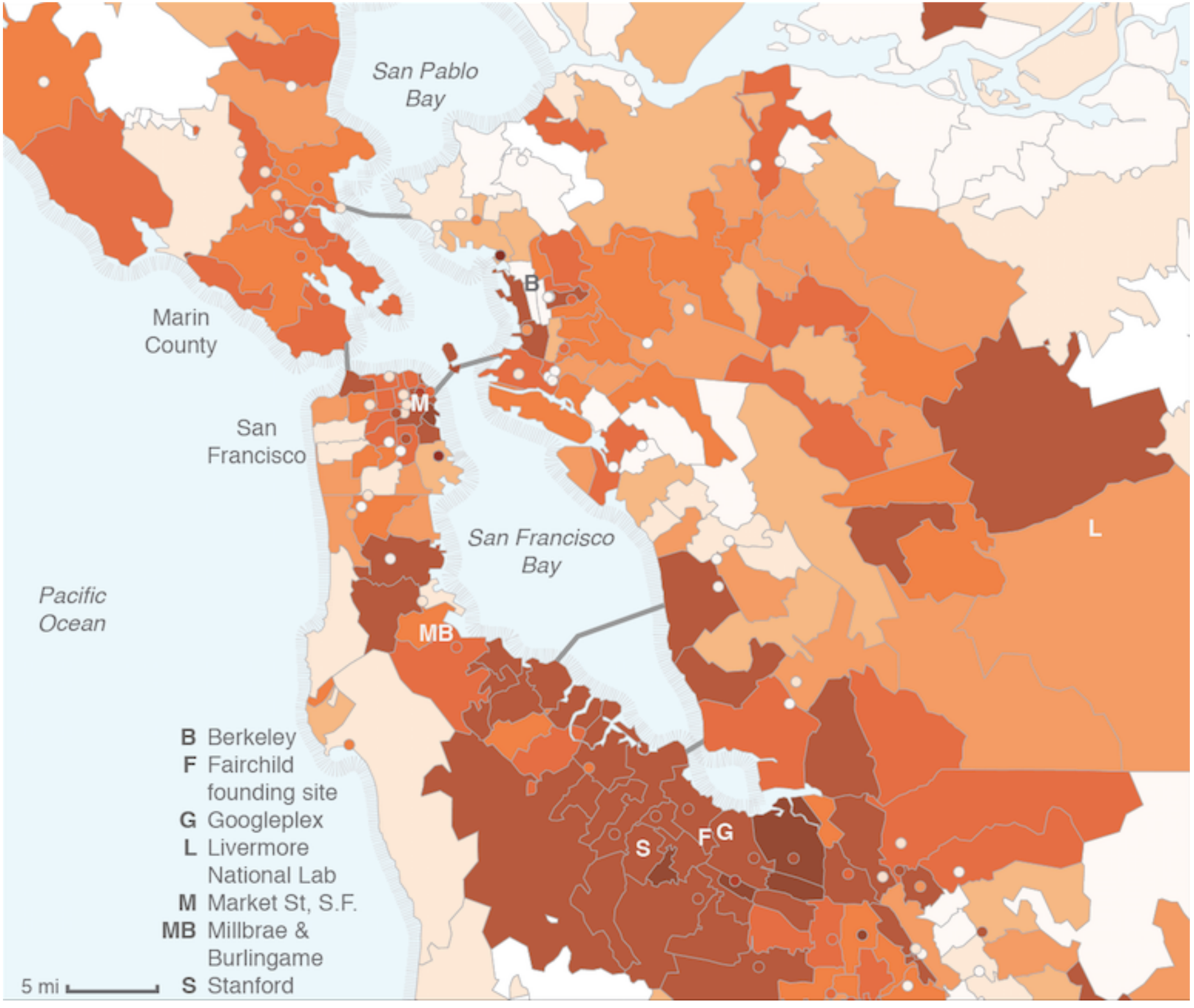
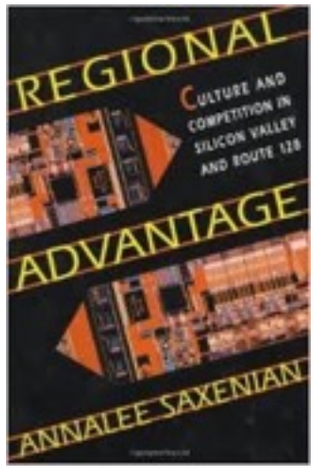
A Theory of Silicon Valley

John J. Horton
NYU Stern School of Business
October 26th, 2015

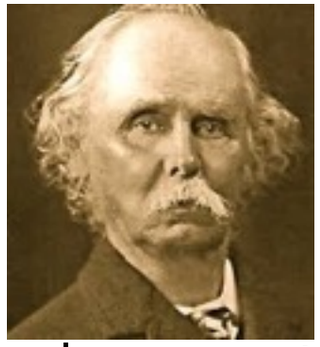


Source: Guzman and Stern (2015)

Silicon Valley Explanations



"Culture"
(Saxenian)



Agglomeration economies in ideas, people, supplies
(Marshall; Glaezer, Ellison & Kerr)

Unenforceable non-compete agreements & frequent job-hopping
(Fallick, Fleischman & Rebitzer)

Spill-overs from corporate & academic R&D
(Jaffe)

This paper

- Goal: **Not** a theory of **why** it emerged, but a theory of **how** the software-focused entrepreneurship found in Silicon Valley "works."

