Colocation of Production and Innovation: Evidence from the United States

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Disclaimer

This work is unofficial and thus has not undergone the review accorded to official Census Bureau publications. All results have been reviewed to ensure that no confidential information is disclosed. The views expressed in the paper are those of the authors and not necessarily those of the U.S. Census Bureau. DRB Approval Numbers CBDRB-FY20-P1916-R8726 and CBDRB-FY20-P1916-R8756.

Motivation

- Manufactures have traditionally performed the majority of innovation
- US manufacturing employment is declining
- Concern that manufacturing loss will reduce US innovation
  - Import competition from low-wage countries
  - Offshoring of production to low-wage countries
- "Once manufacturing departs from a country's shores, engineering and production know-how leave as well, and innovation ultimately follows. It's become increasingly clear that 'manufacture there' now also means 'innovate there'." (WSJ 2019)
- Ideas seem to be getting harder to find (Bloom et al. 2020)

Main questions

- How have the mix and activities of innovating firms evolved over time?
- Does R&D need to be colocated with manufacturing?
- What mechanisms drive this relationship?

Why shocks to manufacturing may affect innovation

- Complementarities between production and R&D?
- Gains from reallocation and specialization?
- Colocation can occur within geographic borders, firm borders, or both

Main Contributions

- Trends for US innovators from 1977 to 2016
  - Patenting shifts from manufacturing (MFs) to non-manufacturing firms (NMFs)
  - Later cohorts of former manufacturers firms (FMFs) continue innovating
- Firms with manufacturing (M) and innovation (P) plants patent more
  - M and P plants tend to spread out within firms over time, but some remain very close
  - Firms with M and P plants within 5 miles patent relatively more ($\approx$12 percent)
- Future plans
  - Analyze where patenting occurs within firms
  - Analyze margins that drive changes in colocation
  - Estimate relationship with patenting and proximity across firms

Outline of Talk

- Portrait of US innovation
- New measures of M and P plant colocation
- Descriptive relationship between colocation and innovation
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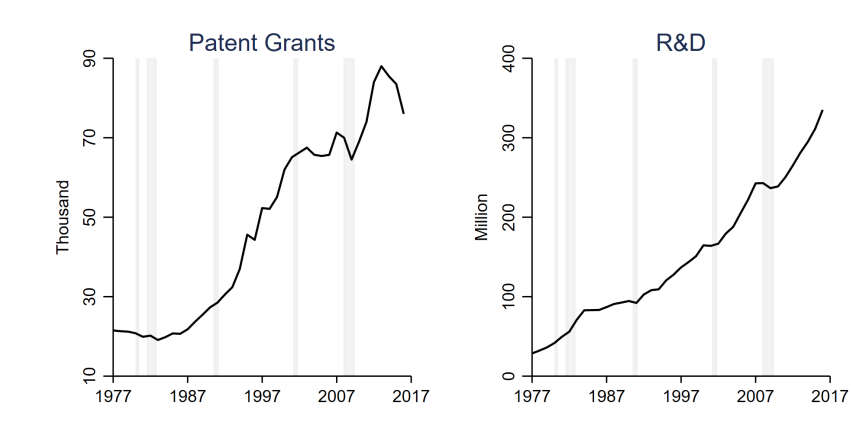
New dataset on US innovation from 1977 to 2016

- Longitudinal Business Database
  - Every private, non-farm employer establishment from 1977 to 2016
  - Consistent establishment-level NAICS classification (Fort and Klimek 2018)
  - **Establishment geocodes from the Business Register**
- Economic Censuses of manufacturing, wholesale, retail, and services
  - Establishment-level sales, inputs, etc. at 5-year intervals
- Longitudinal foreign trade transactions database
  - Firm-level import and export transactions from 1992 to 2016
- R&D surveys at the enterprise level from 1977 to 2016
  - Survey on Industrial Research and Development (1977-2007)
  - Business R&D and Innovation Survey (2008-2016)
- USPTO database on **US patents from 1973 to 2018**
  - Name and address matching to firms and firm-city-states in LBD
  - Identify manufacturing and processing patents

