Mini Course on:
Economics of Ideas and Innovation-Led Growth
Part 2

Ufuk Akcigit
University of Pennsylvania & NBER

July 23, 2013 - Bilkent University

Safety Pin

Walter Hunt (1796-1859)

USPTO Patent Number 6281

UNITED STATES PATENT OFFICE.

WALTER HUNT, OF NEW YORK, N. Y., ASSIGNOR TO WM. RICHARDSON AND JNO. RICHARDSON.

DRESS-PIN.

Specification of Letters Patent No. 6,281, dated April 10, 1849.

To all whom it may concern:

Be it known that I, WALTER HUNT, of the city, county, and State of New York, have invented a new and useful Improvement in the Make or Form of Dress-Pins, of which the following is a faithful and accurate description.

The distinguishing features of this invention consist in the construction of a pin made of one piece of wire or metal combining a spring, and clasp or catch, in which catch, the point of said pin is forced and by its own spring securely retained. They may be made of common pin wire, or of the precious metals.

See Figure 1 in the annexed drawings (which are drawn upon a full scale, and in which the same letters refer to similar parts,) which figure presents a side view of said pin, and in which is shown the three distinct mechanical features, viz: the pin A, the coiled spring B, and the catch D, which is made at the extreme end of the wire bar C, extended from B. Fig. 2 is a similar view of a pin with an elliptical coiled spring, the pin being detached from the catch D and thrown open by the spring B. Fig. 3 gives a top view of the same. Fig. 4 is a top view of the spring made in a flat spiral coil. Fig. 5 is a side view of the same.

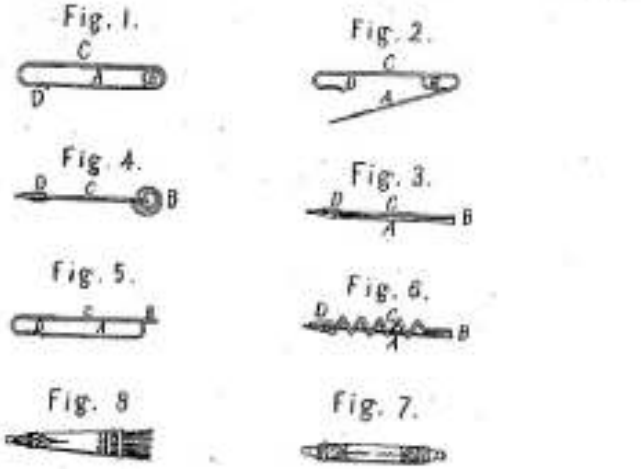
Any ornamental design may be attached to the bar C, (see Figs. 6, 7 and 8,) which combined with the advantages of the spring and catch, renders it equally ornamental, and at the same time more secure and durable than any other plan of a clasp pin, heretofore in use, there being no joint to break or pivot to wear or get loose as in other plans. Another great advantage unknown in other plans is found in the perfect convenience of inserting these into the dress, without danger of bending the pin, or wounding the fingers, which renders them equally adapted to either ornamental, common dress, or nursery uses. The same principle is applicable to hair-pins.

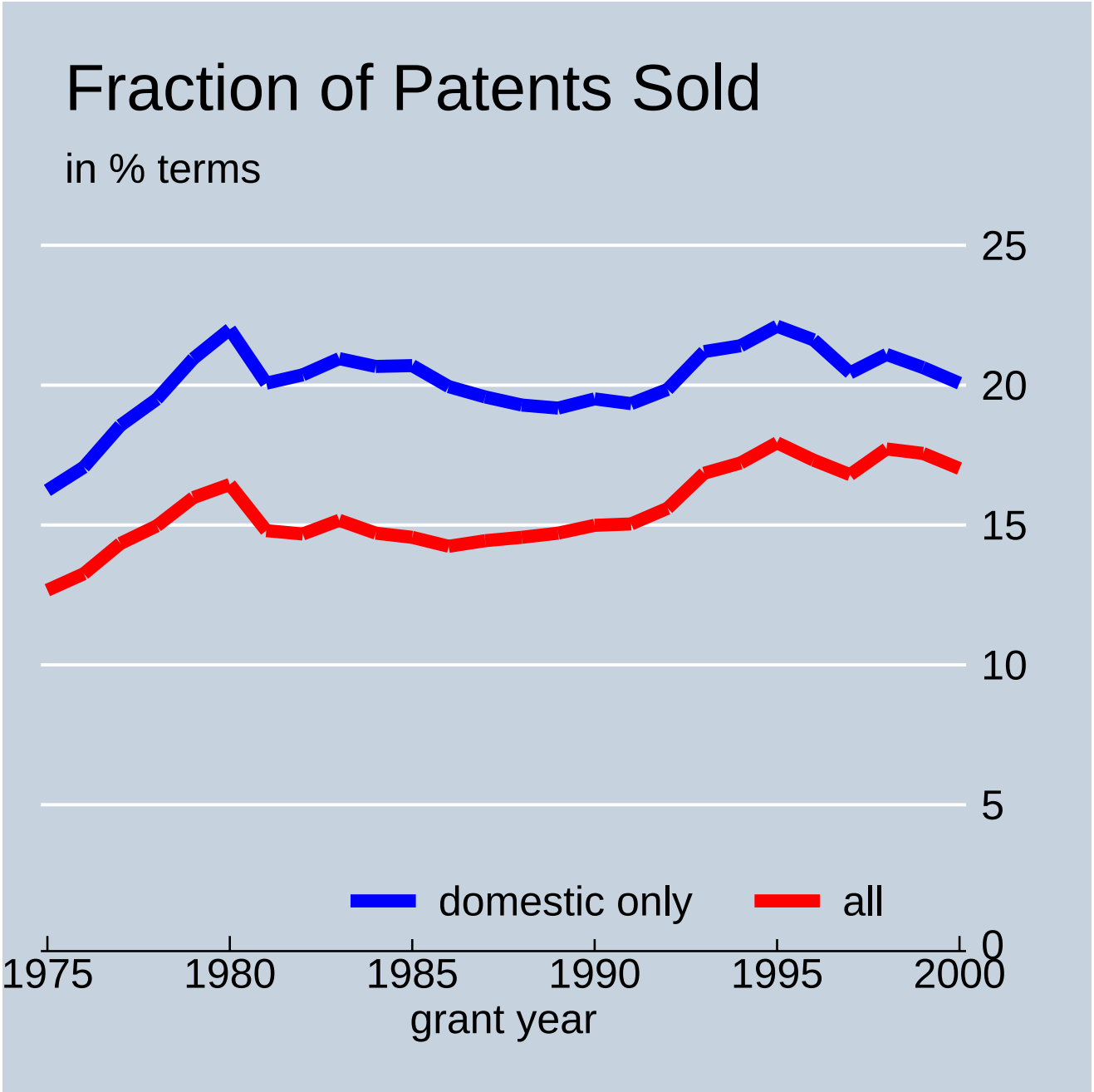
My claims in the above described invention, for which I desire to secure Letters Patent are confined to the construction of dress-pins, hair-pins, &c., made from one entire piece of wire or metal, (without a joint or hinge, or any additional metal except for ornament,) forming said pin and combining with it in one and the same piece of wire, a coiled or curved spring, and a clasp or catch, constructed substantially as above set forth and described.

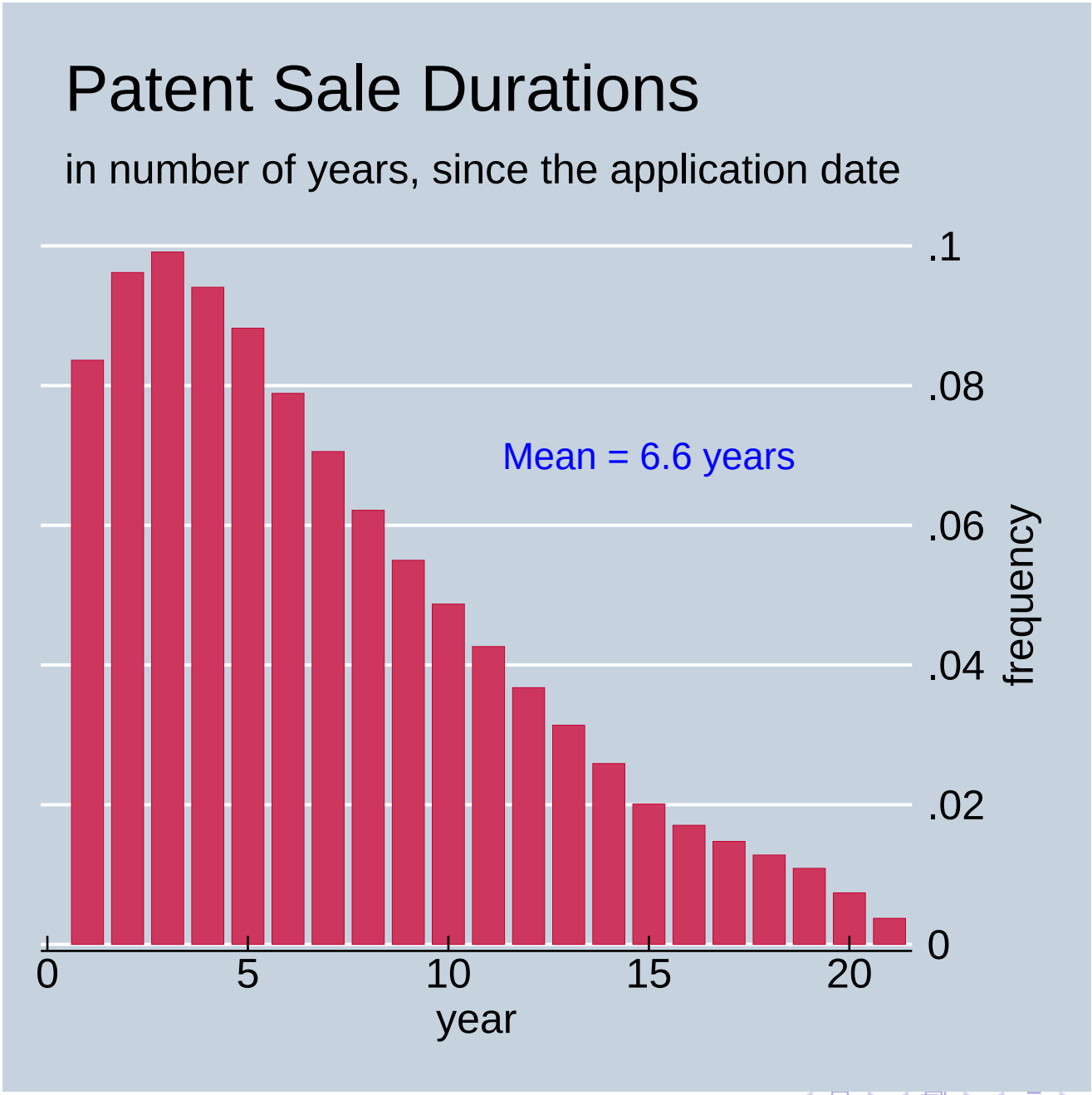
WALTER HUNT.

