

20598 – Finance with Big Data

Week 9 Lecture: Financial Intermediation in the age of AI

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Outline

Fairness

ML and discrimination in Finance

Search Frictions

PE and VC

Machine Learning in FinTech Lending

What did we learn last week?

- FinTech lenders leverage **alternative data** to evaluate credit worthiness
- **Digital footprint** perform well in predicting default (better than traditional data)
- Could foster **financial inclusion** and access to financial services → reducing **inequality**

So, all good?

Artificial stupidity : Google Vision Cloud AI

Objects Labels Web Properties Safe Search



Screenshot from 2020-04-02 11-51-45.png

Objects Labels Logos Web Properties Safe Search



Screenshot from 2020-04-03 09-51-57.png

Artificial stupidity : Google Vision Cloud AI

Objects **Labels** Web Properties Safe Search



Screenshot from 2020-04-02 11-51-45.png

Hand 72%

Objects **Labels** Logos Web Properties Safe Search



Screenshot from 2020-04-03 09-51-57.png

Hand 77%

Artificial stupidity : Google Vision Cloud AI

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Screenshot from 2020-04-02 11-51-45.png

Hand	72%
Monocular	60%

Objects Labels Logos Web Properties Safe Search



Screenshot from 2020-04-03 09-51-57.png

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Artificial stupidity : Google Vision Cloud AI

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Screenshot from 2020-04-03 09-51-57.png

Hand	77%
Gun	61%



Fairness?

Discrimination in Economics and Finance

Taste-based discrimination: decision maker acts as if they're willing to sacrifice utility in order to discriminate (Gary Becker, '50s)

Statistical discrimination: decision maker makes rational inferences on the basis of a group membership (gender, ethnicity, etc.) in an attempt to maximize profit

Discrimination in Economics and Finance

Taste-based discrimination: decision maker acts as if they're willing to sacrifice utility in order to discriminate (Gary Becker, '50s)

- An employer hires an less-qualified man over a more qualified woman (productivity loss to satisfy it's gender bias)

Statistical discrimination: decision maker makes rational inferences on the basis of a group membership (gender, ethnicity, etc.) in an attempt to maximize profit

- Female workers are offered lower wages because females are perceived to be less productive (i.e., lower productivity in historical data)

Discrimination in Economics and Finance

- Algorithms are increasingly used in econ-related domains:
 - Criminal justice: Should a defendant be granted bail ?
 - Hiring: Should an applicant be hired ?
 - Healthcare: Should a patient be tested ?

Discrimination in Economics and Finance

- Algorithms are increasingly used in econ-related domains:
 - Criminal justice: Should a defendant be granted bail ?
 - Hiring: Should an applicant be hired ?
 - Healthcare: Should a patient be tested ?
 - Asset management: Should a stock be bought ?
 - VC: Should we invest in a firm ?
 - Banking: Should an applicant receive a loan ?
- Widespread fears that algorithmic decision-making may **reflect** or **worsen** existing socioeconomic disparities/discriminations (both taste-based and statistical)

Consumer-lending discrimination (Bartlett et al., 2022)

- U.S. fair-lending law prohibits lenders from making credit choices that disparately affect minority borrowers if those choices are based on characteristics unrelated to creditworthiness
- E.g., charging higher rates to applicants in financial deserts cannot be justified as a legitimate business necessity (even if profit maximizing)

Consumer-lending discrimination (Bartlett et al., 2022)

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- E.g., charging higher rates to applicants in financial deserts cannot be justified as a legitimate business necessity (even if profit maximizing)
- A long literature finds differences between minority and non-minority borrowers in both mortgage-approval probabilities and interest rates paid.
- Yet, little is known about FinTech lending

Consumer-lending discrimination (Bartlett et al., 2022)

Research questions:

- i Do minority borrowers are discriminated by FinTech lenders?
- ii If yes, is it better or worth than traditional banks?

Consumer-lending discrimination (Bartlett et al., 2022)

- Investigate mortgage discrimination using data from government-sponsored enterprises (GSEs) — Fannie Mae and Freddie Mac — and from the Federal Housing Administration (FHA)
- **Idea:** GSEs determine credit-risk pricing depending only on where the borrower sits in an 8×8 matrix of loan-to-value ratios and credit scores

Consumer-lending discrimination (Bartlett et al., 2022)

	Loan-to-value ratio							
Credit score	2,0%	2,2%	2,4%	2,6%	2,8%	3,0%	3,2%	3,4%
	2,2%	2,6%	3,0%	3,4%	3,8%	4,2%	4,6%	5,0%
	2,4%	3,0%	...	...	...	...	...	...
	2,6%	3,4%	...	...	...	...	...	...
	2,8%	3,8%	...	...	...	...	...	...
	3,0%	4,2%	...	...	...	...	...	...
	3,2%	4,6%	...	...	...	...	...	...
	3,4%	5,0%	...	...	...	...	...	Max

Consumer-lending discrimination (Bartlett et al., 2022)

- Critical point: even if the GSE pricing grid is not the optimal model for predicting default, it completely determines the price that must be paid
 - All **legitimate-business-necessity variables** are thus observed
- any interest-rate differences between loans within a given credit score/LTV grid cell cannot reflect differential credit risk, and may therefore reflect discrimination.

Consumer-lending discrimination (Bartlett et al., 2022)

- Data set includes loan-level information on income, race, ethnicity, LTVs, debt-to-income ratios, + all contract terms
- Indicators for whether the lender primarily used algorithmic scoring
- About 5.7 million loans issued between 2009 and 2015 using the full merged data

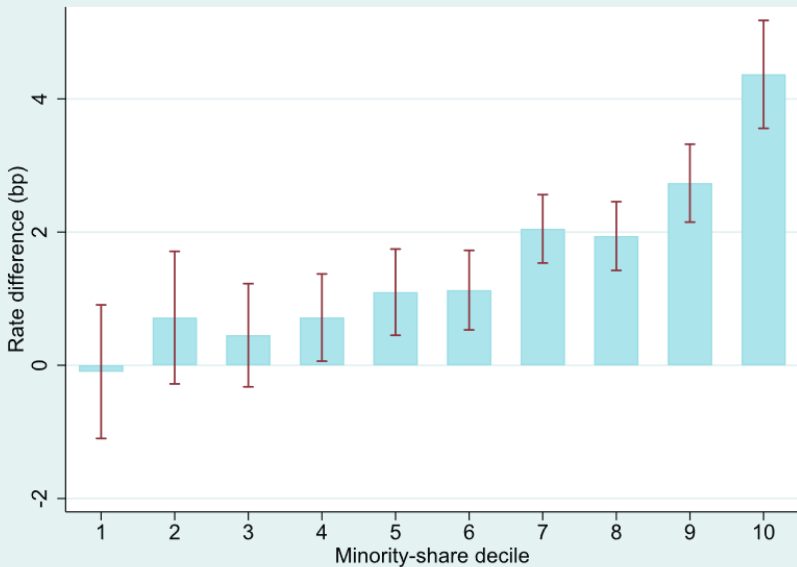
Table 4

Interest-rate differentials: FinTech vs. non-FinTech lenders. The table reports interest-rate differentials as in Table 3, split by FinTech vs. non-FinTech lenders (as defined by Buchak et al., 2018). The dependent variable is the interest rate on originated fixed-rate mortgages in basis points. The independent variable equals 1 if the borrower is Black or Latinx, and 0 otherwise. Fixed effects are included for cash-out $\times$ GSE-grid bucket $\times$ year/month, lender $\times$ year/month, and loan-amount decile. Standard errors are clustered at the lender level. ***, **, and * indicate significance at the 1%, 5%, and 10% conventional levels.