- My model: "Silicon Valley" in three markets: **(1)** financial market for venture capital **(2)** labor market for engineers **(3)** product market for what successful startups sell.

- Key economic actors are "**engineers**" who are needed both to:

  - (1) **found** companies as entrepreneur-engineers

  - (2) **scale** companies as employee-engineers

Recent “products” of SV entrepreneurship

UBER

Instagram

airbnb

Google

Dropbox

Founder backgrounds

CS @ Harvard

UBER

CS @ UCLA

Instagram

CS @ Stanford

CS @ Harvard

CS @ Stanford

CS @ Stanford

Dropbox

CS @ MIT

Outline of my model

1. “Engineers” choose entrepreneurship or employment based on expected financial returns

2. Each engineer-entrepreneur selects a business idea from a pool of ideas

3. Engineer-entrepreneurs obtain seed capital from VCs in exchange for equity in their startup

4. Startups pursuing same idea compete; the world learns if (1) a startup idea “works” (has viable product market) and (2) which particularly startup company succeeds (product market is winner-take-all)

5. Successful startups generate profits split between entrepreneurs and VCs. They also demand engineer labor, which determines the market wage for employee-engineers

	w Employee wages	**e** Retained equity	**q_0** Startup success probability	**π** Profits	**g** Entre-preneurial fraction
c↑ Startup costs	↓	↓	↑	↑	↓
s↑ Supply of engineers	↓	↓	↓	↑	Ambiguous
κ↑ Stock of Ideas	↑	↑	↑	↓	Ambiguous
R↑ Size of product market	↑	↑	↓	↑	↑

Strategic implications

- For “participants” in this system (entrepreneurs, VCs & incumbents), how can you escape the terrible world of fierce competition described by the model?

- There are several places where acting “against” the assumptions of the model would have payoffs (I’ll give examples as they arise)

Three markets

Financial market for Seed Capital

ANDREESSEN HOROWITZ

BENCHMARK CAPITAL

SEQUOIA

greylockpartners.

Labor market for Engineers

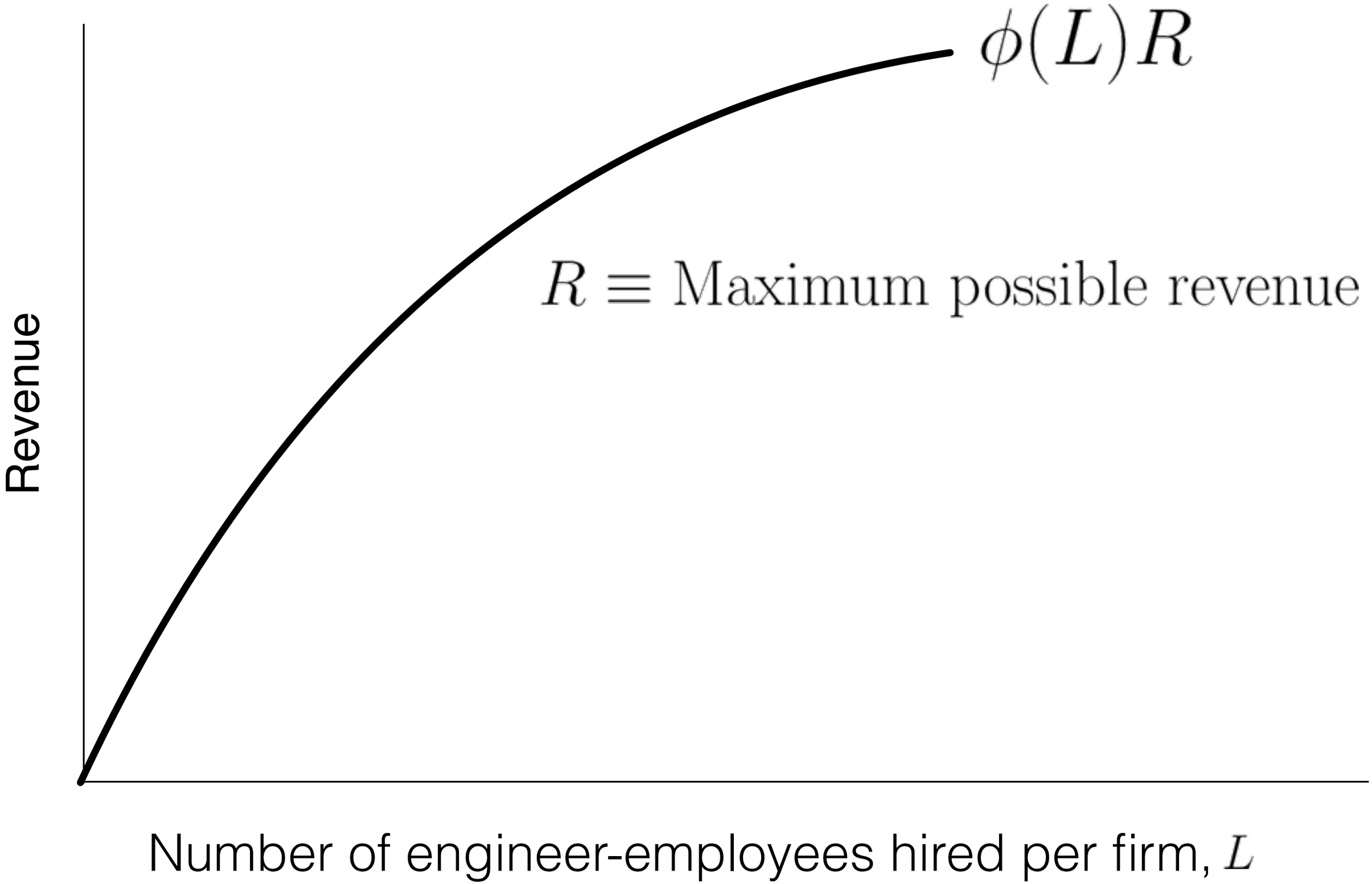
Product market for what Silicon Valley sells