US innovation grows over the last 40 years



- We examine granted patents by their application year

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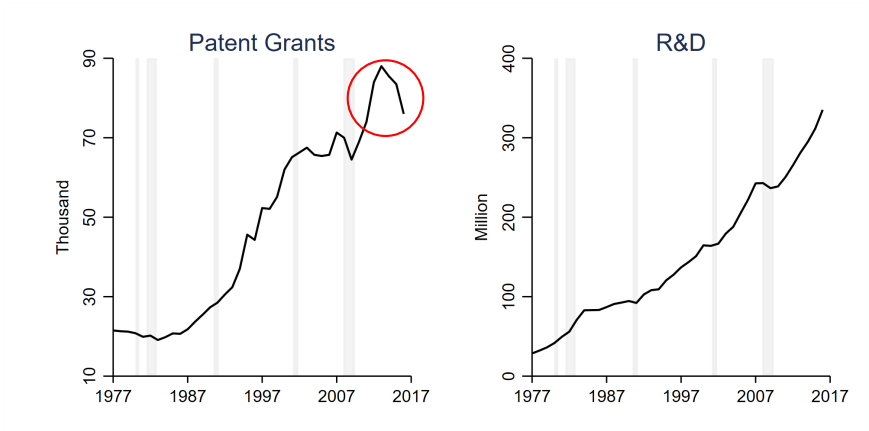
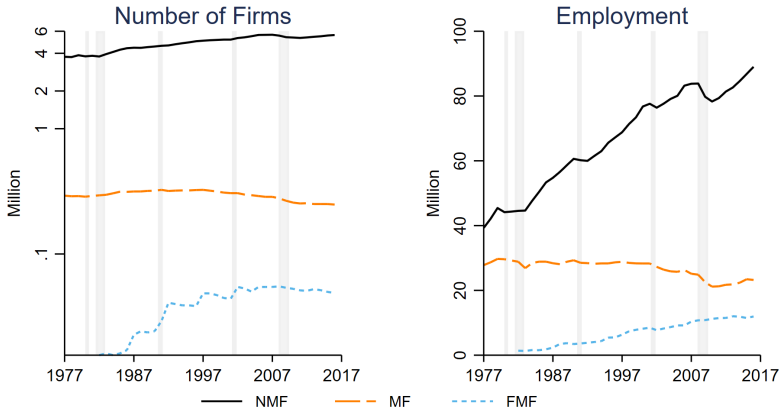


- We examine granted patents by their application year
- The decline in 2015 is an artifact of the application to grant lag

We define firm types to analyze innovators

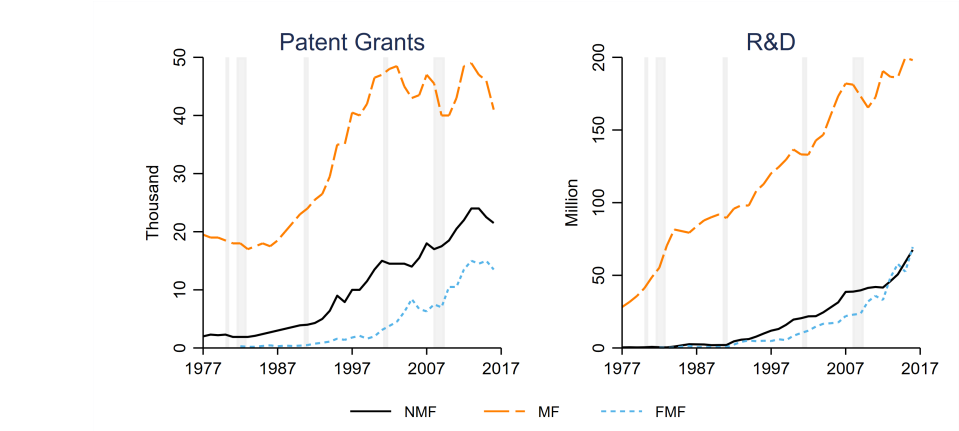
- Classify firms into 3 mutually-exclusive types by year t
  - *MF*s: Manufacturing firms ($\geq$1 manufaturing plant in year t)
  - *NMF*s: Non-manufacturing firms (0 manufacturing plants up to t)
  - *FMF*s: Former manufacturing firms ($\geq$1 manufacturing plant prior to t; 0 in t)