Witnesses:
JOHN M. KNOX,
JNO. R. CHAPIN.

W. Hunt.
Pin.
No 6281. Patented Apr. 10. 1849.




Fraction of Patents Sold
in % terms
25
20
15
10
5
0
domestic only
all
1975
1980
1985
1990
1995
2000
grant year


Patent Sale Durations
in number of years, since the application date
Mean = 6.6 years
.1
.08
.06
.04
.02
0
frequency
0
5
10
15
20
year

Motivation

- Ideas are the engines of economic progress.
- Ideas may be initially mismatched.
- Questions:
  - Is there a misallocation of ideas?
  - Can we quantify its degree?
  - Does the patent resale market mitigate misallocation?
  - How does the misallocation affect growth?

This paper

- Empirics of Firm Dynamics and Patents
  - An empirical measure of technological distance is constructed.
  - A number of empirical facts are obtained from firm & patent data.
- Theoretical Model
  - Ingriedients:
    - the misallocation of ideas
    - the nature of the search frictions
    - the implications for economic growth
  - BGP is completely characterized
  - Stationary firm-size distribution
- Quantitative Analysis
  - The model is calibrated to moments derived from patent technology class, citations, resale, and firm dynamics.
  - Thought experiments to quantify the extent of misallocation due to frictions.

Related Literature

- Growth with matching and other frictions:
  - Chiu, Meh and Wright (2011)
  - Lucas and Moll (2011)
  - Benhabib, Perla, and Tonetti (2012)
  - Chatterjee and Rossi-Hansberg (2012)

- Empirics of patent trades:
  - Serrano (2010, 2013)

Outline

1. Model
2. Data Description
3. Empirical Results
4. Calibration
5. Quantitative Exercises
6. Conclusion

Model

Constructing a Patent-to-Patent Distance Metric

$$d(X,Y) \equiv 1 - \frac{\#(X \cap Y)}{\#(X \cup Y)} \in [0,1]$$

- $\#(X \cap Y)$: Number of patents that cite both X and Y.
- $\#(X \cup Y)$: Number of patents that cite either X or Y or both.
- The more X and Y are cited together, the closer they are.

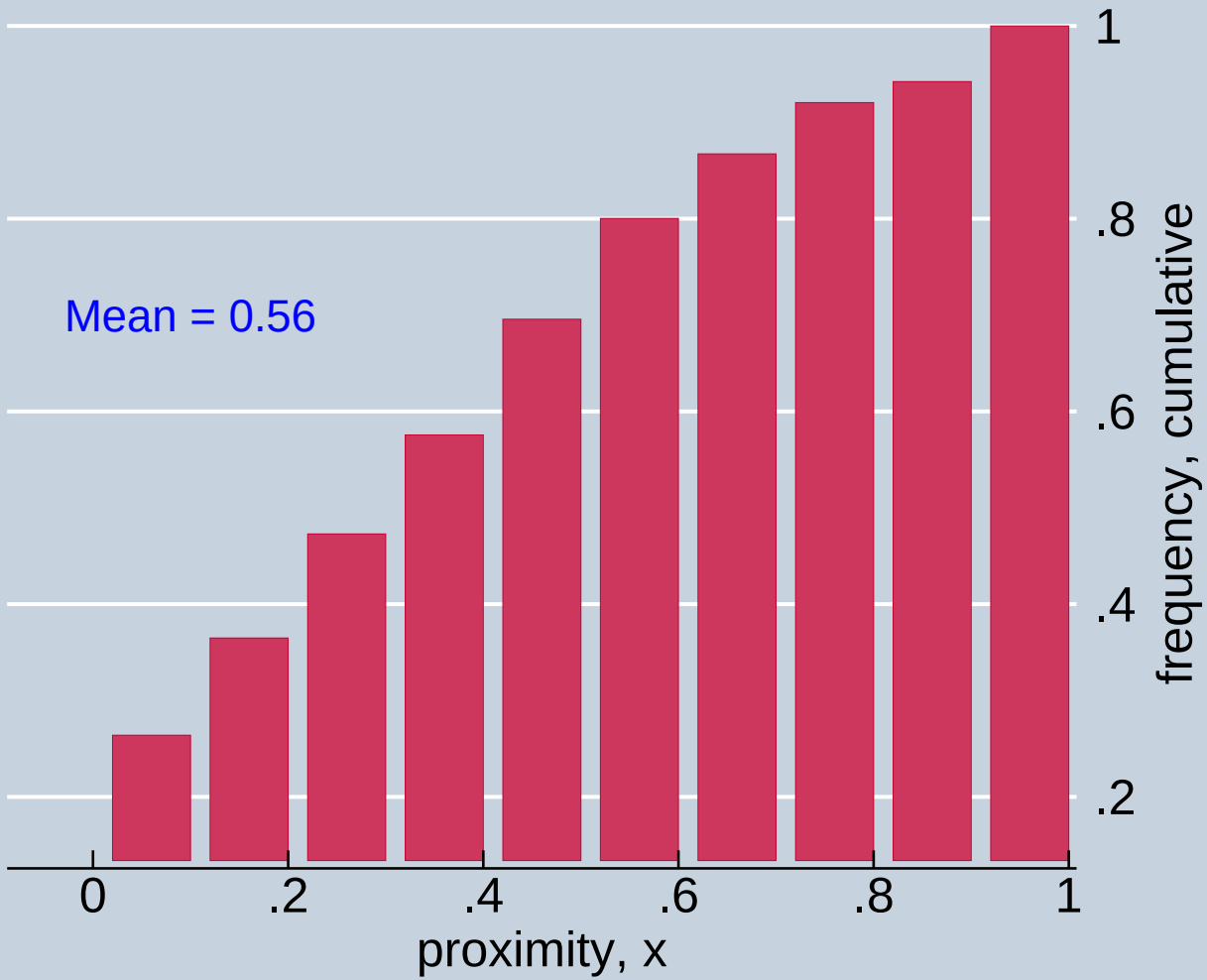
Constructing a Patent-to-Firm Distance Metric

$$d(p,f) \equiv \frac{1}{\|\mathcal{P}_f\|} \sum_{p' \in \mathcal{P}_f} d\left(X_p, Y_{p'}\right) \in [0,1]$$

- p: patent, f: firm
- $\mathcal{P}_f$: patent portfolio of firm f.

Cumulative Proximity Distribution

Proximity to the inventing firm, data



Empirical Facts We Document

1. Real sales and market value are negatively correlated with the distance between a firm and its patents.
2. Patents which are more distant are more likely to be sold.
3. After a patent resale, the distance between a patent and its owner decreases.

Environment

- Time is discrete.
- 3 types of agents: Households, firms, and patent agents.
- Preferences:

$$\sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\epsilon}}{1-\epsilon}$$

- 1 unit of labor is supplied inelastically.
- Household owns all the firms and the capital stock.
- Capital depreciates at rate δ.