VARIABLES	GSE Loans		FHA Loans	
	Purchase	Refinance	Purchase	Refinance
	(1)	(2)	(3)	(4)
	Interest rate	Interest rate	Interest rate	Interest rate
Non-FinTech $\times$ Minority	4.666*** (0.256)	1.631*** (0.238)	4.877*** (0.336)	1.548*** (0.262)
FinTech $\times$ Minority	5.081*** (0.124)	1.565*** (0.271)	3.550*** (0.373)	0.969** (0.385)
Observations	1,371,629	1,540,939	1,533,532	436,420
R-squared	0.803	0.769	0.854	0.869
p-value for test of equality	0.1172	0.8570	0.0084	0.2204
Lender $\times$ year/month FE	Y	Y	Y	Y
Cash-out $\times$ bucket $\times$ year/month FE	Y	Y	Y	Y
Amount decile FE	Y	Y	Y	Y
FinTech FE	Y	Y	Y	Y

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

- Latinx and Black borrowers paid 4.7–4.9 basis points more in interest for home-purchase loans and 1.5–1.6 basis points more for refinance loans



- Even if algorithmic lending can reduce discrimination relative to face-to-face lenders, it is insufficient to eliminate discrimination in loan pricing.

More evidence: Blattner and Nelson, 2021



The Experience

The Programs

Faculty & Research

Insights by Stanford Business

Topics ▾

Q

Finance

How Flawed Data Aggravates Inequality in Credit Scores

Noisy data can trip up algorithms that calculate credit risk, leading to qualified minority and low-income borrowers being rejected.

Fighting discrimination in mortgage lending

A new technique for removing bias in datasets can enable machine-learning models to make loan approval predictions that are both fair and accurate.

Adam Zewe | MIT News Office

March 30, 2022



Fairness in algorithms: Singh et al., 2022

Research question : How to implement bias mitigation?

Research question : How to implement bias mitigation?

- Pre-processing : the transformation of data (e.g., the alteration of balancing distributions) to “repair” inherent biases
- In-processing : the use of classifier optimization or fairness regularization terms to affect model learning and maximize a model's fairness
- Post-processing : the manipulation of model output to improve performance and fairness metrics

Research question : How to implement bias mitigation?

- They target the 3 problems by developing a novel and real-world applicable fair ML classifier for mortgage-lending
- They create a bias mitigation pipeline called **DualFair** (a pre-processing strategy), which approaches intersectional fairness through data sampling techniques
 - Some sub-datasets are far more common in the data, while others are less represented. Thus, there is a huge imbalance that propagate root biases when trained on a model, which need to be taken into account.

Fairness in algorithms: Singh et al., 2022

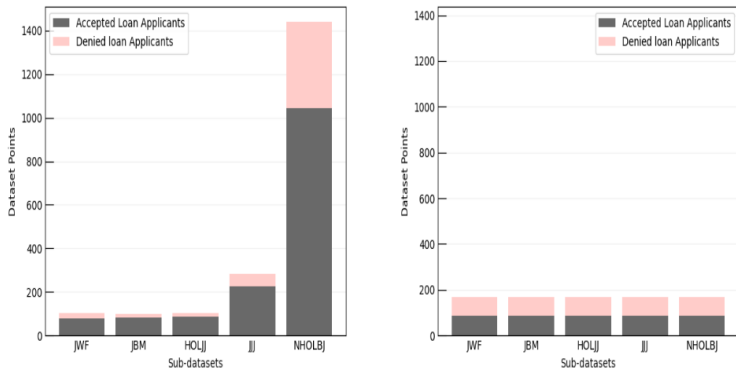


Figure 1. Class and label balancing before (left graph) and after (right graph) using DualFair. (Note: only 5 sub-datasets from the balancing procedure of Connecticut, a smaller sample of HMDA, are shown by the normal 27; note that J denotes joint, B denotes Black, W denotes White, F denotes female, M denotes male, HOL denotes Hispanic or Latino, and NHOL denotes Non-Hispanic or Latino. These denotations form sub-groups shown above. For instance, JJJ is a joint, joint, joint individual and HOLJJ is a Hispanic or Latino, joint, joint individual).

Fairness in algorithms: Singh et al., 2022

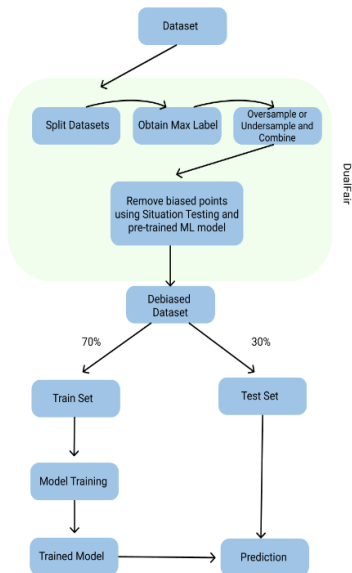


Figure 2. DualFair bias mitigation pipeline.

A close-up photograph of a hand holding a wooden pencil, poised to write on a document. The document has some faint, illegible text. Overlaid on the image is the text 'Course Evaluation!' in a bold, dark blue serif font.

Course Evaluation!



5' break

Search Frictions



Why are so many people unemployed at the same time that there are a large number of job openings?

Search frictions everywhere

- On many markets, buyers and sellers do not always make contact with one another immediately
- Buyers may have trouble finding the goods they are looking for and sellers may not be able to find buyers for the goods they have to offer
 - Job market, housing market, marriage market, monetary theory, Taxis, etc.
- The explicit difficulties buyers and sellers have in locating each other (costly search or search frictions) $\Rightarrow$ market failure

Search frictions everywhere

(Low-Tech) Solution?

Search frictions everywhere

(Low-Tech) Solution? $\Rightarrow$ Centralized markets



Search frictions everywhere

(Low-Tech) Solution? $\Rightarrow$ Centralized markets



Search frictions everywhere

(Digital) Solution?

Search frictions everywhere

(Digital) Solution? $\Rightarrow$ Centralized platforms



Research questions:

- (i) Do **search frictions** matter for banking?
- (ii) How does **ICT* diffusion** impact such frictions?

*ICT: Information and communication technologies

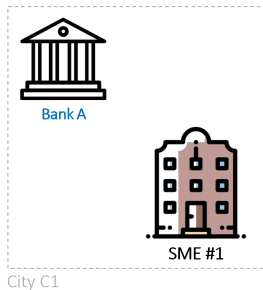
Search frictions in banking ?

Mazet-Sonilhac, 2022

- It is costly for small firms to locate and match with the right banking partner
- Corporate credit markets are inherently decentralized and opaque
 - banks do not post contract terms and no central organization is responsible for setting prices nor conducting transactions
- SMEs multiply loan applications (≈ 3) and undergo a time-consuming application process : > 33 hours on average on loan request paperwork