Starting with the product market

- Product market success rewards entrepreneurs; successful companies also generate the demand for engineer labor.

- Modeling the product market: software-focused companies have complex business models:
    - Two-sided platforms; strong network effects; high fixed costs, low or zero marginal costs; some face incumbents and so on.

- My approach: Some total addressable market, $\mathbf{R}$, for an successful startup, with the realized fraction being an increasing function of number of engineers employed.


$\phi(L)R$
$R \equiv$ Maximum possible revenue
Revenue
Number of engineer-employees hired per firm, L

Labor demand problem

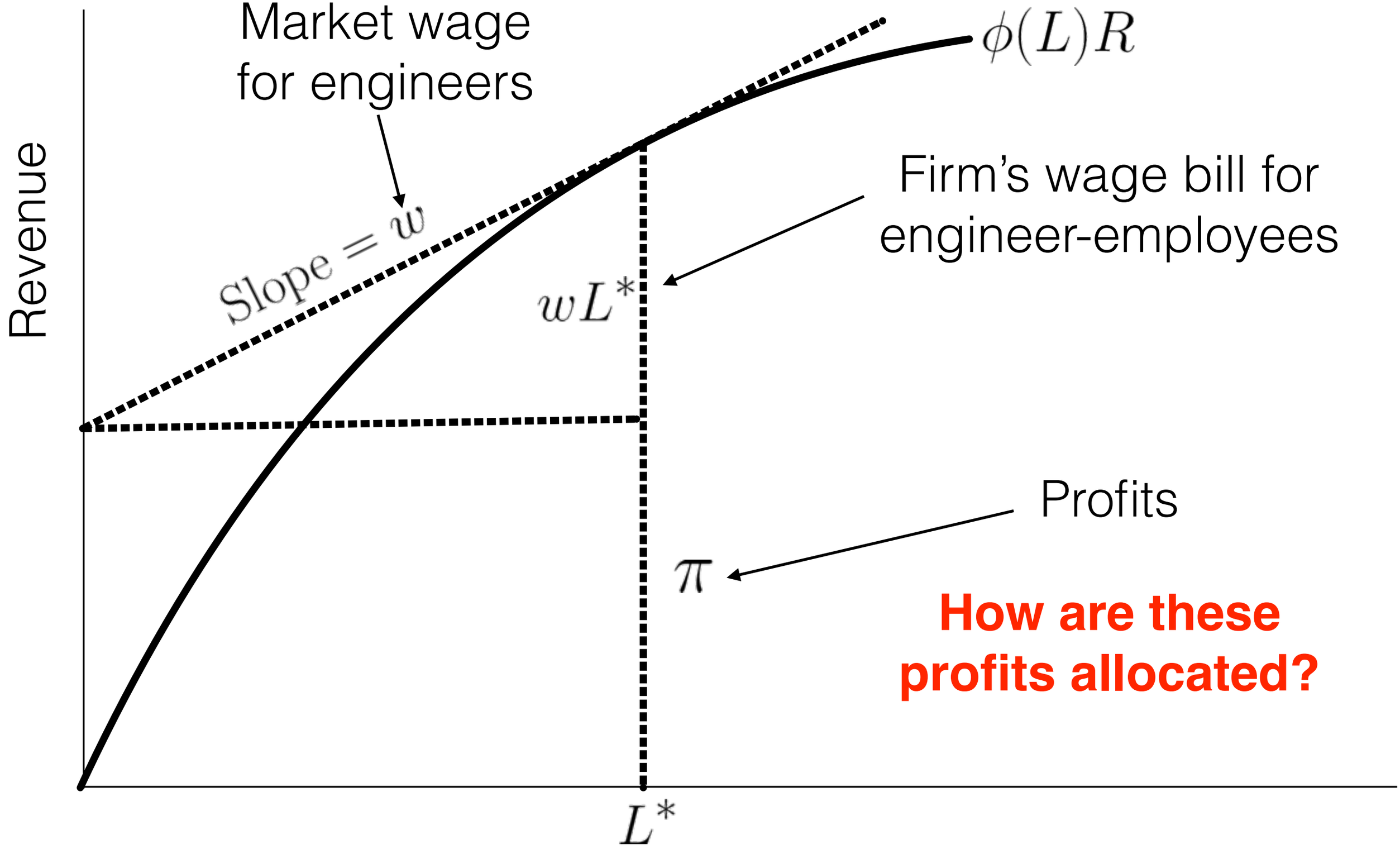
$$\pi(L) = \phi(L)R - wL$$

$$\forall L, \phi(L) \in [0, 1]$$
$$\phi'(L) > 0; \phi''(L) < 0$$

$L \equiv$ Number of scaling engineers

$w \equiv$ Market wage for engineers

$R \equiv$ Maximum possible revenue


Market wage
for engineers
$\phi(L)R$
Revenue
$\text{Slope} = w$
wL^*
Firm's wage bill for
engineer-employees
Profits
π
How are these
profits allocated?
L^*
Number of engineer-employees hired per firm, L

