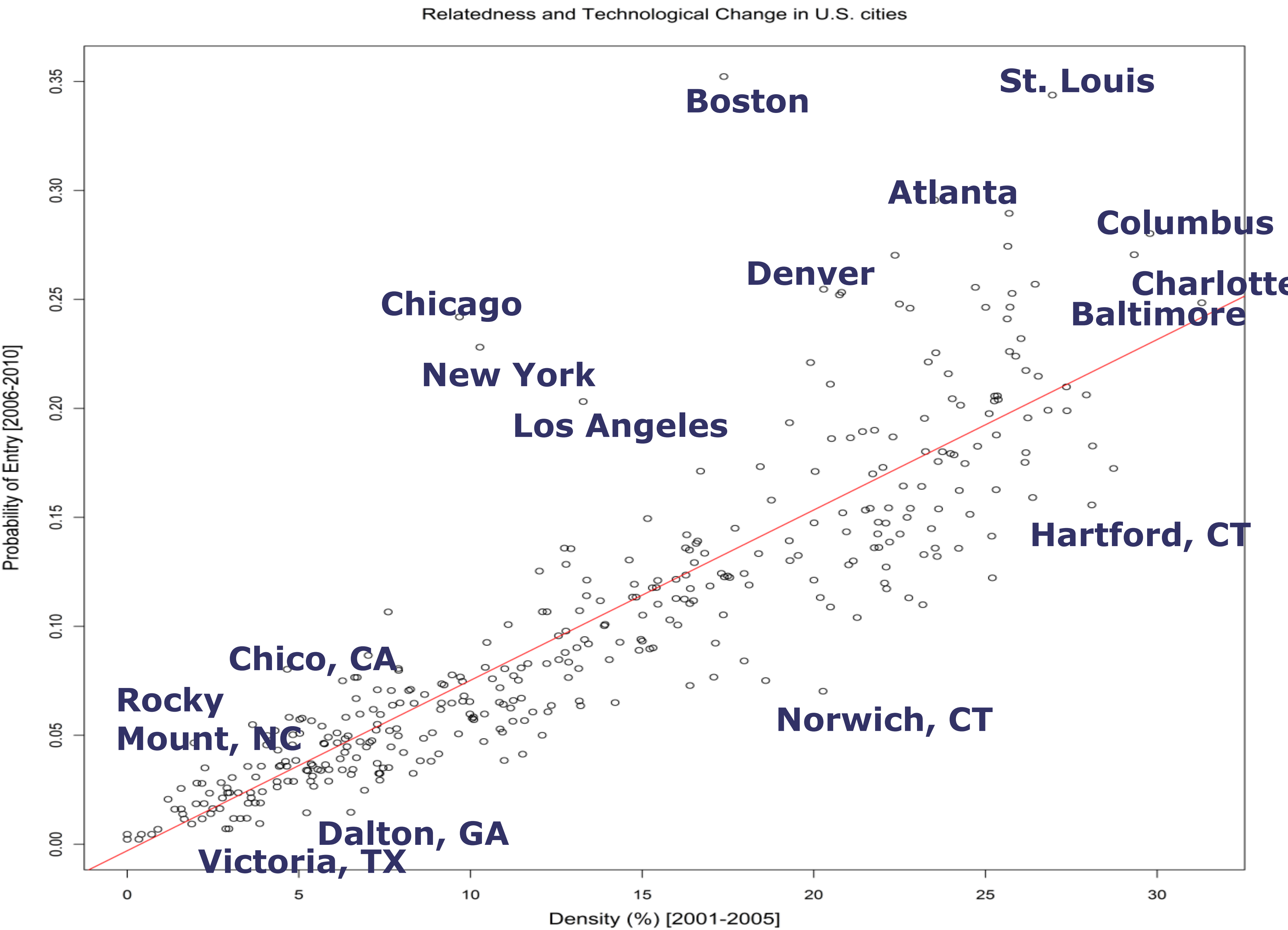
The density of related technologies

$$D_{i,c,t} = \frac{\sum_{i} x_i \varphi_{ij}}{\sum_{i} \varphi_{ij}} \times 100$$

City (MSA)	Tech. class (3 digits)	Density (%)
New-York	428	10
New-York	524	100
Los Angeles	428	80
Los Angeles	524	0
...	...	...