Firms outside manufacturing dominate in levels and growth



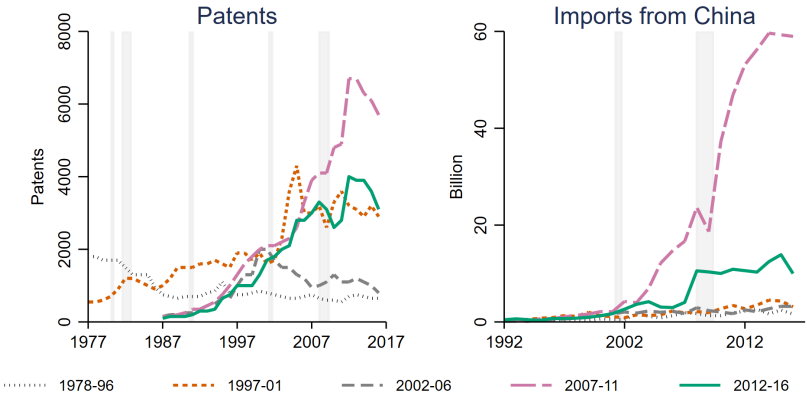
- Manufacturing firms (*MF*s) have non-manufacturing employment
- Former manufacturing firms (*FMF*s) have considerable growth

Manufacturing firms dominate US innovation



- *MF*s' patent shares decline from 91% to 54% in 2016
- *NMF*s' account for 28% of patents in 2016
- *FMF*s' account for 18% of patents in 2016

Permanent *FMF*s' patents differ by cohort



- Firms that exit manufacturing from 2007-11 exhibit strongest growth
- 2007-11 cohort also exhibits dramatic Chinese import growth
- Employment dynamics across cohorts are more similar

Summary of new facts

- Firms outside manufacturing grow their share of patents and R&D
- Some firms that exit manufacturing continue patenting intensively
- Imports by patenting firms suggestive of offshoring

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Measuring the colocation of US production and innovation

- Identify establishments focused on innovation (P plants)
  - Scientific Research and Development Services (i.e., R&D labs), NAICS 5417
  - Professional Scientific and Technical Services, NAICS 5413-5416
  - Corporate, Subsidiary, and Regional Managing Offices (i.e., HQs), NAICS 551114
  - Information and Telecommunications, NAICS 5112, 517, 518
- Descriptive regressions on patenting and firm types indicate
  - **Firms with M and P estabs patent 65 percentage points more**
  - **Within firms, patenting is 15 pp higher when firm has M and P estabs**
  - Control for time-varying firm size, age, and patent stocks
- Measure the distance between innovation and manufacturing estabs
  - Focus on firms with both M and P, i.e., MP firms
  - Average distance between estabs: $dist_{ft}^{avg}$
  - Minimum distance between estabs: $dist_{ft}^{min}$
  - Calculate the median and average of these firm-level measures

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Colocation of *MP* firms' *M* and *P* plants

	Minimum ($dist_{ft}^{min}$)		Average ($dist_{ft}^{avg}$)	
	Mean	Median	Mean	Median
1977	95	3	445	301
1982	115	4	457	322
1987	120	5	470	336
1992	141	6	487	359
1997	153	6	502	381
2002	139	5	501	387
2007	142	5	498	383
2012	137	6	517	416

- The median firm has at least one proximate pair of *M* and *P* establishments
- Average distances are much larger than minimums
- Distances grow over time, but the minimum distance stays small

▸ Patents ▸ Employment

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The relationship between innovation and colocation for *MP* firms