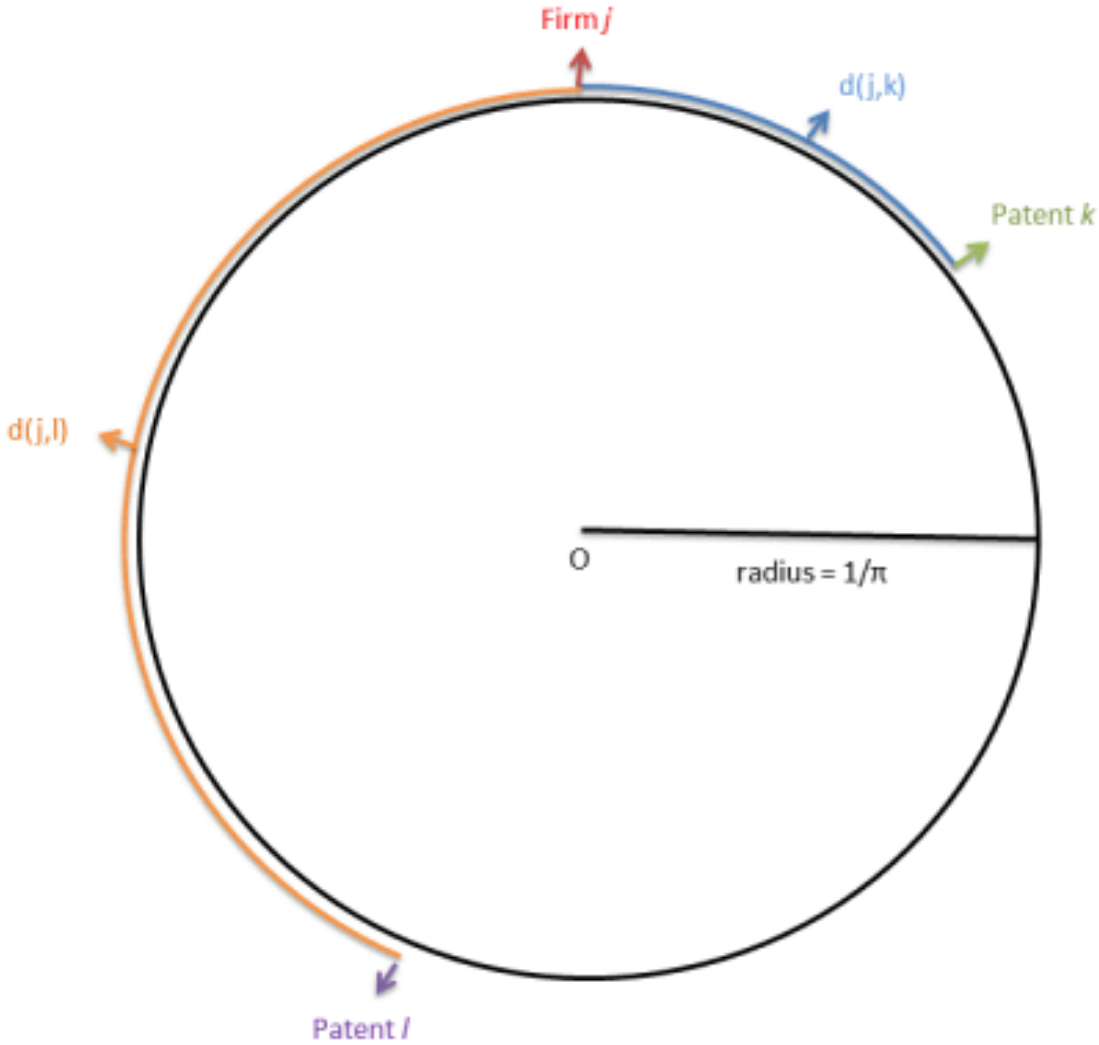
Firms

- Firms produce final output:

$$o = z^{\zeta} k^{\kappa} l^{1-\zeta-\kappa}$$

- Perfect competition.
- Firms are characterized by their productivity z, and technological location.

Technology Circle



Evolution of Productivity

- A firm can increase its productivity by using an idea:

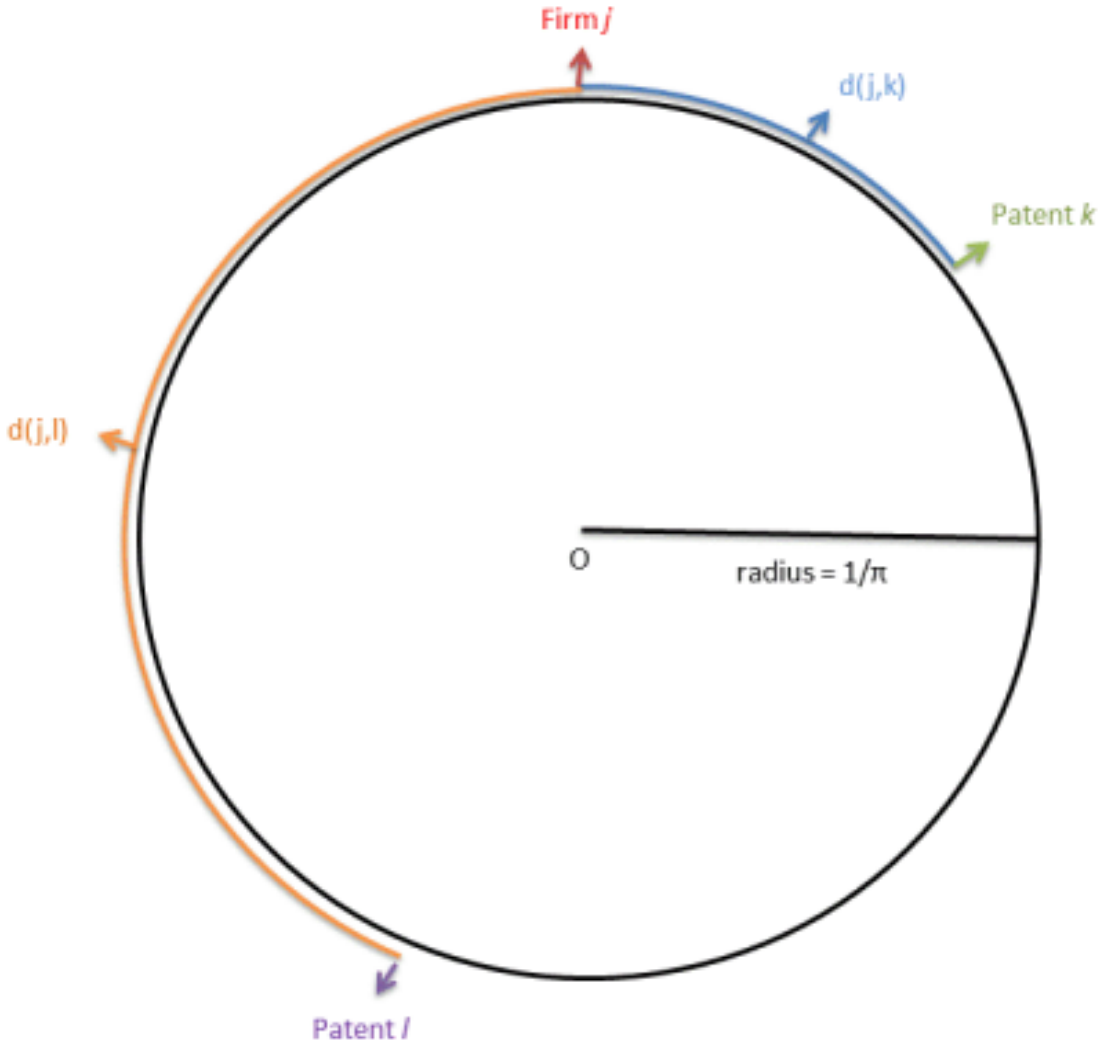
$$z' = L(z, x; \bullet) = z + \gamma\, x\, \mathbf{z}$$

  - z: initial productivity
  - z': new productivity
  - x: proximity of the idea to the firm

$$x \equiv 1 - d$$

  - $\mathbf{z} = \int z dZ(z)$: average productivity
  - γ: scale parameter

Technology Circle



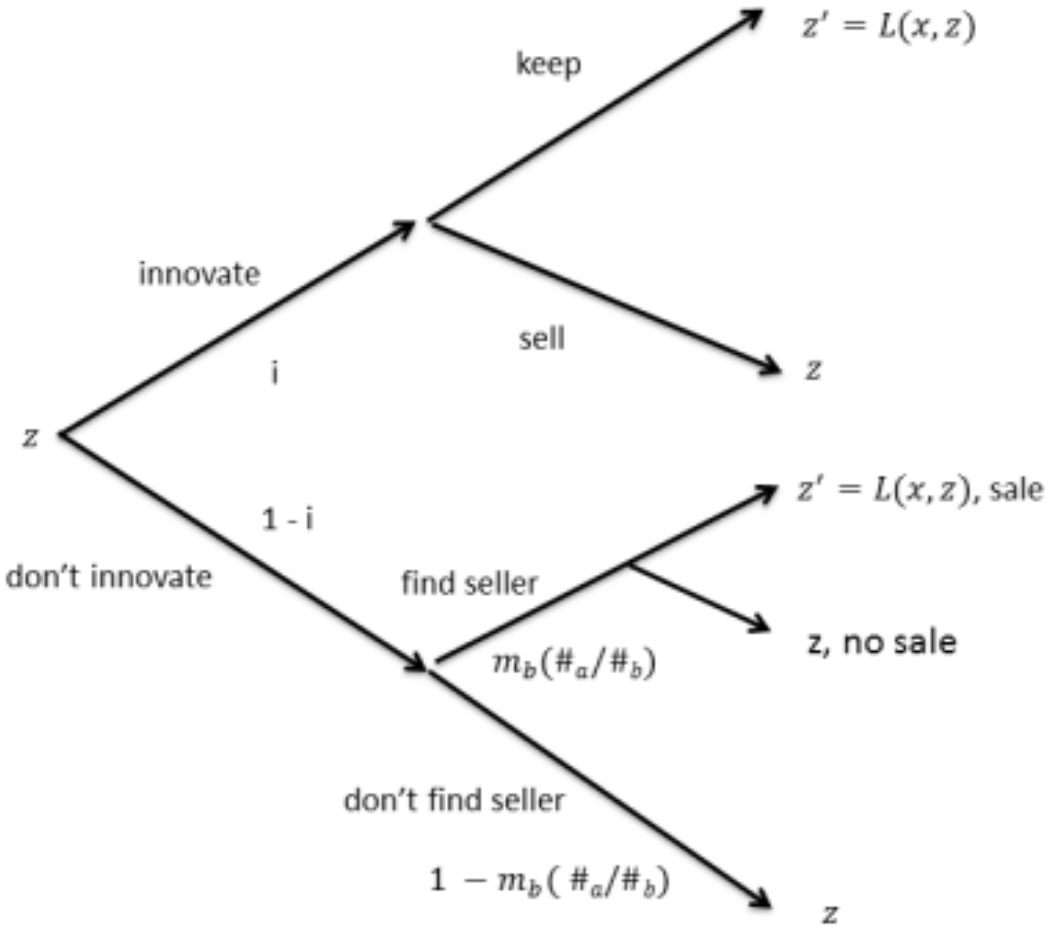
Innovation

- Innovation is costly:

$$C(i;\bullet) = i^{1+\rho}\frac{\chi}{1+\rho}\mathbf{z}^{\zeta/(\zeta+\lambda)}$$

  - i: probability of inventing a new idea
  - χ: R&D cost scale parameter
  - ρ: R&D elasticity parameter
  - $\mathbf{z}^{\zeta/(\zeta+\lambda)}$: endogenous scale factor

Timing of Events for a Firm



Patent Agency & Agents...