Getting seed capital

- Only an **engineer** can found a company.
- The **entrepreneur-engineer** requires seed capital, **c**, that can only be provided by VCs.
- The entrepreneur-engineer sells **(1- e)** of the startup's equity in exchange for **c**. They keep **e**.
- In equilibrium, VCs get a market return of **r** on their startup investments.

Market clearing in the VC market

$$\underbrace{(1+r)c}_{\text{VC return in equilibrium}} = \underbrace{(1-e)}_{\text{\% of company sold to VCs}} \underbrace{q_0}_{\text{Expected startup profits}} \pi$$

We need the **startup success probability**.

Total startup costs: $C = (1+r)c$

Startup success probability

- Three aspects to success probability:

    1. Can this particularly startup "execute" on their startup idea?

    2. Does the startup idea lead to a viable product market for *some* firm?

    3. Will this startup beat out all other startups pursuing this idea?

- **My model**: For (1), I assume all engineers can execute. For (2), ex ante product market viability is publicly known. For (3), one winner selected at random from all entrants *on that idea*.

Software-focused entrepreneurship and ideas

- Few *software* startups are commercializing basic or applied research:

  - Most startups are exploring something that a new general purpose technology has made possible.

  - Role/importance of patents far less clear (e.g., Hall & MacGarvie)

  - **VC claim**: “Ideas don’t matter” **Translation**: “Any obviously good idea will attract lots of entrants, so execution is paramount.”

Nature of business ideas

"*The transistor*"

My claim:
Software entrepreneurship is mostly here

"*This strip mall would be a good place for a dry cleaners.*"

Requires: Nobel-prize worthy research

Requires: No research whatsoever

Modeling startup ideas

- There are κ ideas available and are free to pursue by any engineer

- Each idea has some ex ante probability of leading to a viable product market (common knowledge); all viable product markets are the same

- Product markets are winner-take-all

Some ideas are obviously good & attract lots of entrants:
“A website people can use to search for other websites”

Some “bad” ideas just are not ripe:
“Take orders online and deliver goods”

kozmo.com
We'll be right over.™

freshdirect

Instacart
ORDER GROCERIES ONLINE
DELIVERY IN 1 HOUR!
OFFICE
HOME
GIFTS

PrimeNow
SKIP THE TRIP.
ONE-HOUR DELIVERY.
EXCLUSIVELY FOR AMAZON PRIME MEMBERS

2000

2015

There is a heterogeneous pool of κ startup ideas

"Website to search for websites"

"Hail a cab with your phone"

"Text messages that disappear"

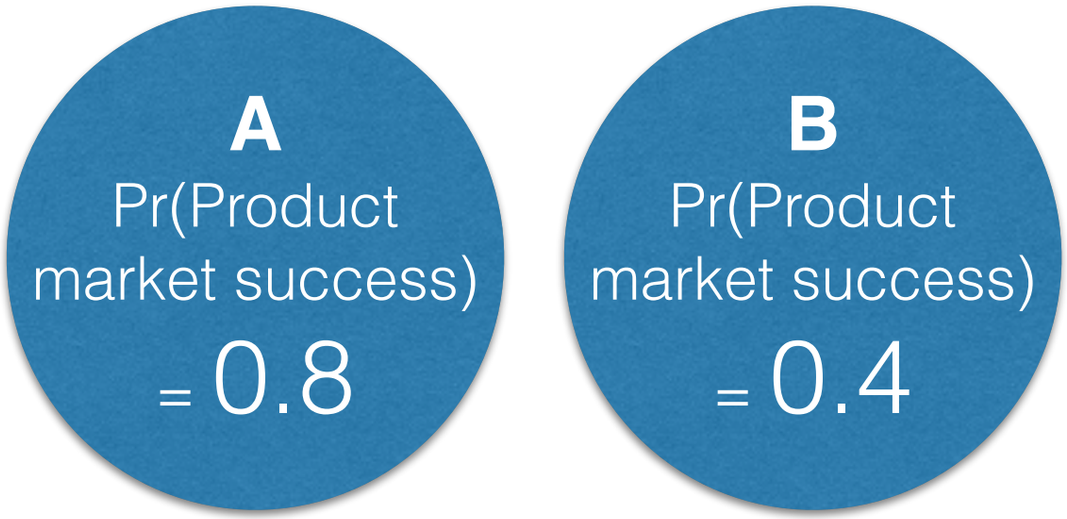
"Photo-taking app with filters"

"Rent out your spare bedroom"

"Upload & watch videos"