- Estimate how patenting relates to distance between M and P establishments

$$\begin{aligned} ln(\widetilde{y}_{ft}) = \quad & \delta_1 \left[dist_{ft}^{min} \in (0,5) \right] + \delta_2 \left[dist_{ft}^{min} \in (5,60) \right] + \\ & \gamma ln(PatentStock_{f,t-1}^{dep}) + \beta X_{ft} + \alpha_t + \alpha_c + \alpha_f + \varepsilon_{fct} \end{aligned}$$

- $ln(\widetilde{y}_{ft})$: $sinh^{-1}$ transform of firm's granted patents applied for in t:$t+4$
- $dist_{ft}^{min}$: indicators for the minimum distance between firm's M and P plants
- $ln(PatentStock_{f,t-1}^{dep})$: firm's depreciated and 1-year lagged patent stock
- X_{ft}: time-varying firm size and age controls
- $\alpha_t, \alpha_c, \alpha_f$: year, county, and firm fixed effects
- Omitted category is *MP* firms with M & P plants over 60 miles apart

MP firm patenting is higher when *M* and *P* estabs are closer

Dependent variable is: $ln(y_{f,t:t+4})$

	(1)	(2)	(3)	(4)
	patents	citations	manuf patents	process pats
$dist_{ft}^{min} \in (0,5)$	0.116***	0.243***	0.115***	0.0682***
	(0.0279)	(0.051)	(0.026)	(0.020)
$dist_{ft}^{min} \in (5,60)$	0.0764***	0.133**	0.0721***	0.0415**
	(0.028)	(0.052)	(0.027)	(0.021)
$ln(Patent\ Stock_{f,t-1}^{dep})$	0.278***	0.126***	0.264***	0.278***
	(0.015)	(0.023)	(0.015)	(0.014)
Emp_{ft}, Age_{ft}	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
FIPS Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.881	0.835	0.883	0.872
Observations	34,500	34,500	34,500	34,500

Dep var is inverse hyperbolic sine transformation of the sum of subsequently granted patents (or citations) applied for by firm f in years t to $t+4$. Standard errors clustered by firm. * p<0.10, ** p<0.05, *** p<0.01

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Analyze whether patent creation occurs in firms' colocated regions

- Use inventor locations to assign patents to regions (CZs) and estimate:

$$\begin{aligned} ln(\widetilde{y}_{frst}) = \quad & \gamma_1 M_{frst} + \gamma_2 P_{frst} + \gamma_3 (M_{frst} \times P_{frst}) + \\ & \delta ln(PatentStock^{dep}_{frs,t-1}) + \beta X_{frst} + \alpha_t + \alpha_r + \alpha_s + \alpha_f + \varepsilon_{frt} \end{aligned}$$

- M and P are indicators of (or emp in) plants of firm f in region r and state s
- Identify spillovers using *other* firms' M and P employment in region
- Include firm-time, region-time, and firm-region fixed effects

Policy-induced changes to the cost of R&D

- Exploit plausibly exogenous variation in R&D costs across years and states
- Use inventor locations to assign patents to regions (CZs) and estimate:

$$
\begin{aligned}
ln(\widetilde{y}_{frst}) = \quad & \gamma_1 M_{frst} + \gamma_2 P_{frst} + \gamma_3 (M_{frst} \times P_{frst}) + \\
& \eta RD_{st} + \eta_1 (M_{frst} \times RD_{st}) + \eta_2 (P_{frst} \times RD_{st}) + \eta_3 (M_{frst} \times P_{frst} \times RD_{st}) + \\
& \delta ln(PatentStock^{dep}_{frs,t-1}) + \beta X_{frst} + \alpha_t + \alpha_r + \alpha_s + \alpha_f + \varepsilon_{frt}
\end{aligned}
$$