- Agency:
  - buys patents from firms at the competitive price q instantenously (w/o S&M frictions).
- Each agent:
  - goes to the market with a single patent to sell,
  - tries to meet a buyer and sell their patent.
  - Matching is subject to search frictions.
  - The buying price P is determined by Nash Bargaining.
  - Bargaining power of patent agents: ω
  - Patents expire at exogeneous rate: $1 - \sigma \approx 1/17$.

Matching Technology

- Total matches:

$$M(\#_a, \#_b) = \eta(\#_a)^{\mu}(\#_b)^{1-\mu}$$

- $\#_a$: measure of patent agents.
- $\#_b$: measure of potential buyers.
- η: matching scale parameter.
- μ: Cobb-Douglas weight of patent agents.

- Matches are completely random with respect to technology class.

Value Function of a Patent Resale Agent

$$
\begin{aligned}
A(\bullet) \quad = \quad & \underbrace{m_a\left(\frac{\#_a}{\#_b}\right)}_{\text{Meet a buyer}} \underbrace{\int\int I_a(z,x;\bullet)P(z,x;\bullet)dG(z)dD(x)}_{\text{Expected sale revenue}} \\
& + \Bigg[\underbrace{m_a\left(\frac{\#_a}{\#_b}\right)\int\int [1-I_a(z,x;\bullet)]dG(z)dD(x)}_{\text{Meet but no trade}} \\
& + \underbrace{[1-m_a\left(\frac{\#_a}{\#_b}\right)]}_{\text{Fail to meet}} \Bigg] \quad \underbrace{r\sigma A(\bullet')}_{\text{Continuation value}}
\end{aligned}
$$

- $I_a(z,x;\bullet) = 1$ if sale, 0 otherwise

Value Function of a Buyer Firm

$$
\begin{aligned}
B(z;\bullet) \quad = \quad & \underbrace{m_b\left(\frac{\#_a}{\#_b}\right)}_{\text{Meet an agent}} \int \Bigg[\underbrace{[1 - I_a(z,x;\bullet)][\Pi(z;\bullet) + rV(z;\bullet')]}_{\text{Don't buy}} \\
& + \underbrace{I_a(z,x;\bullet)[\Pi(\overbrace{L(z,x;\bullet)}^{z'};\bullet) - P(z,x;\bullet) + rV(\overbrace{L(z,x;\bullet)}^{z'};\bullet)]}_{\text{Buy}} \Bigg] dD(x) \\
& + \underbrace{[1 - m_b\left(\frac{\#_a}{\#_b}\right)]}_{\text{Don't meet}} \underbrace{[\Pi(z;\bullet) + rV(z;\bullet')]}_{\text{Produce with old productivity}}
\end{aligned}
$$

Value Function of a Keeper Firm

$$K(L(z,x;\bullet);\bullet) = \underbrace{\Pi(\overbrace{L(z,x;\bullet)}^{z'};\bullet)}_{\text{Period profit}} + \underbrace{rV(\overbrace{L(z,x;\bullet)}^{z'};\bullet')}_{\text{Continuation value}}$$

Value Function of a Seller Firm

$$S(z;\bullet) = \underbrace{\Pi(z;\bullet)}_{\text{Period profit}} + \underbrace{\sigma q}_{\text{Proceeds from sale}} + \underbrace{rV(z;\bullet')}_{\text{Continuation value}}$$

Value Function Before Innovation

$$V(z;\bullet) = \max_{i\in[0,1]} \Bigg\{ \underbrace{i}_{\text{Innovate}} \int \Big[\underbrace{I_k(z,x;\bullet)K(\overbrace{L(z,x;\bullet)}^{z'};\bullet')}_{\text{Keep}} + \underbrace{[1-I_k(z,x;\bullet)]S(z;\bullet')}_{\text{Sell}} \Big] \underbrace{dX(x)}_{\text{Proximity distribution}} + \underbrace{(1-i)}_{\text{Fail to innovate}} \underbrace{B(z;\bullet)}_{\text{Buyer}} - \underbrace{C(i;\bullet)}_{\text{Cost of R\&D}} \Bigg\}$$

Symmetric BGP Equilibrium

A set of prices and allocations such that:

- Mean productivity grows at the constant rate **g**
- Market tightness is constant.
- Policy functions for keeping and selling patents are optimal.
- Innovation decision maximizes a firm's value function.
- Firms hire capital and labor optimally.
- Households save and consume optimally.
- Markets clear.

Symmetric BGP Equilibrium

- All value functions and policy rules have tractable closed-form solutions.
  - Linear value functions.
  - Cut-off policy rules.
- Solving a nonlinear system of 17 equations and 17 unknowns.

Invariant Firm-Size Distribution

- Firm size is equal to relative productivity: $l = \frac{z}{\mathbf{z}} = \hat{z}$
- Recall the law of motion:

$$\begin{aligned} z' &= z + \gamma x \mathbf{z} \\ \hat{z}' &= \frac{1}{\mathbf{g}}\hat{z} + \frac{\gamma}{\mathbf{g}}x \end{aligned}$$

Proposition

Existence of a Unique Stationary Firm-Size Distribution: *The stochastic process for the relative productivity converges weakly to a unique invariant distribution.*

Data Description

Data Sources

- NBER-USPTO Utility Patents Grant Data (PDP):
  - Contains information on all 3,210,261 utility patents granted between 1976-2006 in the US.
  - Citation links between patents are available.
  - Each patent is assigned a technology class according to International Patent Classification (IPC).
  - The innovating firms are uniquely identifiable.

Data Sources

- Compustat North American Fundamentals - Annual:
  - Contains balance sheet information on firms publicly traded between 1976-2006 in the US.
  - Can be linked to NBER patent data using existing procedures (Bessen (2009)).

Data Sources

- Patent Reassignment Data (PRD):
  - Recently released under Google Patents Beta.
  - Contains information on all 767,815 patents sales between 1980-2012 in the US.
  - Can be linked to NBER patent data using patent numbers or a company name matching algorithm.

Constructing a Patent-to-Patent Distance Metric

- The first two digits of the IPC code of a patent characterizes its technological position.
- A notion of distance between 2-digit IPC codes is required.
-

$$d(X,Y) \equiv 1 - \frac{\#(X \cap Y)}{\#(X \cup Y)} \in [0,1]$$

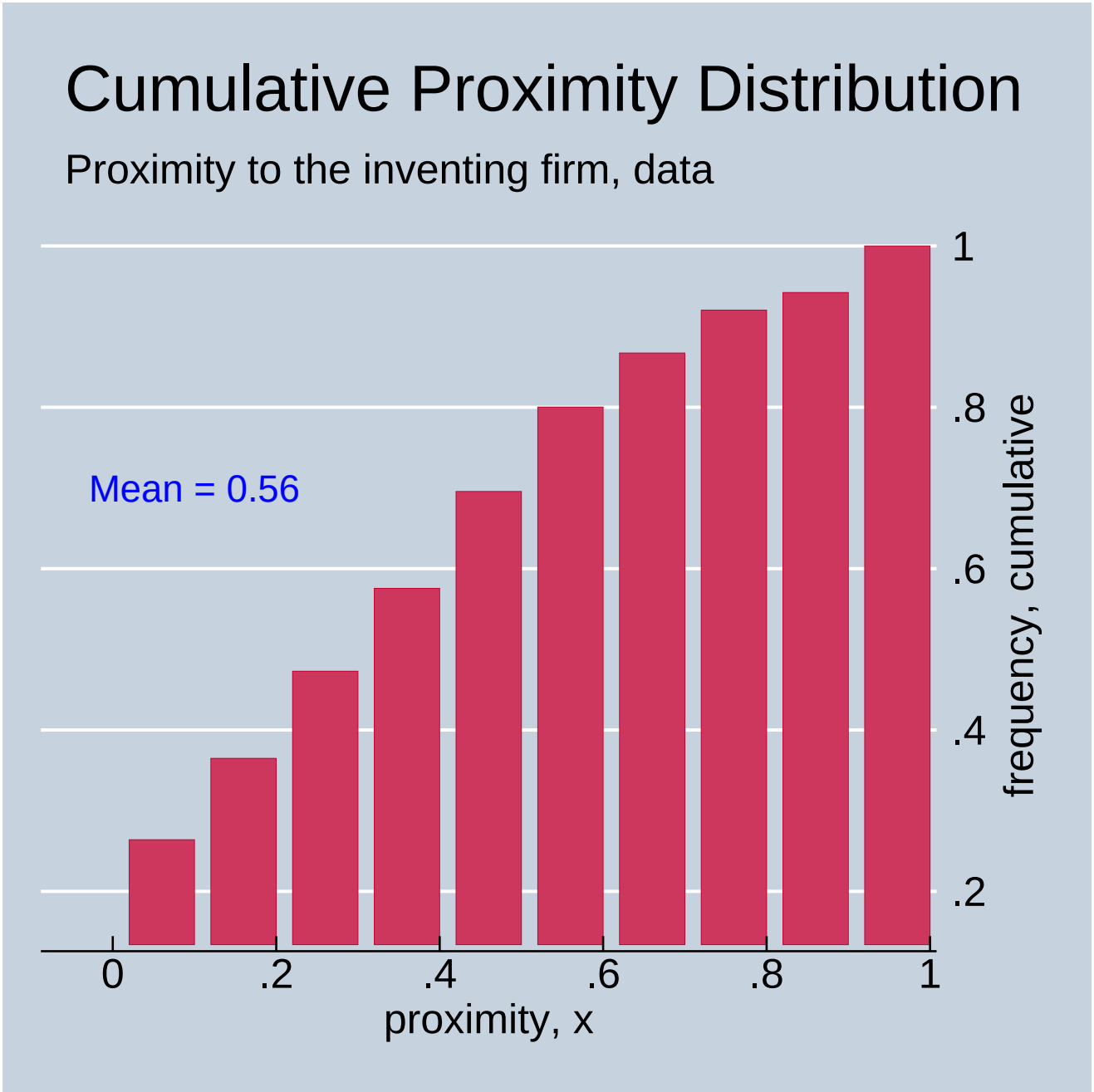
- $\#(X \cap Y)$: Number of patents that cite both X and Y.
- $\#(X \cup Y)$: Number of patents that cite either X or Y or both.
- The more X and Y are cited together, the closer they are to each other.