*The **Density Index** measures the relatedness of a new technology to the pre-existing set of technologies produced in this particular city.*

Density = a city-technology variable


Relatedness and Technological Change in U.S. cities
Probability of Entry [2006-2010]
Density (%) [2001-2005]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0
5
10
15
20
25
30
Boston
St. Louis
Atlanta
Columbus
Denver
Charlotte
Chicago
Baltimore
New York
Los Angeles
Hartford, CT
Chico, CA
Rocky Mount, NC
Norwich, CT
Dalton, GA
Victoria, TX

The econometric model

$$Entry_{i,c,t} = \beta_1 Density_{i,c,t-1} + \beta_2 City_{c,t-1} + \beta_3 Techno_{i,t-1} + \phi_c + \psi_i + \alpha_t + \varepsilon_{i,c,t}$$

***Entry$_{i,c,t}$* = 1** *if a technology i that did not belong to the portfolio of the city c in time t-1 enters its technology space in time t.*

Emergence of new technologies in U.S. cities (1981-2010)

Dependent variable is: **Entry $_t$**	Model 1 Rel. density	Model 2 City variables	Model 3 Tech. variables	Model 4 Full model	Model 5 Full model (F.E.)
Relatedness density $_{t-1}$	0.00515979 ** (0.00012770)			0.00373407 ** (0.00014135)	0.00271463 ** (0.00016884)
Log (Employment) $_{t-1}$		0.04934166 ** (0.00286818)		0.03611889 ** (0.00247147)	0.04633250 ** (0.00782869)
Population density $_{t-1}$		0.00001106 (0.00000997)		0.00002520 ** (0.00000843)	-0.00021341 ** (0.00003836)
Inventive capacity $_{t-1}$		0.07718815 ** (0.01294204)		0.03883926 ** (0.0078352020)	-0.08487966 ** (0.01505564)
Tech. Specialization $_{t-1}$		-0.00089296 ** (0.00011548)		-0.00047160 ** (0.00009315)	0.00005120 (0.00011022)
MSA growth rate $_{t-1}$		0.04443962 ** (0.00355534)		0.04032813 ** (0.00353667)	0.00865397 ** (0.00298386)
Log (Income per employee) $_{t-1}$		-0.07584685 ** (0.00441610)		-0.10127439 ** (0.00538561)	0.00368879 (0.01663469)
Log (Nb. Inventors) $_{t-1}$			0.02658895 ** (0.00197752)	0.02324554 ** (0.00183672)	0.00159990 (0.00246612)
Tech. concentration $_{t-1}$			-0.00102840 ** (0.00014936)	-0.00010693 (0.00011541)	0.00041990 * (0.00016760)
Date established $_{t-1}$			-0.00056684 ** (0.00007012)	-0.00042520 ** (0.00005456)	-0.00330620 ** (0.00017699)
Tech. growth rate $_{t-1}$			0.01423964 ** (0.00233334)	0.02183910 ** (0.00285492)	0.01141729 ** (0.00260757)
Constant	0.09258502 ** (0.00194271)	0.09296771 ** (0.00378306)	0.09019069 ** (0.00398429)	0.08909252 ** (0.00183778)	0.11108572 ** (0.01040890)
City F.E.	No	No	No	No	Yes
Technology F.E.	No	No	No	No	Yes
Period F.E.	No	No	No	No	Yes
R^2	0.11	0.04	0.02	0.13	0.16
N	748,458	653,660	656,618	572,550	572,550

*Notes: The dependent variable entry = 1 if a given technology (n = 438) enters in the technological portfolio of a given city (n = 366) during the corresponding 5-years window (n = 6), and 0 otherwise. The independent variables are centered around their mean. Coefficients are statistically significant at the *p <0.05; and **p <0.01 level. Heteroskedasticity-robust standard errors (clustered at the city and technology level) in parentheses.*

Entry of new technologies in U.S. cities - Robustness check

Dependent variable is: **Entry** $_t$	**Alternative relatedness measures**		**Outliers analysis**			**GLM specifications**	
	Model COOC [Fixed Effects]	Model USPTO [Fixed Effects]	w/o top density[#]	w/o top cities[†]	w/o top techno[‡]	Logistic regression	Probit regression
Density $_{t-1}$ [baseline]			0.00224635 ** (0.00016733)	0.00264742 ** (0.00018286)	0.00239119 ** (0.00017202)	0.0216442 ** (0.0002433)	0.0125646 ** (0.0001334)
Density $_{t-1}$ [COOC]	0.00184525 ** (0.00016940)						
Density $_{t-1}$ [USPTO]		0.00142651 ** (0.00014815)					
City controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tech. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City F.E.	Yes	Yes	Yes	Yes	Yes	No	No
Technology F.E.	Yes	Yes	Yes	Yes	Yes	No	No
Period F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2/Pseudo R^2	0.15	0.15	0.11	0.15	0.14	0.19	0.19
N	572,550	572,550	495,077	515,350	514,091	572,550	572,550