Example: Allocation of entrepreneurs over ideas

Total number of entrepreneurs



E	Pursuing A	Pursuing B
1	1	0
3	2	1
6	4	2

Entrepreneur-engineers distribute themselves over startup ideas

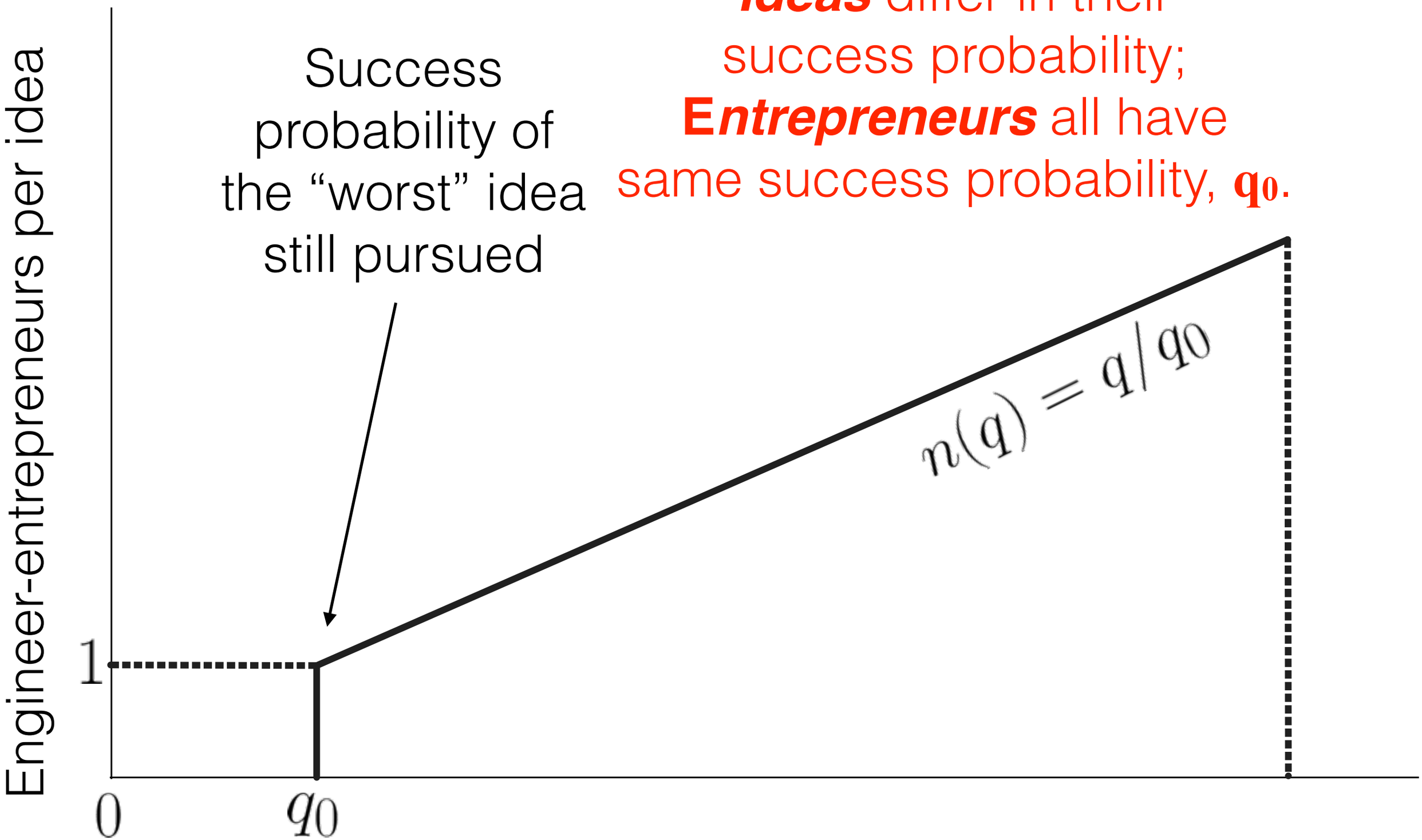
Idea success probability → q

Number of engineers pursuing idea → $n(q)$

$$\frac{q}{n(q)} = q_0$$

q_0: Quality of worst idea pursued

Ideas differ in their success probability; **E*ntrepreneurs*** all have same success probability, $\mathbf{q_0}$.



Total number of entrepreneur-engineers

$$N = \kappa \int_{q_0}^{1} \frac{q}{q_0} \underbrace{f(q)}_{\text{pdf for idea success probability}} dq.$$

Back to the labor market: number of engineer-employees

$$N \, q_0 \, d(w)$$

Number of entrepreneurs

Success probability

Firm demand schedule for engineers

Successful firm demand schedule for engineer labor:

$$d(w) = \frac{\partial \pi}{\partial w} = L^*$$

Allocation of engineers between employment and entrepreneurship

$$\underline{S} = \underline{N} + N q_0 d(w)$$

Number of engineers

Number of entrepreneur-engineers

Number of employee-engineers

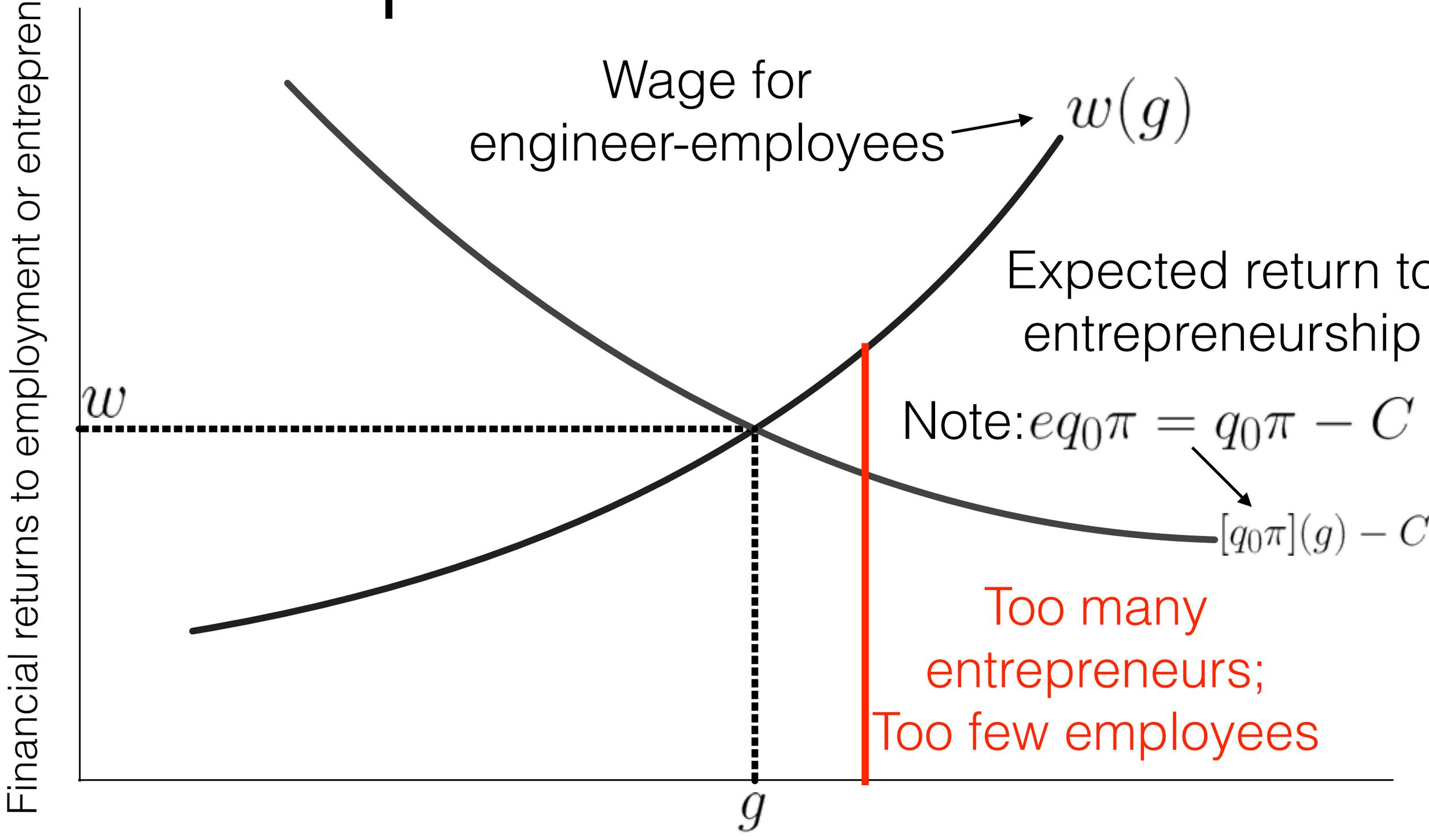
Fraction of engineers devoted to entrepreneurship