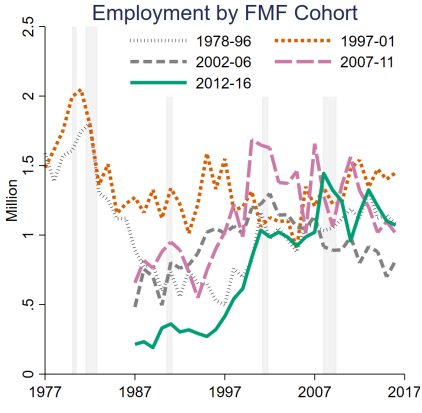
- RD_{st} measures state-by-year R&D tax credits
- η_3 tells us if the effect of lower R&D costs is highest in a firm's colocated regions
- M and P are indicators of (or emp in) plants of firm f in region r and state s
- Identify spillovers using *other* firms' M and P employment in region
- Include firm-time, region-time, and firm-region fixed effects

Conclusion

- Non-manufacturers' share of aggregate patents grows from 9% to 46%
- Firms with M and P establishments still seem to innovate most
- Considerable spatial distribution in these M and P estabs within firms
- Firm patents are higher when their M and P estabs are colocated
- Still need to understand what drives this relationship
  - Does patenting occur in the colocated regions?
  - Is R&D more productive in colocated regions?

Appendix

Former manufacturing firms' employment by cohort



- Employment dynamics are similar in 2000s
- Cohort that exits in 2002-06 least resilient

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NAICS 5413-5416 and 5112, 517, 518

- Professional, Scientific, and Technical Services
  - 5413: Architectural, Engineering, and Related Services
  - 5414: Specialized Design Services
  - 5415: Computer Systems Design and Related Services
  - 5416: Management, Scientific, and Technical Consulting Services
- Information
  - 5112: Software Publishers
  - 517: Telecommunications
  - 518: Data Processing, Hosting, and Related Services

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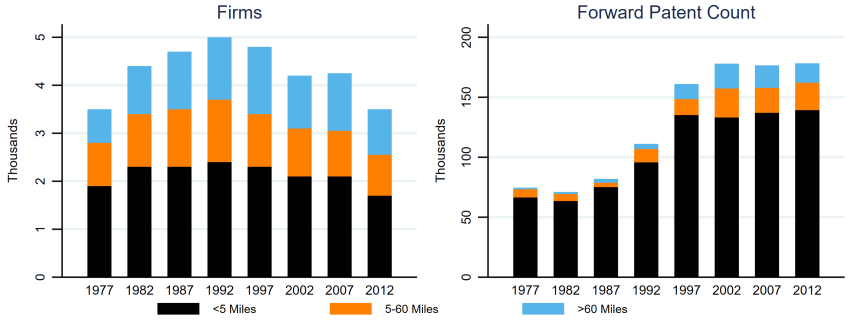
Distribution of *MP* firms and their patents by distance bins



- Firms with colocated M and P plants patent more

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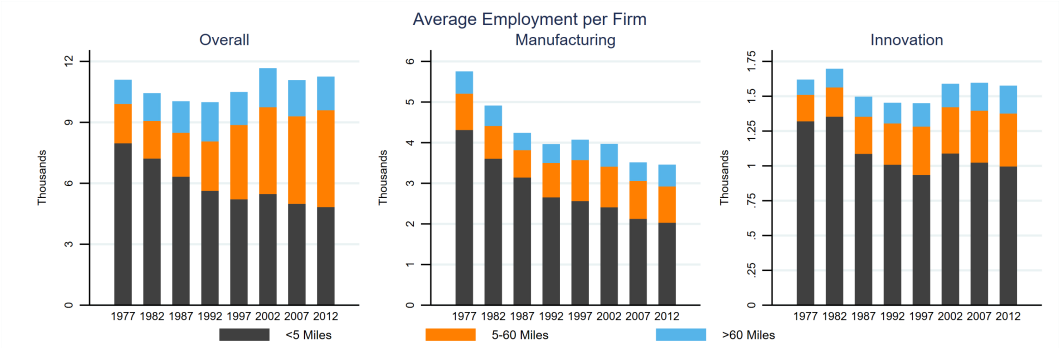
MP firms are reallocating workers towards *P*



- Average *M&P* firm size fairly constant
- Manufacturing employment shrinks most for colocated firms

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Bristol Meyers Squibb: Patent 10167343

(12) **United States Patent**
Lonberg et al.