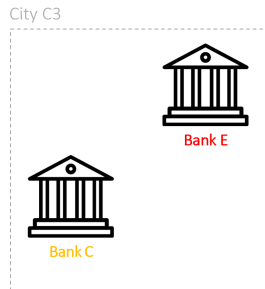
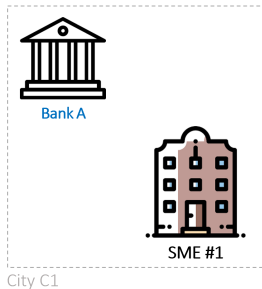
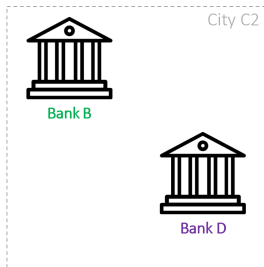
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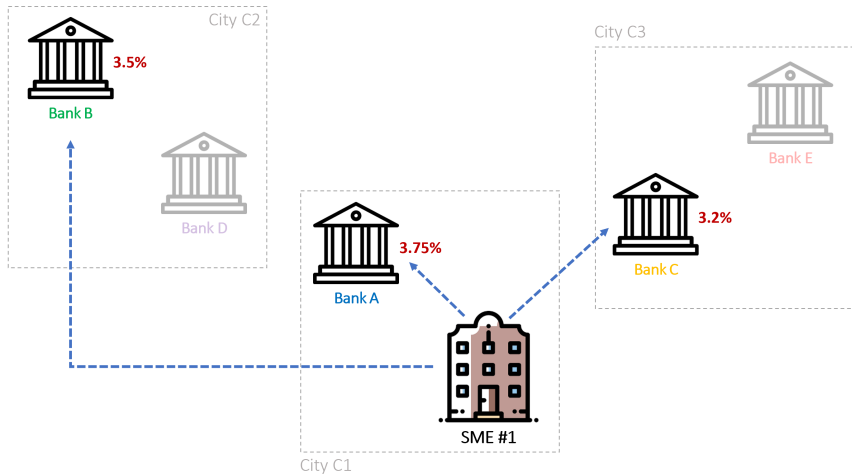
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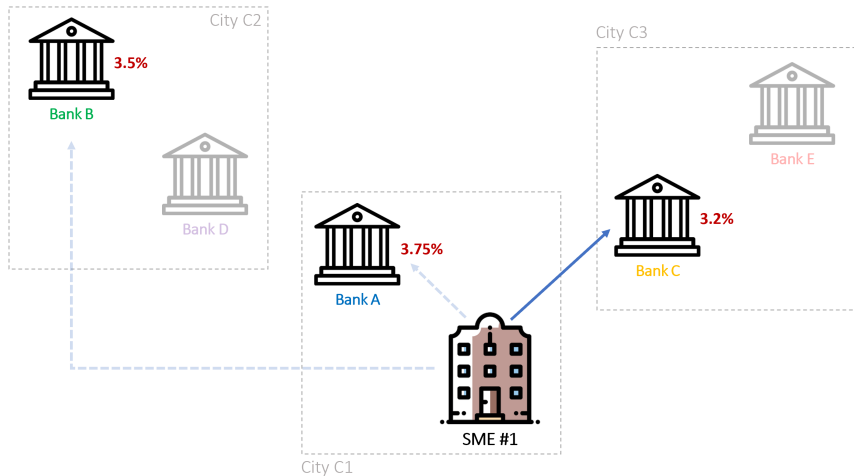
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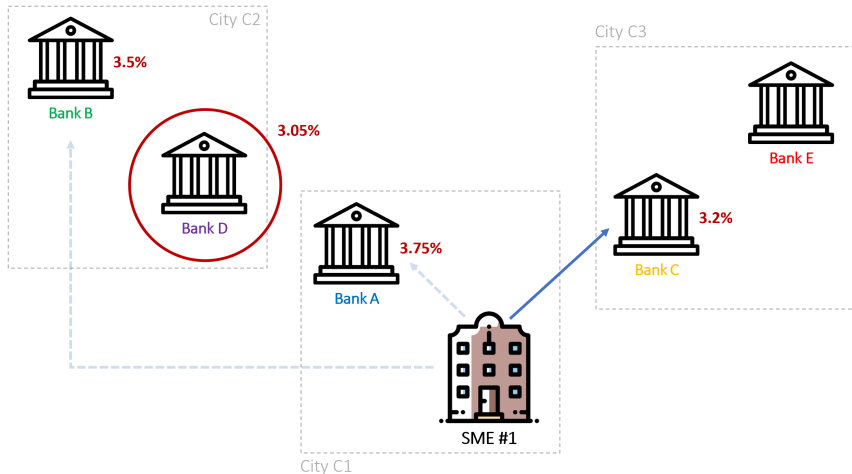
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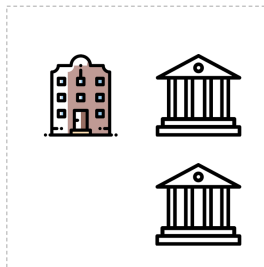
Search frictions in banking?

Mazet-Sonilhac, 2022

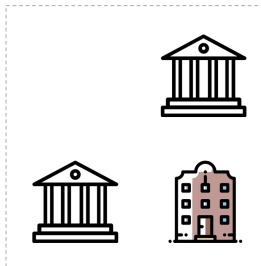
1. **First contribution** : I develop a partial equilibrium model of firm-bank matching
 - **Search frictions** hinder firm's ability to locate and match with the right banking partner
- ⇒ I generate a number of predictions linking a **variation in the level of search frictions** to (i) credit flows between cities and (ii) the cost of debt for SMEs
2. **Second contribution** : I propose a novel IV for the timing of BI diffusion
 - Use the **predicted local variations** in BI access to estimate the impact of a reduction in search frictions
3. **Third contribution** : I take the model to the data, using firm-bank matched data (24 million obs.)

Search frictions in banking?

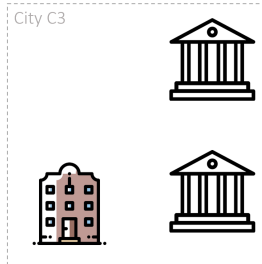
Mazet-Sonilhac, 2022



City C2



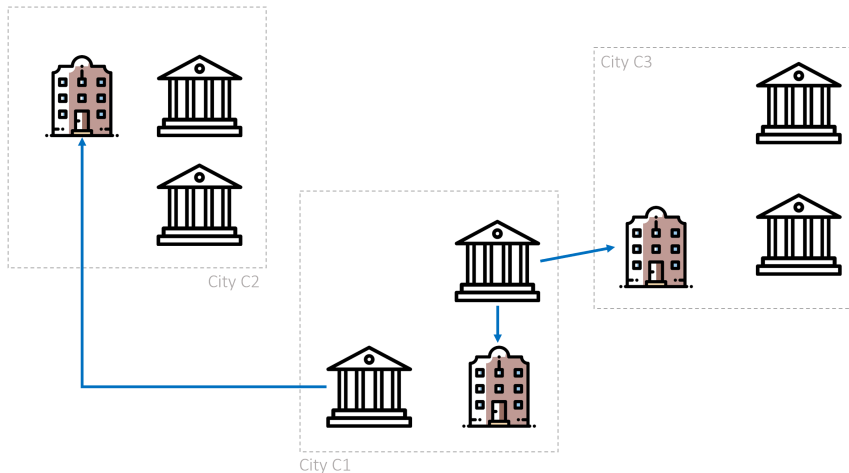
City C1



City C3

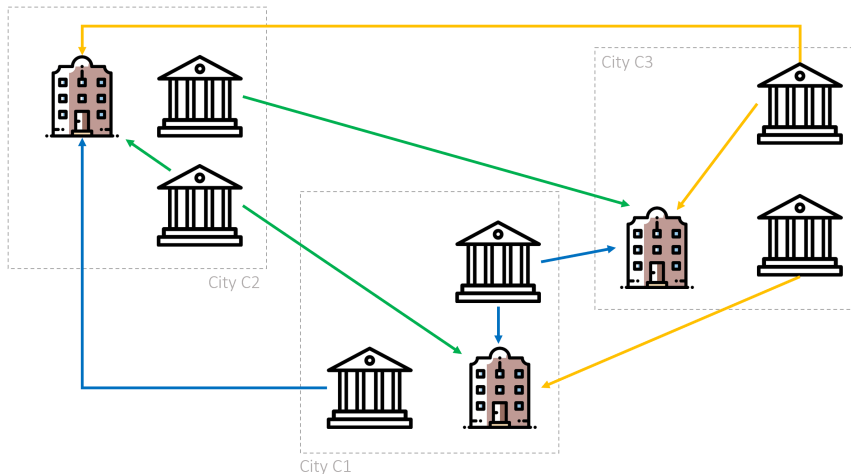
Search frictions in banking?