$$g = \frac{1}{1 + q_0 d(w)}$$

$$gS \equiv \text{Entrepreneurs}$$

$$(1-g)S \equiv \text{Employees}$$

Occupational selection



Key equilibrium assumption: Occupational indifference

$$\underline{w} = \underline{e q_0 \pi}$$

Employee-Engineer wage

Entrepreneur-Engineer retained equity

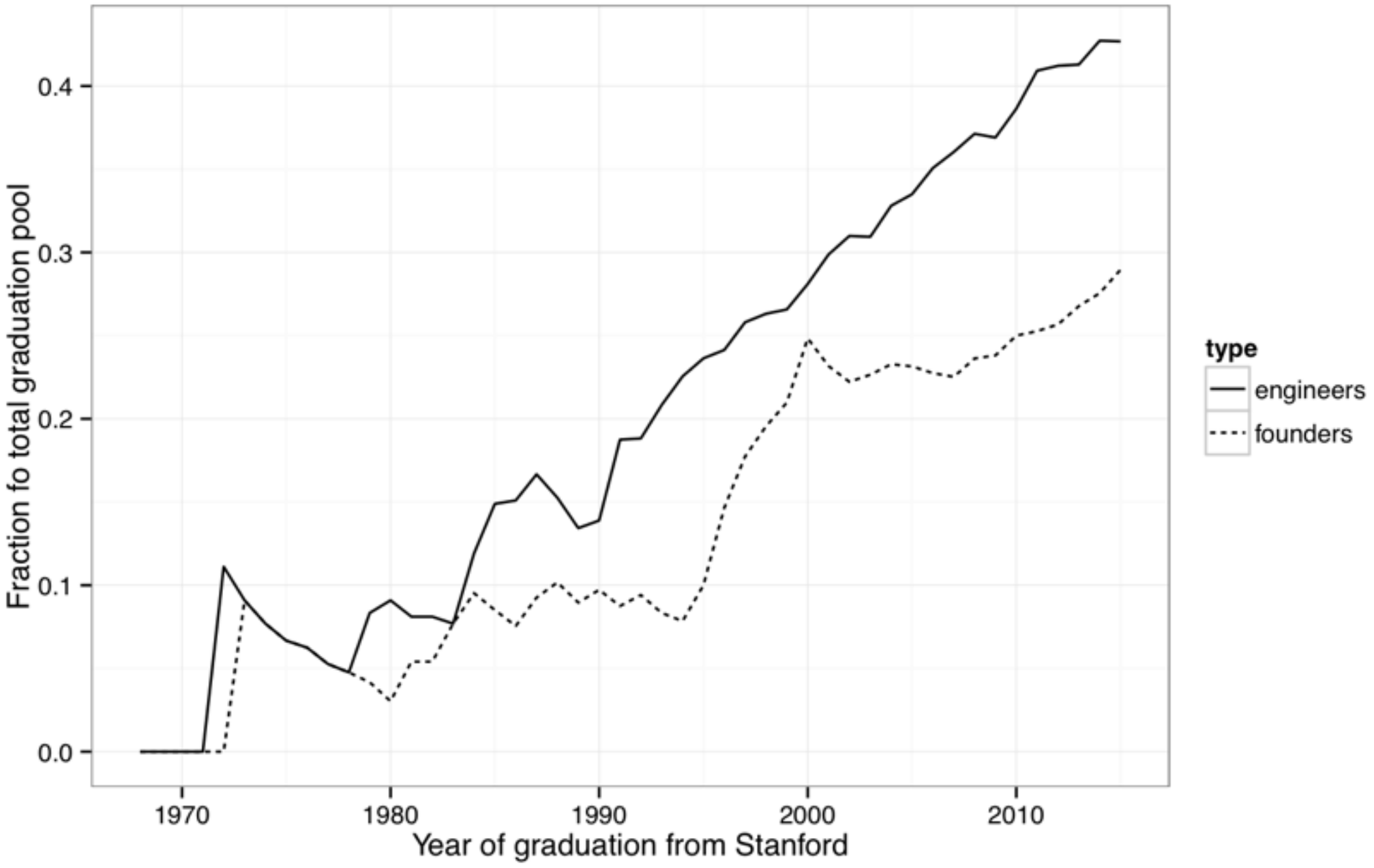
Startup success probability

Profits, if successful

But what about…?

- Factors like:
  - Appetite for risk?
  - Taste for small/big company/entrepreneurship?
  - Sectoral-specific productivity ala Lazear or Roy?
- Response:
  - “Methodology of positive economics” view of assumptions
  - A big chunk of the paper focuses on assessing these claims, but patterns of tech entrepreneurship are not consistent with risk-based views
  - Adding taste-based sorting probably does not matter for comparative statics results anyway (investigating)

Career choices of Stanford CS PhDs, by year



Query: “Google or startup”

Do a startup

Join Google

CDIXON BLOG

STARTUP AS A CAREER

Every time an engineer joins Google, a startup dies

BY CDIXON ON
FEBRUARY 11, 2010

Brian Acton

Brian Acton

San Francisco Bay Area | Internet

Current	WhatsApp Inc.
Previous	Yahoo! Inc., Apple Computer, Adobe
Education	Stanford University