Constructing a Patent-to-Firm Distance Metric

- A patent has a single technology class.
- A firm may have multiple patents belonging to different technology classes.
-

$$d(p,f) \equiv \frac{1}{\|\mathcal{P}_f\|} \sum_{p' \in \mathcal{P}_f} d\left(X_p, Y_{p'}\right) \in [0,1]$$

- p: patent, f: firm
- $\mathcal{P}_f$: patent portfolio of firm f.


Cumulative Proximity Distribution
Proximity to the inventing firm, data
Mean = 0.56
1
.8
.6
.4
.2
frequency, cumulative
0
.2
.4
.6
.8
1
proximity, x

Value of the Patent Stock

- Citation number is accepted as a good proxy for patent quality after adjusting for truncation and industry effects. (Hall, Jaffe, Trajtenberg (2005))
- *patent stock (f)* = $\sum_{p \in \mathcal{P}_f}$ citation weight of patent p
- *distance adjusted patent stock (f)* =
  $\sum_{p \in \mathcal{P}_f}$ citation weight of patent $p \times$ distance of patent p

Empirical Results

Fact 1: Firm Moments

- The patent portfolio of a firm is positively correlated with real sales and market value.
- The distance between the firm and its patents affects these correlations negatively.

Fact 1: Firm Moments

TABLE 2: FIRM MOMENT REGRESSIONS

Variable	*log real sales*	*log market value*
log patent stock	0.191^{***}	0.037^{***}
	(0.008)	(0.008)
log dist-adj pat stock	-0.006^{***}	-0.018^{***}
	(0.003)	(0.003)
log employment	0.936^{***}	0.728^{***}
	(0.008)	(0.008)
intercept	yes	yes
year	yes	yes
firm fixed effect	yes	yes
Obs	23,028	36,094
R^2	0.96	0.92

Standard errors are reported in parantheses.

*10%, **5%, ***1% significance.

Fact 2: Patent Sale Decision

- Firms are more likely to sell patents that are technologically distant.

Fact 2: Patent Sale Decision

TABLE 3: PATENT SALE DECISION

Variable	*Indicator (=1 if sold)*
distance	0.0227^{***}
	(0.001)
patent quality	0.0004^{***}
	(0.000)
log (size of patent portfolio)	-0.0160^{***}
	(0.000)
intercept, year, firm f.e.	yes
Obs	2,564,305
R^2	0.4158
mean dep var	15.61

Standard errors are reported in parantheses.

*10%, **5%, ***1% significance.

Fact 3: Distance Reduction Following Patent Resale

- On average, the distance between a patent and its owner decreases after it is sold.

Fact 3: Distance Reduction Following Patent Resale

TABLE 4: DISTANCE REDUCTION ON RESALE

Variable	Change in distance $d(p, f_b) - d(p, f_s)$
intercept	-0.176^{***}
	(0.056)
year fixed effect	yes
seller fixed effect	yes
Obs	24,159
mean dep var	0.556

Standard errors are reported in parantheses.
*10%, **5%, ***1% significance.