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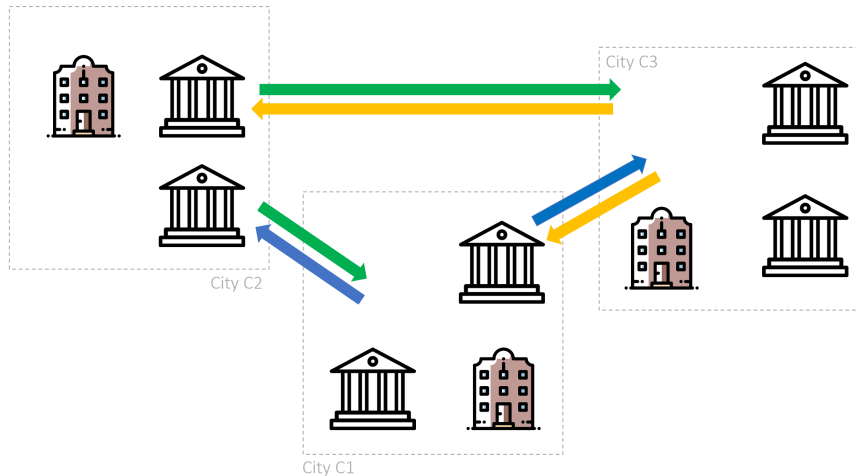
Search frictions in banking?

Mazet-Sonilhac, 2022



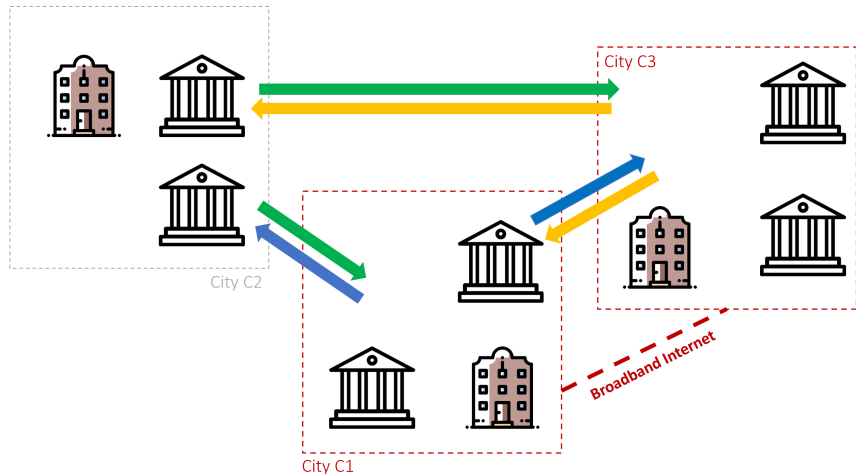
Search frictions in banking?

Mazet-Sonilhac, 2022



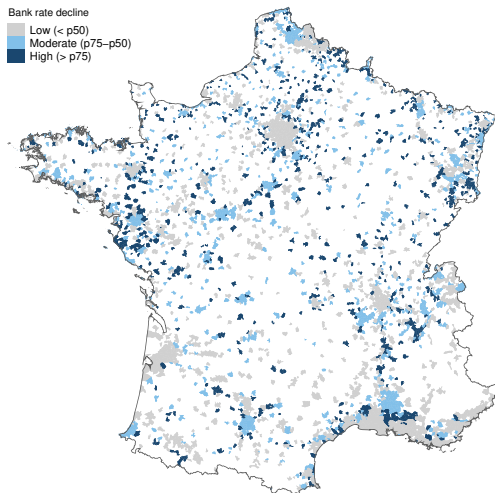
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Mazet-Sonilhac, 2022



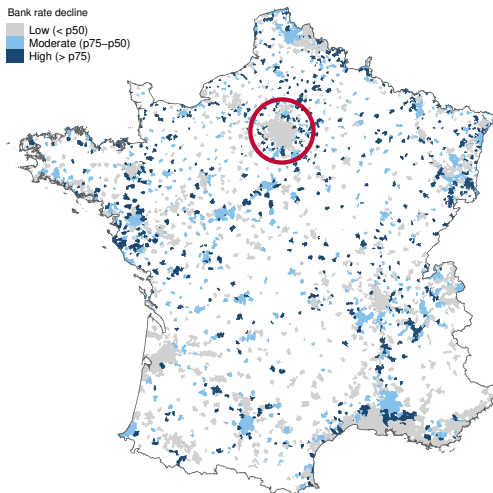
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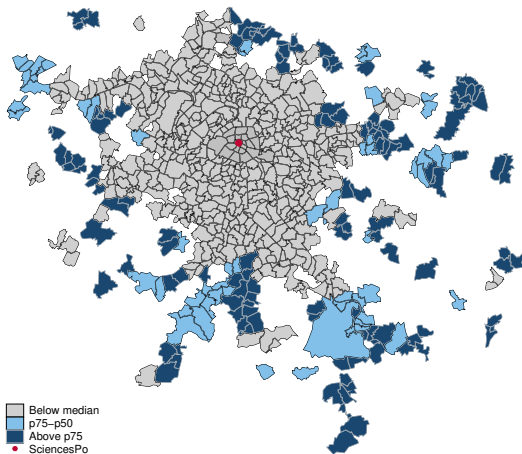
Search frictions in banking?

Mazet-Sonilhac, 2022



Search frictions in banking?

Mazet-Sonilhac, 2022



Search frictions in banking?

BANK OF AMERICA  

Global Banking & Markets

SEARCH: [By Name](#) [By Best Match](#)

Find a Relationship Manager that Matches Your Needs

I am looking for a Relationship Manager in [Find my location](#)

that can help me with 

and speaks 

 SEARCH

RADIUS 

6 RESULTS FOUND [Show Map](#)



BEN GREDLER



DANIEL SCZEPANSKI



MARY FORTI

- [Petersen and Rajan \(2002\)](#) documents the erosion of the local nature of small business lending, with increasing distance between small firms and their lender

Search frictions and AI

Are you a First Timer?

Here is what you need to know!

Specta is an online lending platform that gives you loans of up to 5 Million in one transaction all within 5 minutes! No collateral, no paperwork and no visit to any office.

With Specta, you can take care of urgent personal and business needs anywhere, anytime.

Let's guide you



- Fuster et al (2018) show that fintech lenders process mortgage applications about 20% faster than other lenders

Discussion

Go to [BlackBoard](#) and read the [2010 Nobel Prize Press release](#)

PRESSMEDDELANDE

Press release

11 October 2010

The Prize in Economic Sciences 2010

The Royal Swedish Academy of Sciences has decided to award the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel for 2010 to

Peter A. Diamond

Massachusetts Institute of Technology,
Cambridge, MA, USA,

Dale T. Mortensen and **Christopher A. Pissarides**

Northwestern University,
Evanston, IL, USA and Aarhus
University, Denmark

London School of Economics
and Political Science, UK

"for their analysis of markets with search frictions".

Markets with search costs

Why are so many people unemployed at the same time that there are a large number of job openings?

How can economic policy affect unemployment?