(10) **Patent No.: US 10,167,343 B2**
(45) **Date of Patent: Jan. 1, 2019**

(54) **ANTIBODIES AGAINST CD73**

(71) Applicant: **BRISTOL-MYERS SQUIBB COMPANY**, Princeton, NJ (US)

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(73) Assignee: **BRISTOL-MYERS SQUIBB COMPANY**, Princeton, NJ (US)

(2013.01); ***C07K 16/3069*** (2013.01); ***G01N 33/573*** (2013.01); *A61K 2039/505* (2013.01); *C07K 2317/21* (2013.01); *C07K 2317/31* (2013.01); *C07K 2317/34* (2013.01); *C07K 2317/52* (2013.01); *C07K 2317/522* (2013.01); *C07K 2317/524* (2013.01); *C07K 2317/526* (2013.01); *C07K 2317/53* (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC C07K 2317/92; C07K 2317/76; C07K 2317/56; C07K 2317/21; C07K 2317/34; C07K 16/40; C07K 2317/31; C07K 2317/565; C07K 2317/71; C07K 2317/77; C07K 16/30; C07K 2317/521; C07K 2317/522; C07K 2317/524; C07K 2317/526; C07K 16/3015; C07K 2317/54; C07K 2317/55; A61K 2039/505; A61K 45/06; A61K 49/49558
See application file for complete search history.

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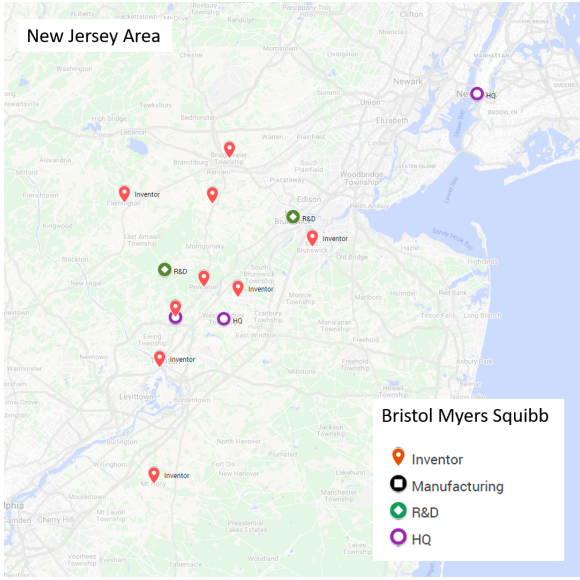
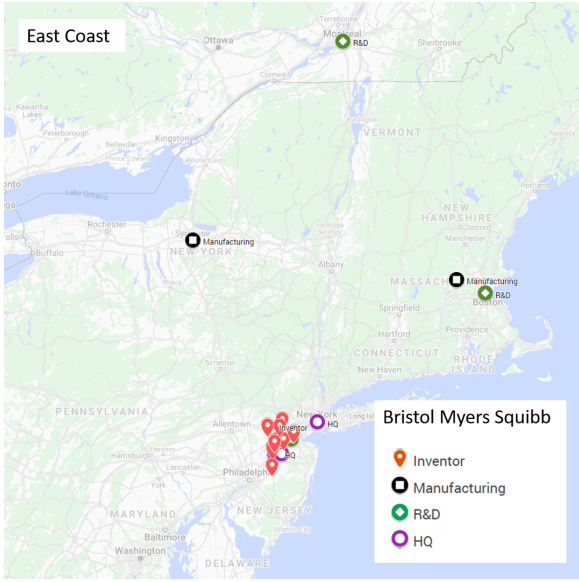
Bristol Meyers Squibb: Patent 10167343