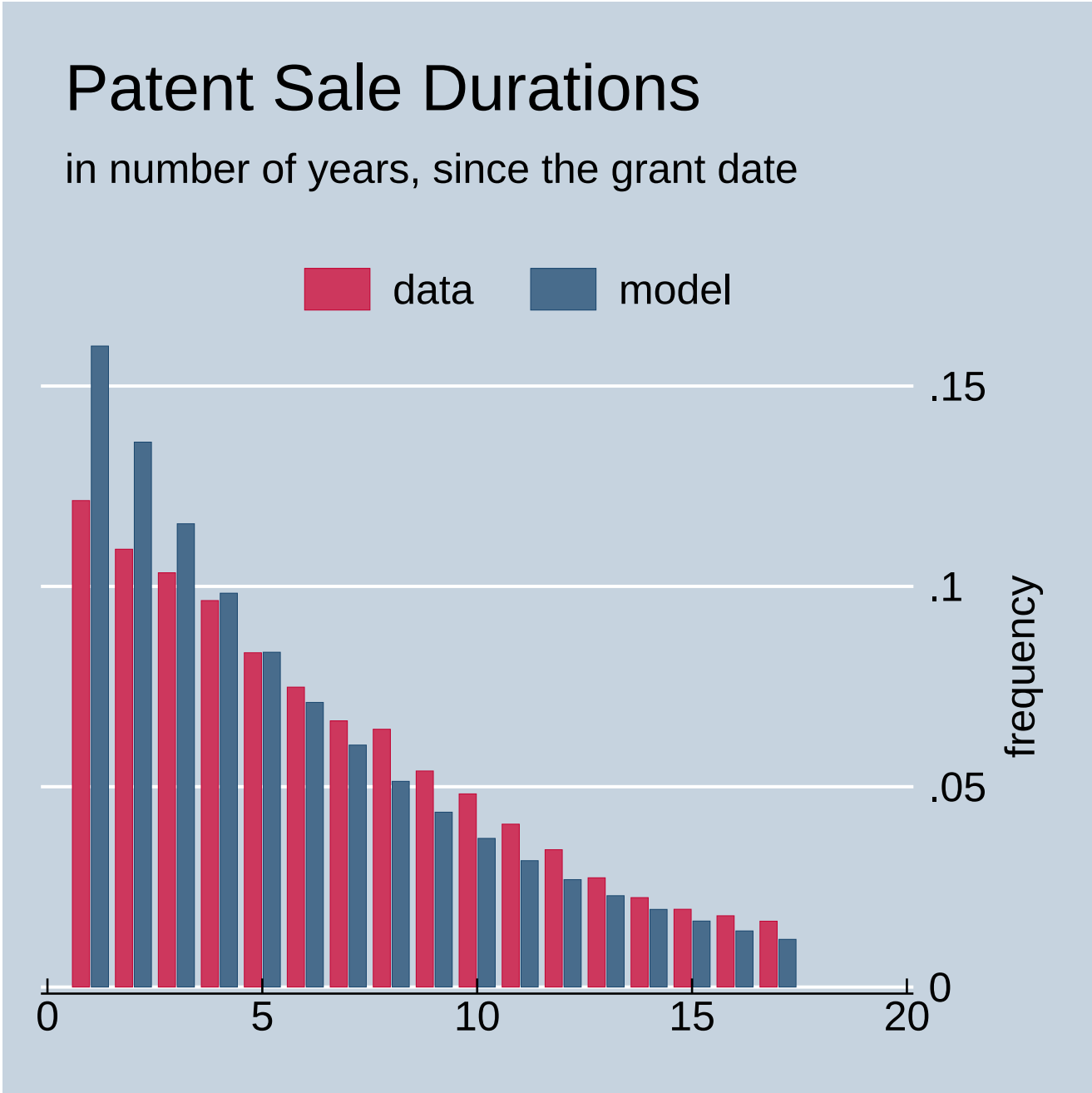
Calibration

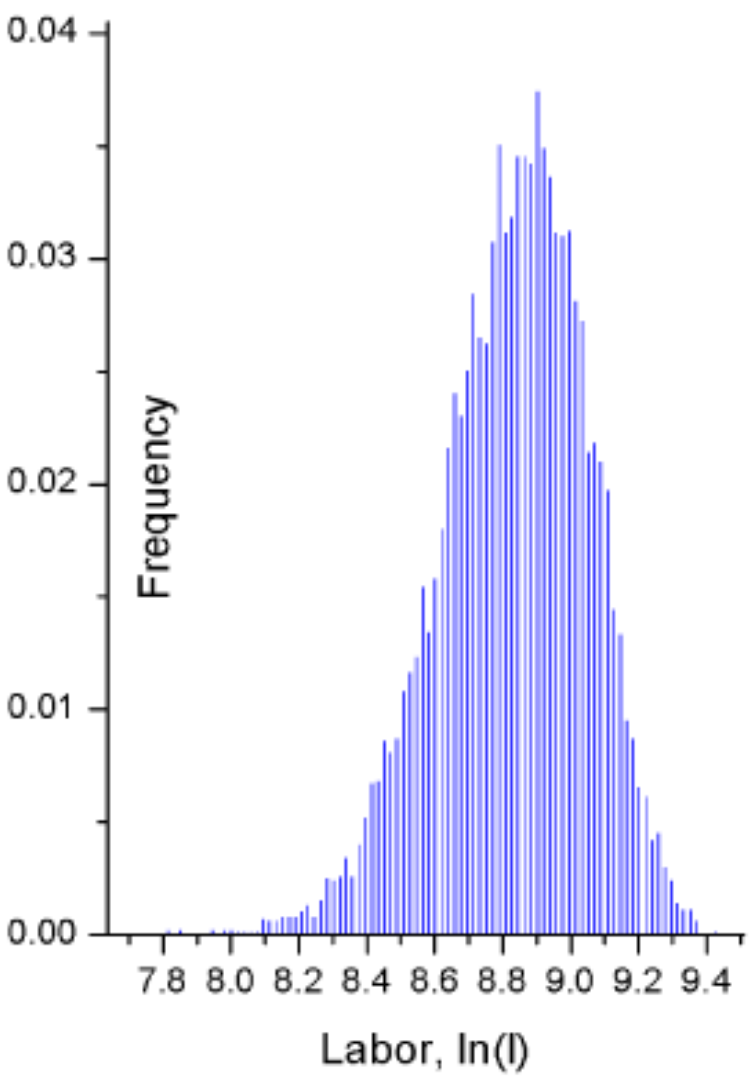
TABLE 5: PARAMETER VALUES

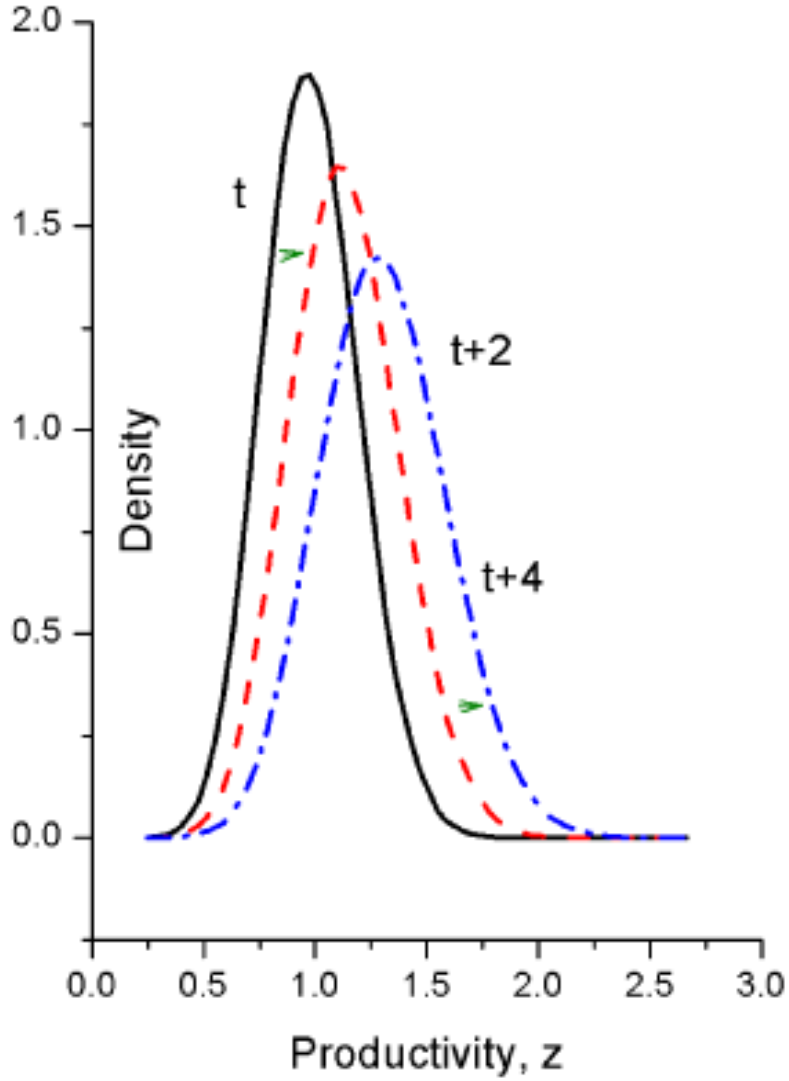
Parameter	*Description*	*Identification*
$\beta = 0.98$	Discount factor	Real interest rate
$\varepsilon = 2.00$	CRRA parameter	Kaplow (2005)
$\kappa = 0.25$	Capital's share	Corrado et. al. (2006)
$\lambda = 0.60$	Labor's share	"
$\delta = 0.07$	Depreciation rate	NIPA
$\sigma = 0.94$	Patent survival rate	U.S. patent law
$\gamma = 0.25$	Law of motion, productivity	Growth rate in GDP
$\chi = 1.42$	Cost of R&D	R&D expenditure to GDP
$\mu = 0.52$	Matching function	Fraction of patents sold
$\eta = 0.18$	Matching function	Duration until sale
$\omega = 0.50$	Bargaining power	Equal for sellers and buyers
$\rho = 3.00$	R&D cost elasticity	Compustat
$X(x)$	Proximity distribution	Empirical distribution

TABLE 6: CALIBRATION TARGETS

Target	*U.S. Data*	*Model*
Long-run growth in output	2.00%	2.00%
Ratio of R&D expenditure to GDP	2.91%	2.84%
Fraction of patents that are sold	15.6%	16.9%
Sale duration distribution	*See next figures*	


Patent Sale Durations
in number of years, since the grant date
data
model
.15
.1
.05
0
frequency
0
5
10
15
20


0.04
0.03
0.02
0.01
0.00
Frequency
7.8 8.0 8.2 8.4 8.6 8.8 9.0 9.2 9.4
Labor, ln(l)


2.0
1.5
1.0
0.5
0.0
Density
t
t+2
t+4
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Productivity, z

Quantitative Analysis

Sources of the Misallocation and its Quantification

- Ideas are not born to the best user,
- S&M frictions: matches are not immediate,
- S&M frictions: matches are not perfect.

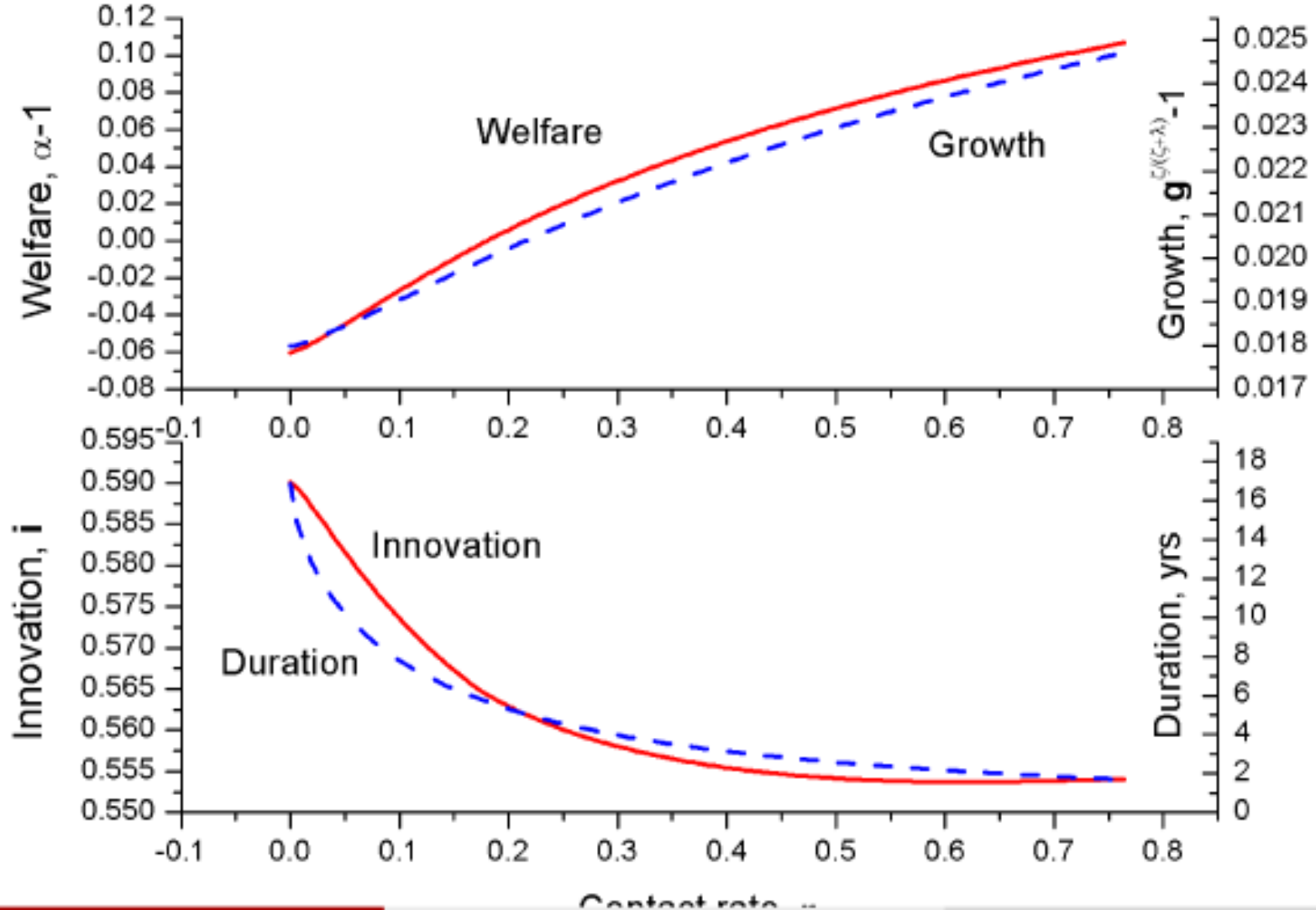
What we do:

- A series of thought experiments will be conducted, where the markets are successively getting more efficient.
- Effect on innovation rate i is ambiguous:
  - Markets are more efficient:
    - q increases $\Rightarrow$ i increases
  - Markets are more efficient:
    - buying ideas is easier $\Rightarrow$ i decreases

Changing the Contact Rate for Matches

- η : Scale factor in the matching function
- Higher $\eta \Rightarrow$ Increased number of matches
- $\eta = 0 \Rightarrow$ Closing patent markets

Changing the Contact Rate for Matches



Perfectly Directed Search

- Baseline model: Conditional upon meeting, proximity $x \sim U[0,1]$
- What if search was perfectly directed?

TABLE 7: PERFECTLY DIRECTED SEARCH

	Baseline Model	*Directed Search*
Output growth rate, $\mathbf{g}^{\zeta/(\zeta+\lambda)} - 1$	0.020	0.024
Innovation rate, i	0.56	0.53
Welfare gain, $\alpha - 1$	0.00	0.10
Fraction of patents sold	0.169	0.275
Growth from patents sold	0.195	0.424
Seller patent price, q	0.13	0.19
Sellers/Buyers, $\#_a/\#_b$	2.19	2.88

Perfectly Directed Search with Maximum Contact Rate

- What if perfectly directed search was accompanied by maximum contact rate?
- η is such that buyer meets a seller with probability 1.

TABLE 8: PERFECTLY DIRECTED SEARCH + MAX. CONTACT RATE

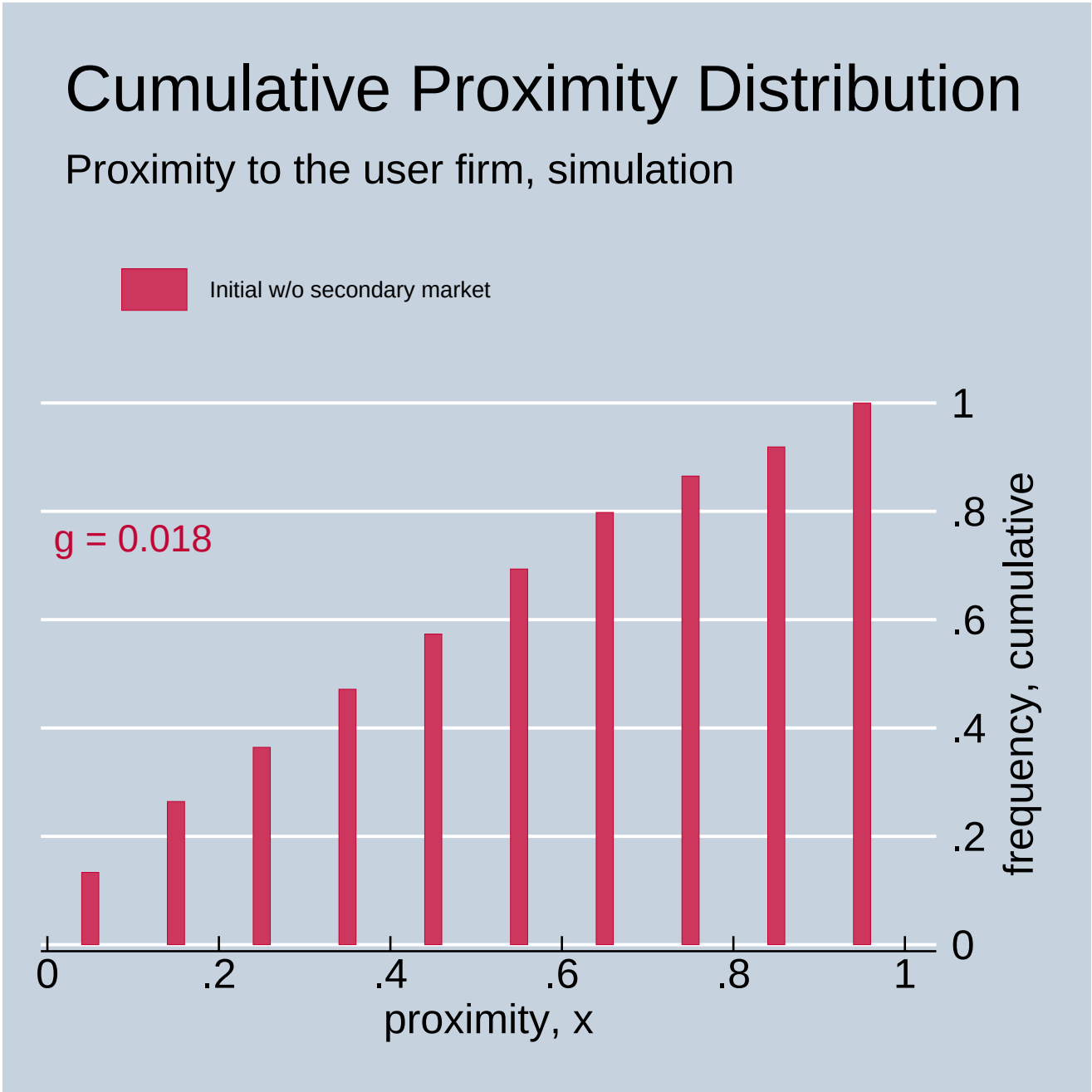
	Baseline Model	*Directed Search*
Output growth rate, $\mathbf{g}^{\zeta/(\zeta+\lambda)} - 1$	0.020	0.035
Innovation rate, i	0.56	0.55
Welfare gain, $\alpha - 1$	0.00	0.36
Fraction of patents sold	0.169	0.802
Growth from patents sold	0.195	0.866
Seller patent price, q	0.13	0.30
Agents/Buyers, $\#_a/\#_b$	2.19	1.36

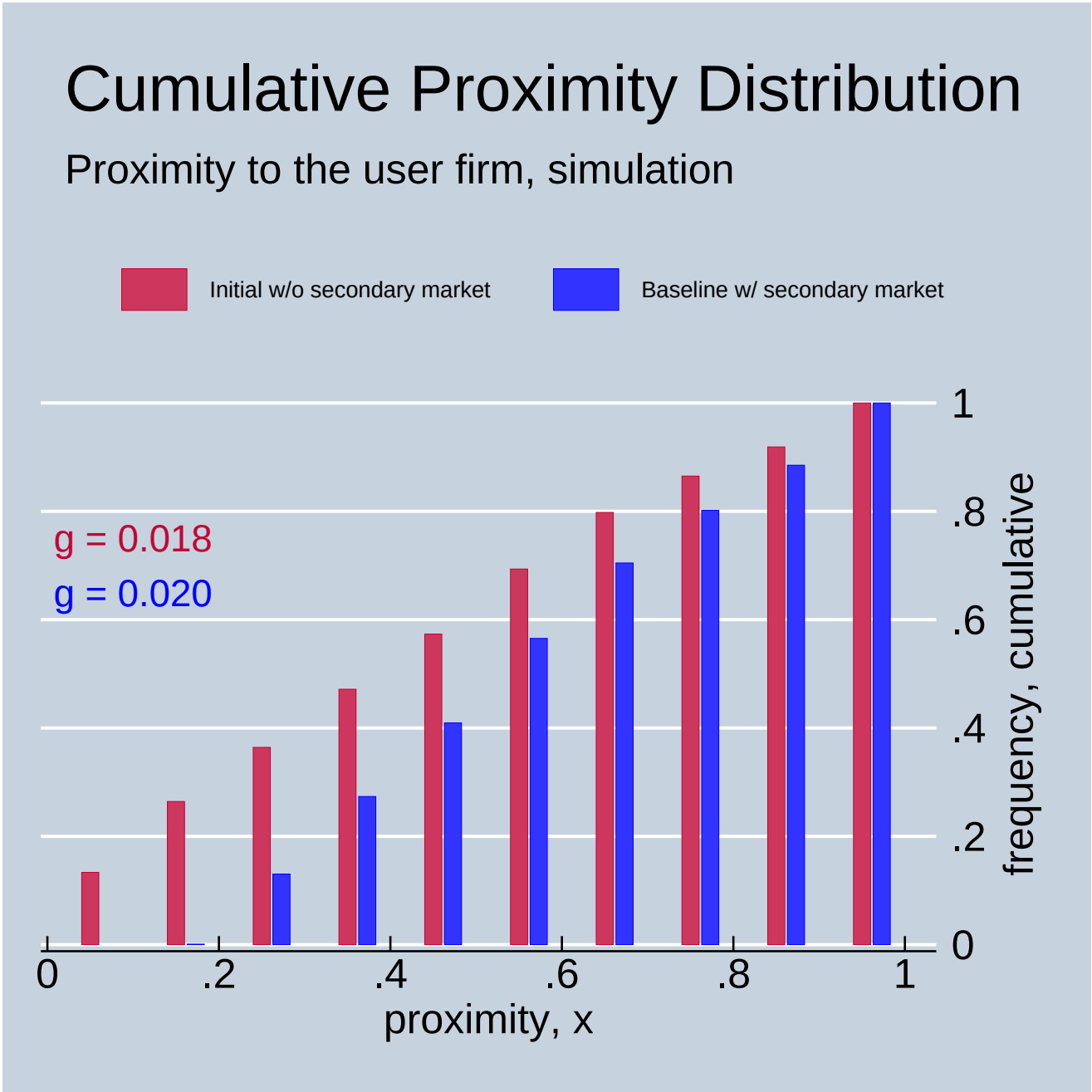
Removing Misallocation of Ideas

- The main source of inefficiency: $X(x)$
- What if there were no misallocation of ideas?