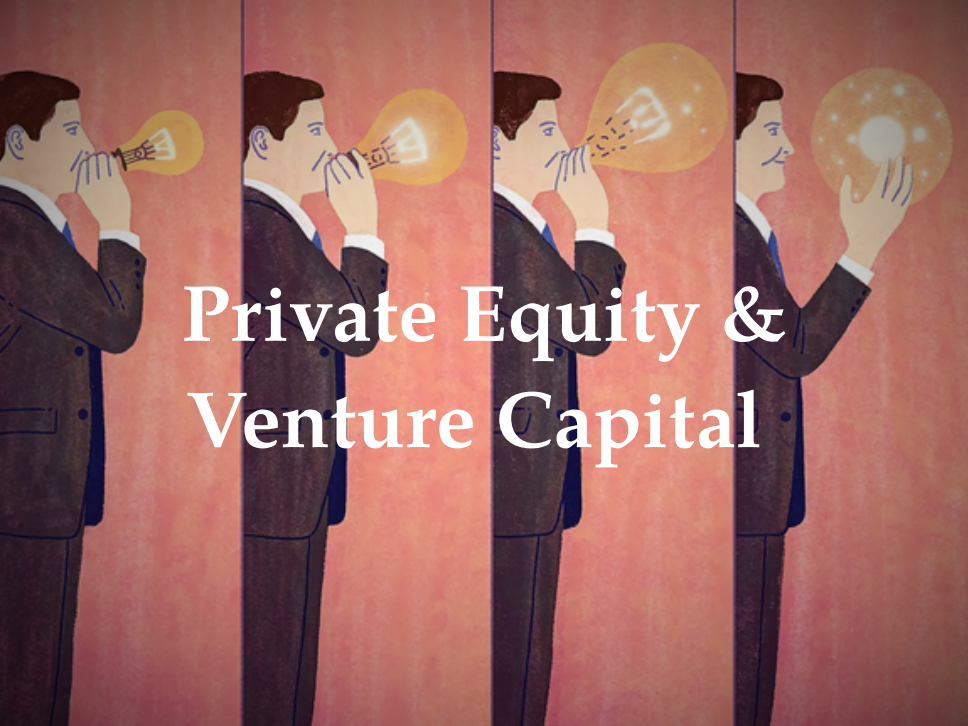
This year's Laureates have developed a theory which can be used to answer these questions. This theory is also applicable to markets other than the labor market.

On many markets, buyers and sellers do not always make

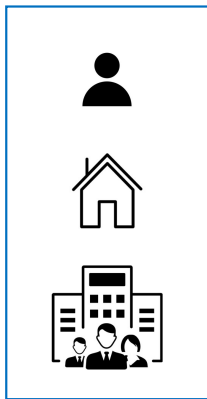
Search theory has been applied to many other areas in addition to the labor market. This includes, in particular, the housing market. The number of homes for sale varies over time, as does the time it takes for a house to find a buyer and the parties to agree on the price. Search theory has also been used to study questions related to monetary theory, public economics, financial economics, regional economics, and family economics.



5' break

An illustration featuring four men in dark suits and blue ties, standing in a row against a reddish-brown background. Each man is shown in profile, facing right. The first man on the left holds a small, standard incandescent lightbulb to his mouth. The second man holds a slightly larger, glowing lightbulb. The third man holds a large, glowing sphere that contains a complex, crystalline or molecular structure. The fourth man on the right holds a large, glowing sphere that contains a bright, multi-pointed star. The spheres increase in size and complexity from left to right, symbolizing the growth and refinement of an idea.

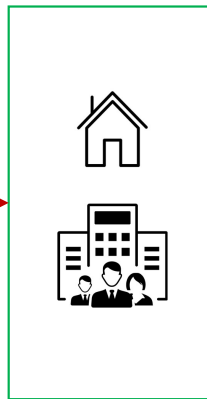
Private Equity & Venture Capital



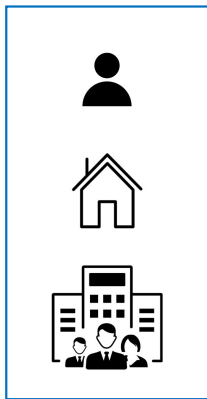
Savings = offer of money

Asset Management
Banks
Private Equity
Venture Capital
FinTech
...

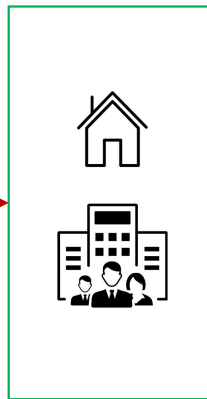
Finance industry
=
Informed intermediaries



Investment = demand of
money



Savings = offer of money



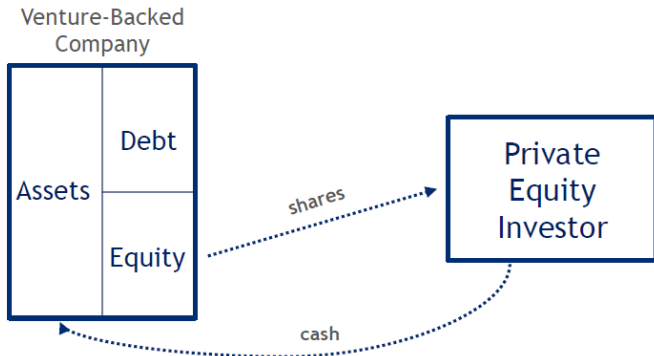
Investment = demand of money

What Is Private Equity (PE) and Venture Capital (VC)?

- The **definition** of PE/VC is based on two aspects, each related to the two main characteristics of the PE relation
 - PE is a **source of financing** : it is an alternative to other sources of liquidity
 - PE is an **investment** made by a financial institution in the equity of a non-listed company
- Throughout this Lecture, the definition of PE will be used in its broad meaning, which also includes Venture Capital
- Venture Capital is a very specific case of PE. It is the investment in the **very early stages** of a company's life.

What Is Private Equity (PE) and Venture Capital (VC)?

- How does it work in practice?



- The investor (PE fund) gets shares of the equity of the company in return for the inflow of cash

What Is Private Equity (PE) and Venture Capital (VC)?

1. A company needing money for a certain and clearly identified reason
2. The company collects money with the issuance of equity on the private market, the company does not pay any interest expenses to the PE fund
3. The PE fund will not only become a shareholder but will contribute to the management of the company. The smaller the company is, the larger the contribution of the PE fund in the business management will be
4. The PE fund will create profit only through the generation of capital gain, i.e. exiting from the investment by selling shares to someone else on the market

PE vs. Investing in a Public Company



Public

Private

PRICING	LIQUIDITY	MONITORING
The price is driven by the market, either upwards or downwards.	Liquidity is very high. Whenever an investor wants to sell the shares of the public company there is always a buyer.	When trading on the stock exchange, there is always a very high level of protection for the shareholders, regardless their stake in the company.
The price is the result of the negotiation process which be both easy or hard.	Selling the shares is not so easy. Since there is no stock exchange, finding a new shareholder can very hard and time consuming.	The shareholders (the PEI) have to protect themselves and the values generated by the company. All of the rules will be stated in a formal agreement.

Why Would a Company Need PE?

Q: Why should a company let an external investor sit on its board of directors and make managerial decisions?

Why Would a Company Need PE?

- Q:** Why should a company let an external investor sit on its board of directors and make managerial decisions?
- A:** The venture-backed company wants to enjoy some direct and indirect benefits decisions

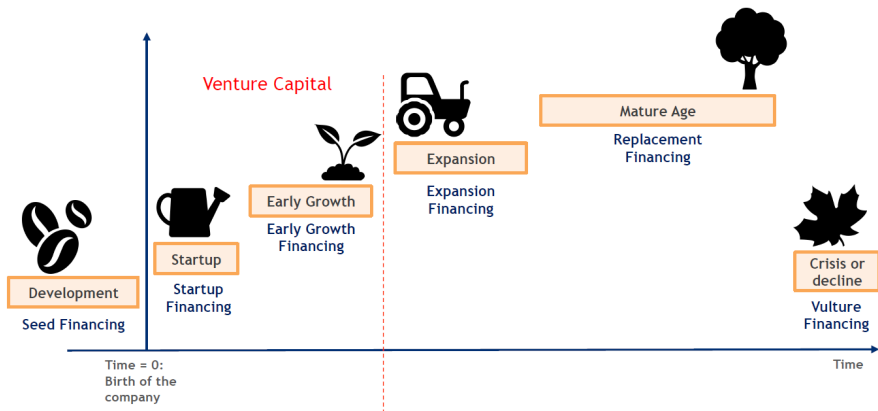
Why Would a Company Need PE?