5 plants and 10 inventors

New Brunswick facility recently transitioned from manufacturing to R&D

Bristol Meyers Squibb: Patent 10167343



2 R&D labs in Cambridge

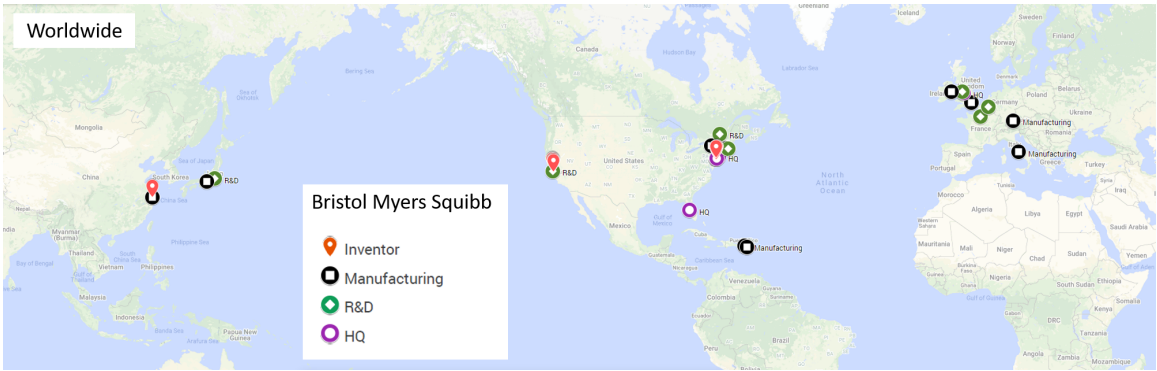
Manufacturing and R&D are colocated in MA

Bristol Meyers Squibb: Patent 10167343

Additional R&D lab in Redwood City, CA and many inventors in area

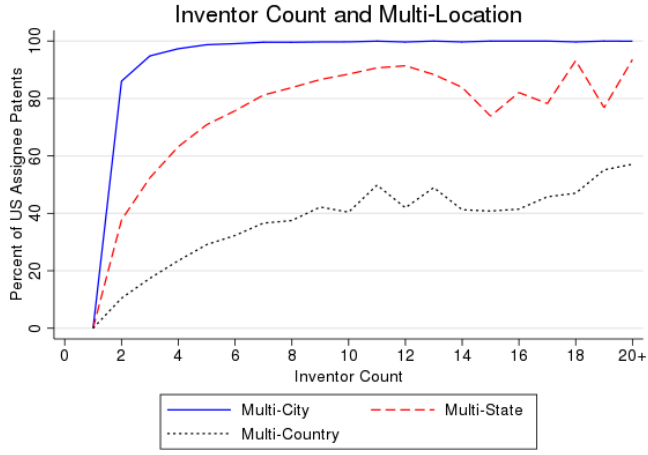
Additional manufacturing plants in Puerto Rico

Bristol Meyers Squibb: Patent 10167343



- 1 manufacturing estab in Shanghai
- 1 inventor also in Shanghai

Inventors tend to span cities and states



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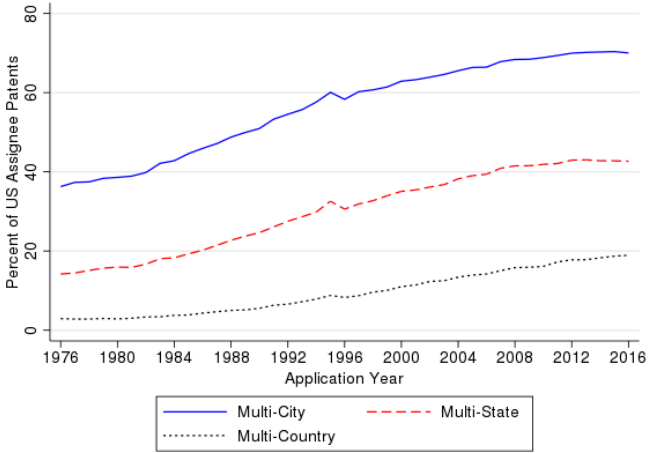
Inventor dispersion has grown over time



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