*Notes: The dependent variable entry = 1 if a given technology (n = 438) enters in the technological portfolio of a given city (n = 366) during the corresponding 5-years window (n = 6), and 0 otherwise. Coefficients are statistically significant at the *p < 0.05; and **p <0.01 level. Heteroskedasticity-robust standard errors (clustered at the city-technology level for the logistic and probit regression; clustered at the city and technology level in all other regressions) in parentheses.*

[#] *The top 10% of the city-technology pairs with the highest density are dropped.*

[†] *The top 10% of the cities that experienced the highest number of technology entry are dropped.*

[‡] *The top 10% of the technologies that entered cities the most frequently are dropped.*

Exit of technologies in U.S. cities (1981-2010)

Dependent variable is: **Exit** $_t$	Model 1 Rel. density	Model 2 City variables	Model 3 Tech. variables	Model 4 Full model	Model 5 Full model (F.E.)
Relatedness density $_{t-1}$	-0.00646272 ** (0.00013398)			-0.00384300 ** (0.00022311)	-0.00287999 ** (0.00021200)
Log (Employment) $_{t-1}$		-0.10857437 ** (0.00614202)		-0.06943327 ** (0.00626204)	-0.08359852 ** (0.01651044)
Population density $_{t-1}$		-0.00003837 * (0.00001950)		-0.00006553 ** (0.00001364)	-0.00011335 * (0.00004718)
Inventive capacity $_{t-1}$		-0.16931248 ** (.05336078)		-0.11188970 ** (.02941733)	-0.02739567 ** (.00841076)
Tech. Specialization $_{t-1}$		0.00437970 ** (0.00061919)		0.00180088 ** (0.00040634)	-0.00056492 (0.00042826)
MSA growth rate $_{t-1}$		-0.16187457 ** (0.00828661)		-0.15036339 ** (0.00882790)	-0.01352593 (0.00966971)
Log (Income per employee) $_{t-1}$		0.22689471 ** (0.01306891)		0.31767021 ** (0.01236049)	0.04962913 (0.03082188)
Log (Nb. Inventors) $_{t-1}$			-0.04660531 ** (0.00593058)	-0.09098814 ** (0.00406299)	-0.05541312 ** (0.00624571)
Tech. concentration $_{t-1}$			0.00418752 ** (0.00047497)	-0.00137922 ** (0.00043938)	-0.00200006 ** (0.00058743)
Date established $_{t-1}$			-0.00018739 (0.00011545)	0.00022470 * (0.00010297)	0.00233776 ** (0.00022809)
Tech. growth rate $_{t-1}$			-0.06741134 ** (0.00590281)	-0.05102216 ** (0.00701074)	-0.01451667 * (0.00652948)
Constant	0.36547167 ** (0.00609779)	0.36534949 ** (0.00841466)	0.36590647 ** (0.01460965)	0.36470402 ** (0.00426248)	0.54798934 ** (0.03747886)
City F.E.	No	No	No	No	Yes
Technology F.E.	No	No	No	No	Yes
Period F.E.	No	No	No	No	Yes
R^2	0.19	0.15	0.03	0.25	0.30
N	213,390	202,584	201,286	191,313	191,313

*Notes: The dependent variable entry = 1 if a given technology (n = 438) exits the technological portfolio of a given city (n = 366) during the corresponding 5-years window (n = 6), and 0 otherwise. The independent variables are centered around their mean. Coefficients are statistically significant at the *p < 0.05; and **p <0.01 level. Heteroskedasticity-robust standard errors (clustered at the city and technology level) in parentheses.*

Conclusion & discussion

- Relatedness has been a crucial driving force behind technological change in U.S. Cities over the past 30 years
- When density of related technologies increases by 10%, the probability of entry increases by about 30 to 55%
- Knowledge transfer dynamics should be encouraged to foster the branching process between incumbents and new techs
- The big question: policy implications of these findings? role of institutions?

Toward a (twofold) diagnostic tool

- We can characterize the knowledge structure of each city by looking at the patents they produce

- Two potential applications:

    - <u>At the city level:</u> support the technological development of cities by "forecasting" their technological trajectory (identification of potential new developments, optimization of their knowledge structure)

    - <u>At the technology level:</u> support the development of a specific technology (green tech) by identifying the cities that have the most favorable knowledge bases for the growth of this specific tech.

Thanks for your attention !

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The US city-knowledge network

366 MSA (cities)
438 tech. classes (knowledge)
USPTO data
> 2,000,000 patents