Q: Why should a company let an external investor sit on its board of directors and make managerial decisions?

A: The venture-backed company wants to enjoy some direct and indirect benefits decisions

- Certification Benefit (only good firms selected)
- Network Benefit (customers, suppliers, banks)
- Knowledge Benefit (how to run the business)
- Financial Benefit (injection of cash → lower risk)

Taxonomy of PE/VC funds



VC-backed firms Hall of Fame

WhatsApp Facebook Snap Alibaba

VC-backed firms Hall of Fame

WhatsApp Facebook Snap Alibaba
Google Twitter Rocket Internet

VC-backed firms Hall of Fame

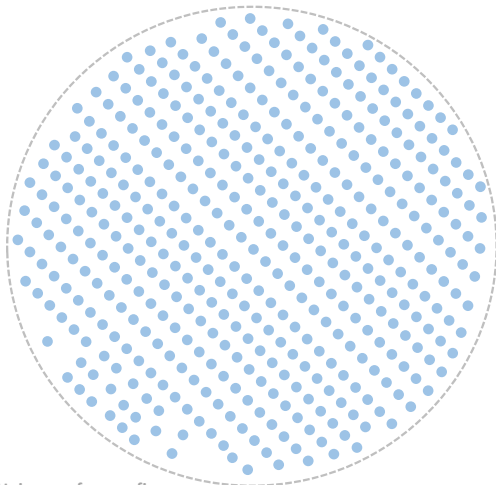
WhatsApp Facebook Snap Alibaba
Google Twitter Rocket Internet
Zalando GitHub Spotify Dropbox

VC-backed firms Hall of Fame

WhatsApp Facebook Snap Alibaba
Google Twitter Rocket Internet
Zalando GitHub Spotify Dropbox
Coinbase Uber Airbnb Zoom

PE/VC as informed intermediaries

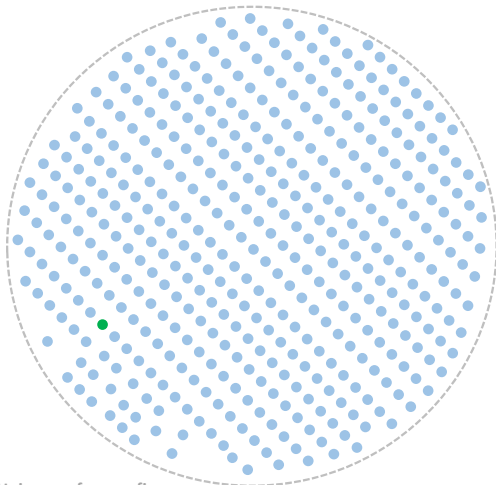
- Investing in a very young firms comes at a (high) **risk**
- PE/VCS constantly **screen the market**, looking for promising startups
 - Invest in many : "spray and pray"
- They face the **two information frictions** that we have studied so far:
 - **Search frictions** : finding the needle in the haystack
 - **Asymmetric information** about the firm type (investment screening)



Universe of young firms



VC Fund



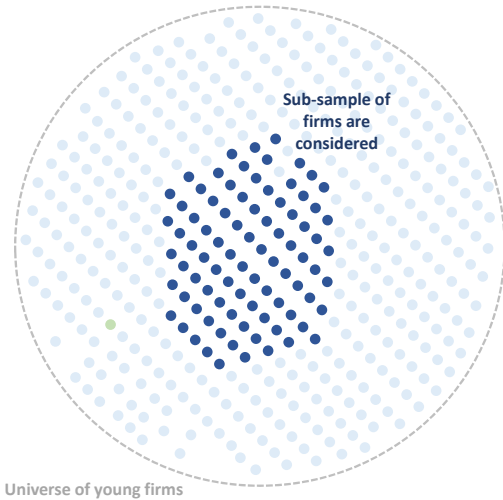
Universe of young firms



Which are the best
firms to invest in?



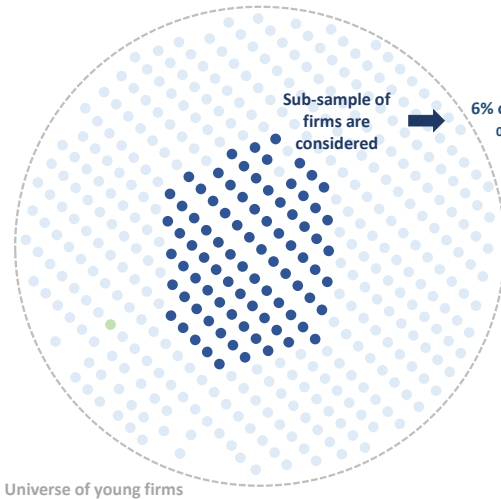
VC Fund



Which are the best firms to invest in?



VC Fund



6% **only** meet VCs
0.5% receive VC-backing



Which are the best
firms to invest in?



VC Fund

Does ML help ?

Venture Capital (Mis)Allocation in the Age of AI

Lyonnet and Stern, 2022

- Are ML algorithms able to identify the most promising firms?
- Not clear: selecting the most promising firms is an extremely difficult task
 - No historical data on new firms
 - Complex set of entrepreneur and firm characteristics

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Research questions:

- i Do VCs back the *best firms* (according to a ML model)?
- ii How do VCs make their investment decisions?

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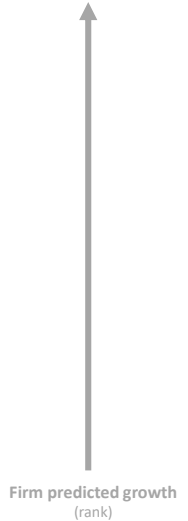
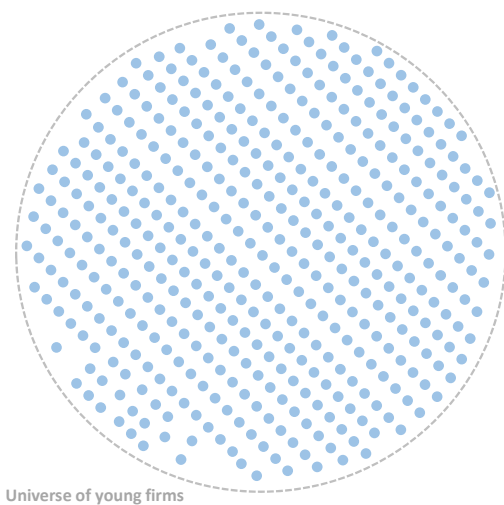
Lyonnet and Stern, 2022

1. Create an **algorithmic investment policy**

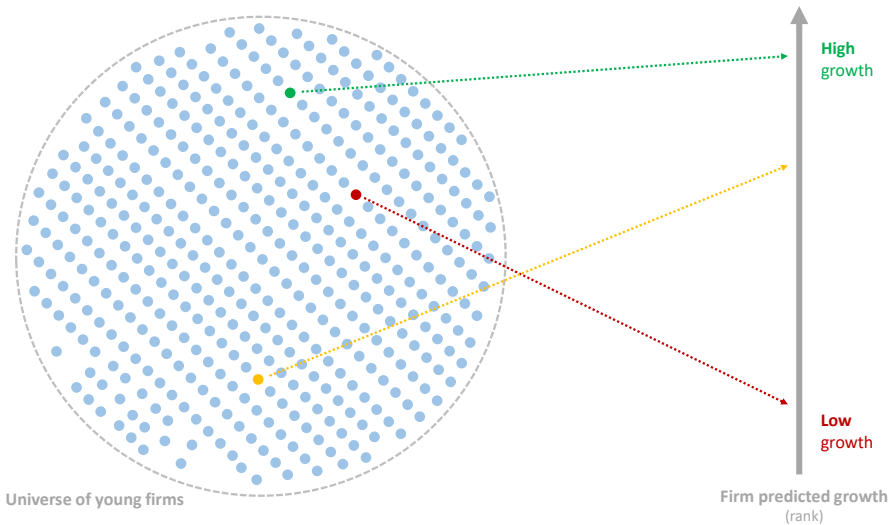
- Build a model that predicts firms' performance (XG Boost)
- Algorithmic investment policy selects firms with the highest performance predictions (Great perf. OOS)