TABLE 8: NO MISALLOCATION

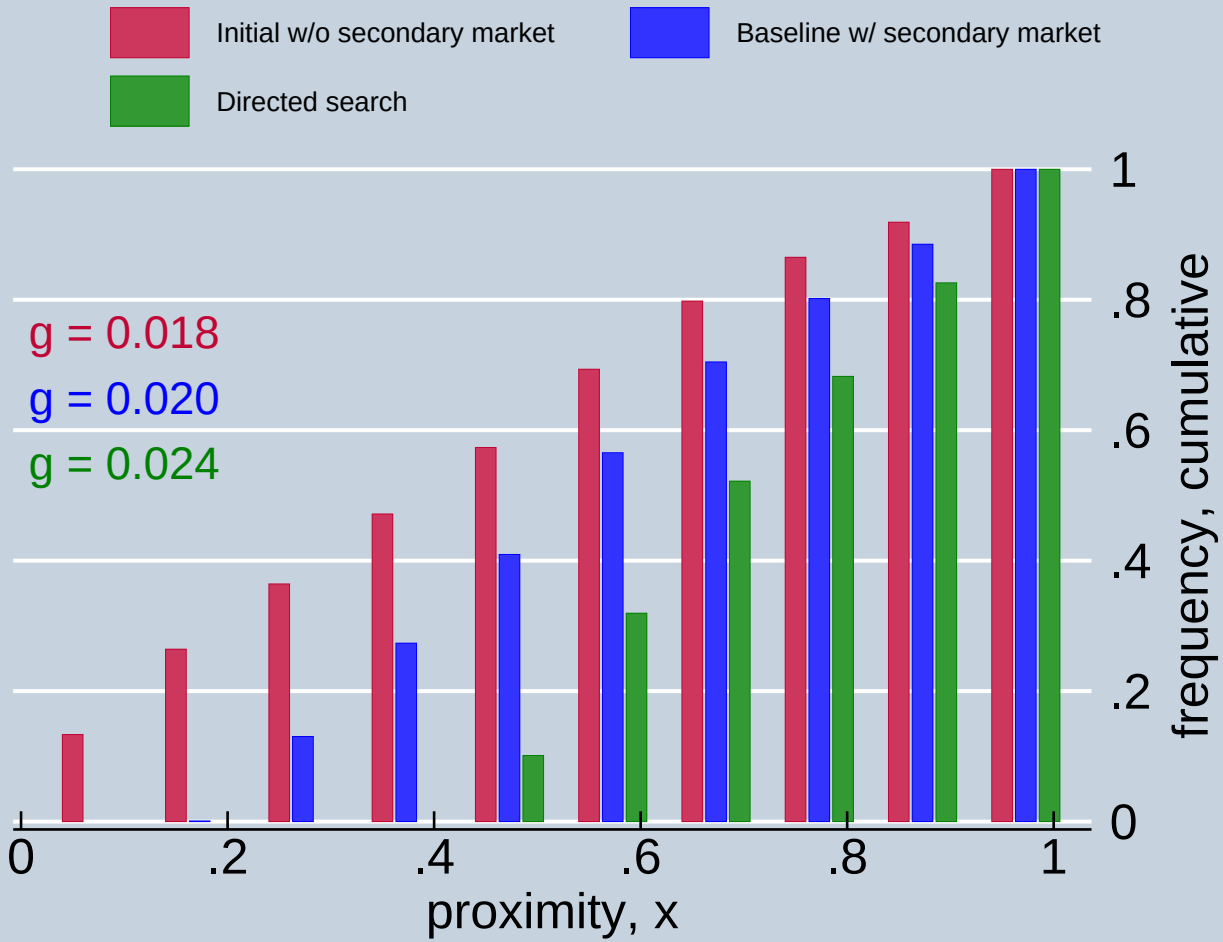
	Baseline Model	*No Misallocation*
Output growth rate, $\mathbf{g}^{\zeta/(\zeta+\lambda)} - 1$	0.020	0.04
Innovation rate, i	0.56	0.60
Welfare gain, $\alpha - 1$	0.00	0.50


Cumulative Proximity Distribution
Proximity to the user firm, simulation
Initial w/o secondary market
g = 0.018
0
.2
.4
.6
.8
1
proximity, x
0
.2
.4
.6
.8
1
frequency, cumulative


Cumulative Proximity Distribution
Proximity to the user firm, simulation
Initial w/o secondary market
Baseline w/ secondary market
g = 0.018
g = 0.020
0
.2
.4
.6
.8
1
proximity, x
0
.2
.4
.6
.8
1
frequency, cumulative

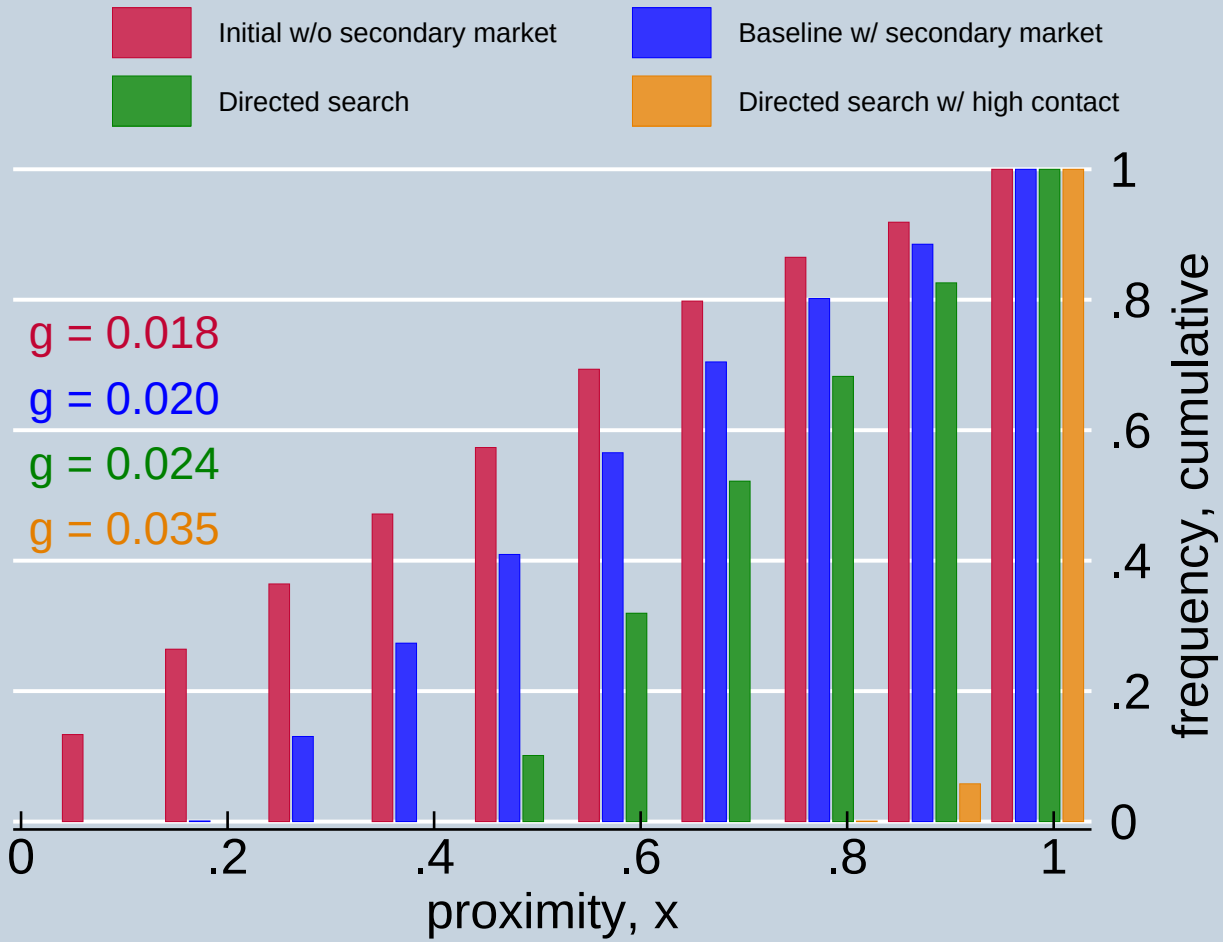
Cumulative Proximity Distribution

Proximity to the user firm, simulation



Cumulative Proximity Distribution

Proximity to the user firm, simulation



Conclusion

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- This paper:
  - offered an empirical strategy to measure the misallocation, and
  - developed a model of misallocation of ideas.
- Misallocation of ideas in production is quantitatively big.
- Misallocation is mitigated significantly by the patent resale market.
- Efficiency of patent resale market has implications for economic growth.

Patent Sale Durations

in number of years, since the application date