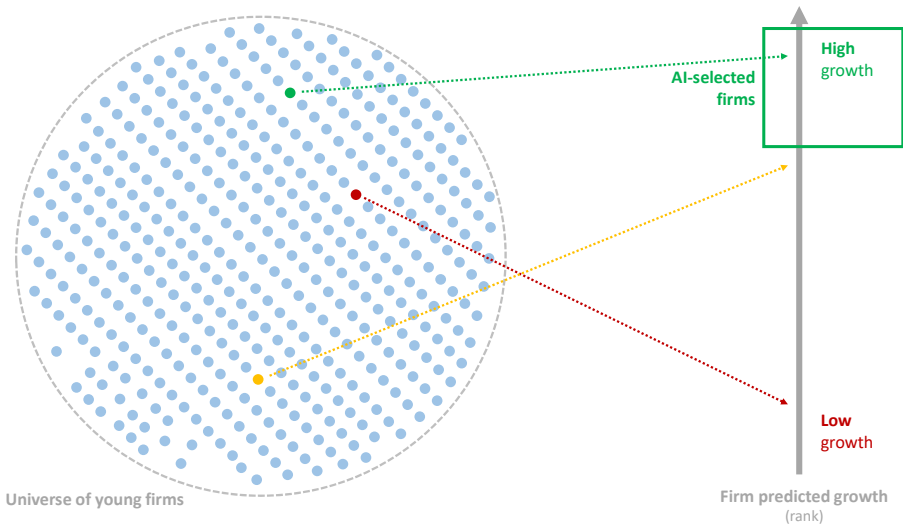
2. **Contrast** algorithmic policy to **VCs' decisions**

- VC-backed firms vs. algorithm-selected firms
- Show which characteristics VCs care about
- Document that these characteristics are representative of the best performing entrepreneurs

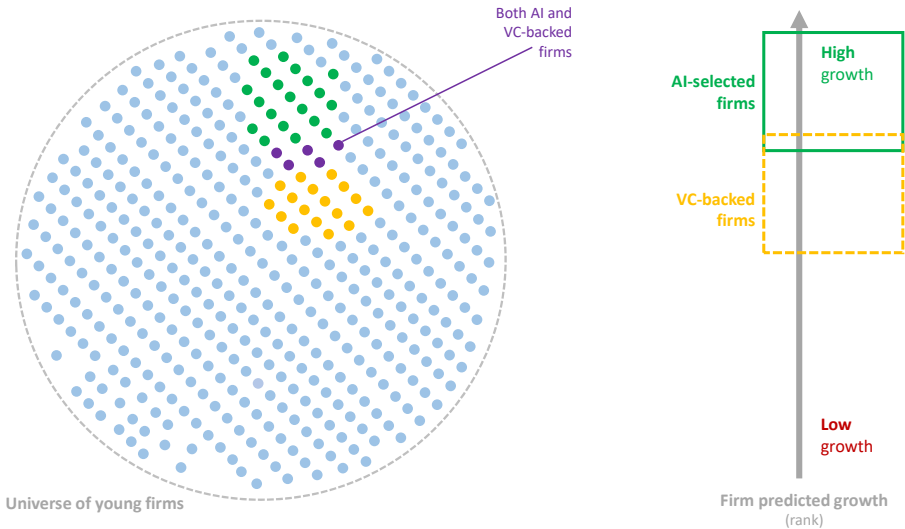


- XG Boost predicts firms' performance based on X a vector of firm and entrepreneur characteristics





- XG Boost selects the most promising firms (Top 0.5%)



- Compare AI-selected firms to VC-backed firms

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Lyonnet and Stern, 2022

Entrepreneur Survey

French
administrative data

4 cohorts every 4 years:
1998-2010

representative sample:
1/3 of all
entrepreneurs

survey questions cover:
demographics
expertise
experience
motivation
expectations
VC-backed

Financial Statements

French
administrative data

Corporate tax filings:
all new firms

Exits

Commercial data

SDC, Zephyr:
M&As + IPOs

Pitchbook:
valuation and revenue
at exit (in a different
sample)

Venture Capital (Mis)Allocation in the Age of AI

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Features

Year of firm creation

Entrepreneur and firm characteristics in entrepreneur survey

Only keep characteristics easily available to VCs in first-pass evaluation

Outcome

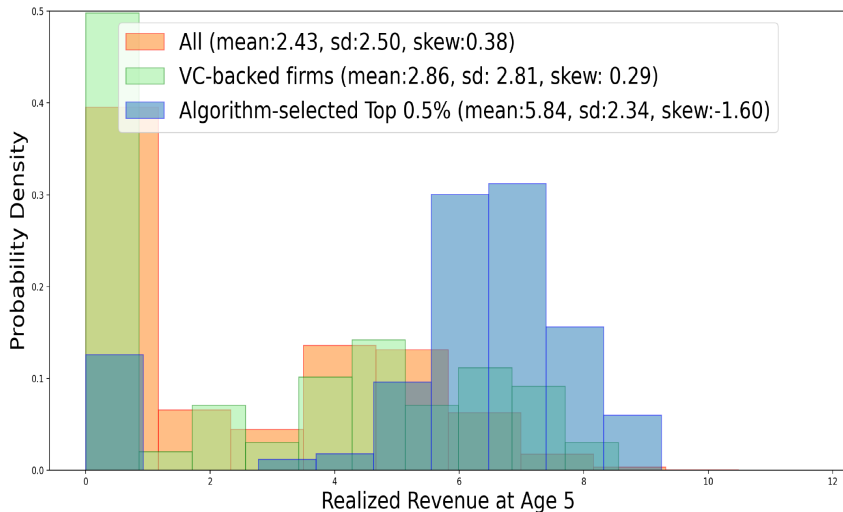
5 or 7 years after firm creation

- revenue (log)
- 1[top 5% revenue]
- successful deals (M&A, IPO, subsequent funding round)

- $n \approx 124k$ new firms in 4 cohorts (1998, 2002, 2006, 2010)
→ drop firms in industries that never receive VC

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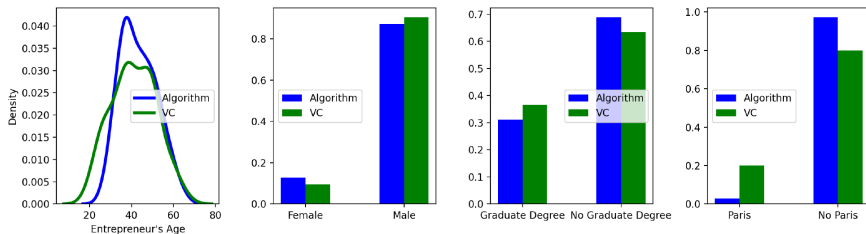


Figure 3: Entrepreneur demographics for VC-backed and algorithm-selected ventures

- VCs **over-weight entrepreneurs' personal features** : gender, education, optimism, and serial entrepreneurs and **locations** (Paris)
- These characteristics are **representative of the best performing entrepreneurs**
- VCs **exaggerate** representative features (stereotypes) of success in their decisions

What about VCs who adopt ML?

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CIO JOURNAL

VC Firms Have Long Backed AI. Now, They Are Using It

Some firms are using AI algorithms to help with investment decisions



AI-Empowered VCs

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The AI powered Venture Capital firm

Investing in early stage European startups

What makes us different

We use proprietary software (known as DIG) to discover, evaluate and support investments in the most promising European startups.

What we look for

The best fit between the business idea, the founding team's DNA and the ability to execute on the product / technology.

How we work with you

With our extensive experience in strategy, product, technology and operations, we support you through the company building process.

[Get Funded](#)

The Adoption of Artificial Intelligence by Venture Capitalists

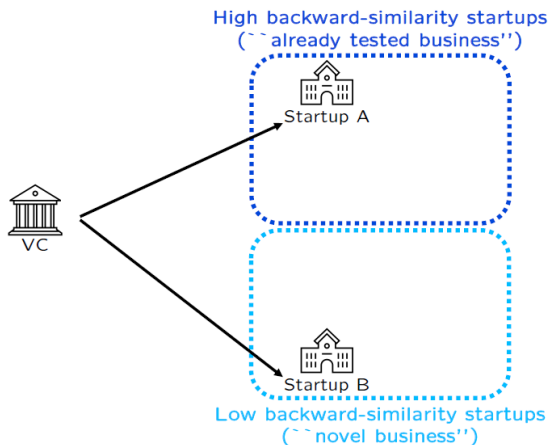
Bonelli, 2022

Research question:

How does AI adoption by VCs
affect startup financing?

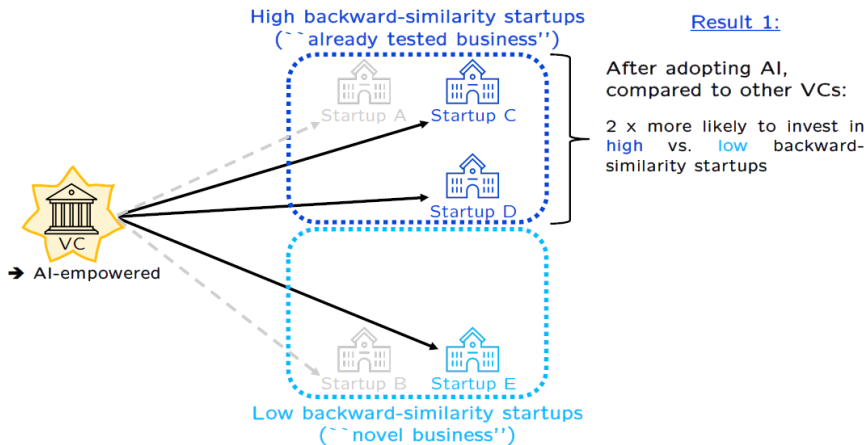
The Adoption of Artificial Intelligence by Venture Capitalists

Bonelli, 2022



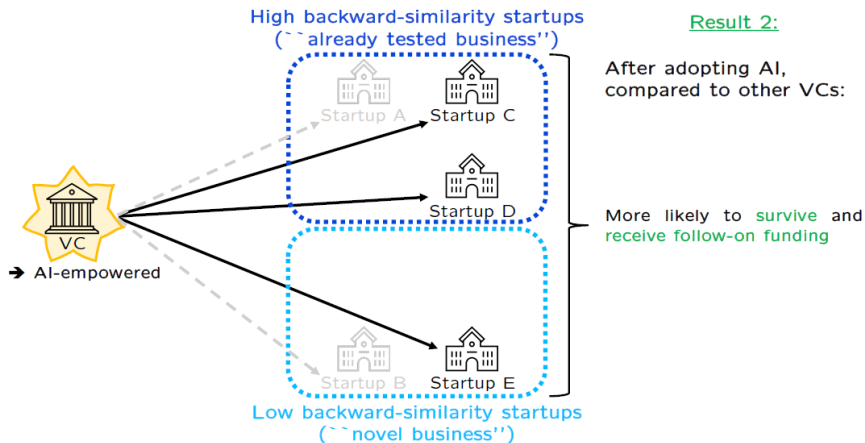
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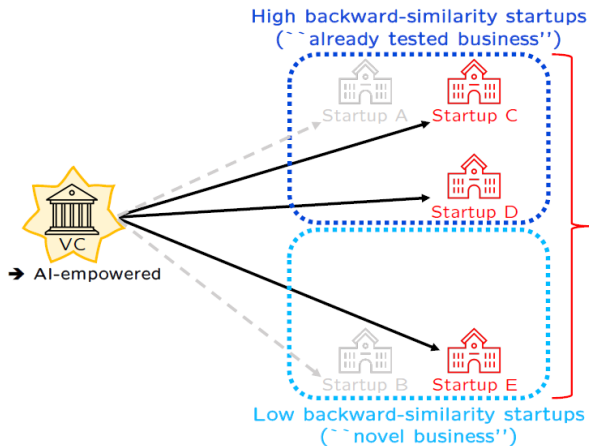
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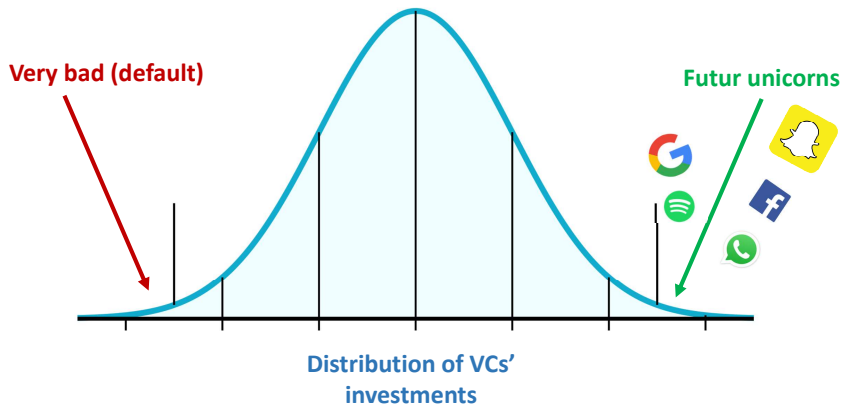


Result 3:

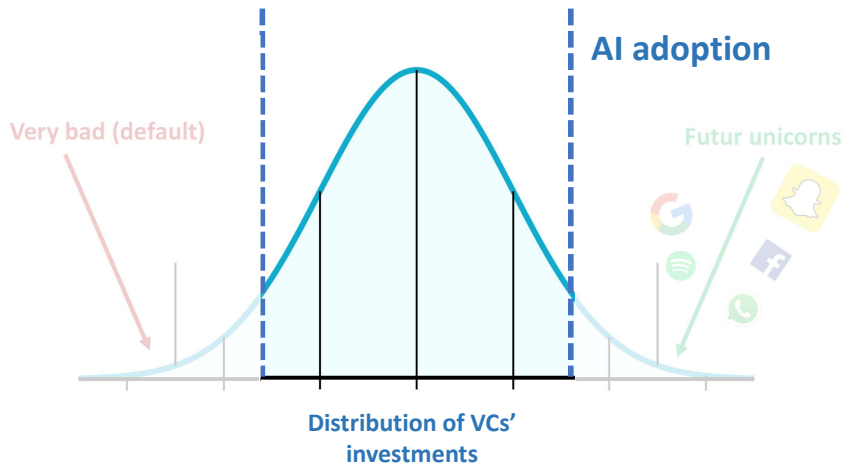
After adopting AI,
compared to other VCs:

- Likelihood of IPO or profitable acquisition: -2.7 p.p.
- New patent applications: -6%
- New highly-cited patents: -3%

AI using historical data not informative about breakthrough companies (Bonelli, 2022)



AI using historical data not informative about breakthrough companies (Bonelli, 2022)



Discussion