Connect

5 years later…

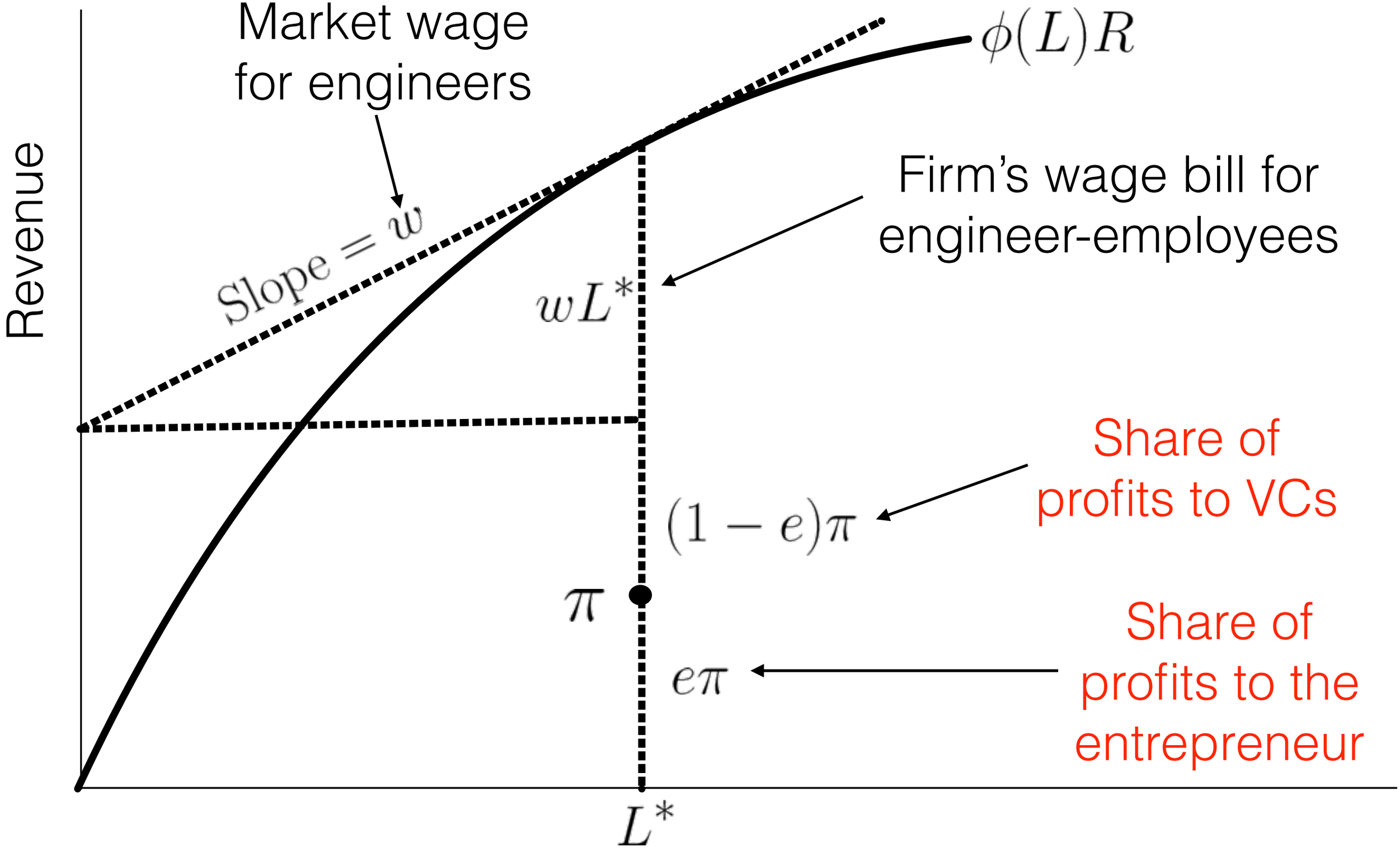
Facebook Closes $19 Billion **WhatsApp** Deal
Forbes - Oct 6, 2014
Facebook says it has wrapped up its landmark $19 billion **acquisition** of **WhatsApp**, a deal that was hashed out in Mark Zuckerberg's house ...

Facebook completes its $22 billion **acquisition** of **WhatsApp** after **...**
In-Depth - Daily Mail - Oct 7, 2014

Explore in depth (323 more articles)

With occupational indifference, an equilibrium

$$w \equiv \text{Engineer wage}$$
$$e \equiv \text{Retained equity}$$
$$q_0 \equiv \text{Startup success probability}$$
$$\pi \equiv \text{Realized profits}$$
$$g \equiv \text{Fraction engineers as entrepreneurs}$$


Market wage
for engineers
$\phi(L)R$
Revenue
$\text{Slope} = w$
wL^*
Firm's wage bill for
engineer-employees
Share of
profits to VCs
$(1-e)\pi$
π
Share of
profits to the
entrepreneur
$e\pi$
L^*
Number of engineer-employees hired per firm, L

Comparative statics predictions

- What are the effects on the equilibrium from changes to:
  - Startup costs
  - Innovation environment
  - Supply of engineers
  - Size of the product market

	Shocked by:
C Startup costs	Software capabilities & cost, web servers (price structure and levels), land prices, bandwidth charges, interest rates, crowdfunding rules, angel investing
S Supply of engineers	H1B Visas, funding for STEM education, housing/real estate prices
κ Stock of Ideas	Changes in ownership patterns (e.g., rise the smartphone), R&D funding, patent and licensing laws/regulations
R Size of product market	Trade restrictions and liberalizations (e.g., China), emergence of new platforms/new general purpose technologies (PC, Web, Smartphone etc.)

Startup costs

Proposition 1. *An increase in startup costs: (1) lowers the wages of engineers, (2) lowers the retained equity of entrepreneurs, (3) raise the startup probability of success, (4) raises expected profits, (5) raises realized profits, and (6) reduces the fraction of engineers pursuing entrepreneurship.*

This morning:

In the news

AngelList receives $400 million for start-ups
CNBC - 21 hours ago
Start-up investing platform **AngelList** announced on Monday ...
Start-up investing platform **AngelList** announced on Monday that its start-ups will be getting **$400 million** from a ...

Coming Soon From China: A $400 Million Bonanza for US Startups
Wall Street Journal - 1 day ago

AngelList To Power The World's Largest Seed Fund With $400M From Chinese Private Equity Firm
TechCrunch - 1 day ago

More news for 400 Million Angel List

	w Employee wages	**e** Retained equity	**q_0** Startup success probability	**π** Profits	**g** Entre-preneurial fraction
c↑ Startup costs	↓	↓	↑	↑	↓

Financial returns to employment or entrepreneurship

Wage for engineer-employees

$w(g)$

Expected return to entrepreneurship

$[q_0\pi](g) - C$

w

g

Fraction of engineers pursuing entrepreneurship

Financial returns to employment or entrepreneurship

Wage for engineer-employees

$w(g)$

Expected return to entrepreneurship

$[q_0\pi](g) - C$

$[q_0\pi](g) - (C + \Delta C)$

Startup costs increase

w

w'

g'

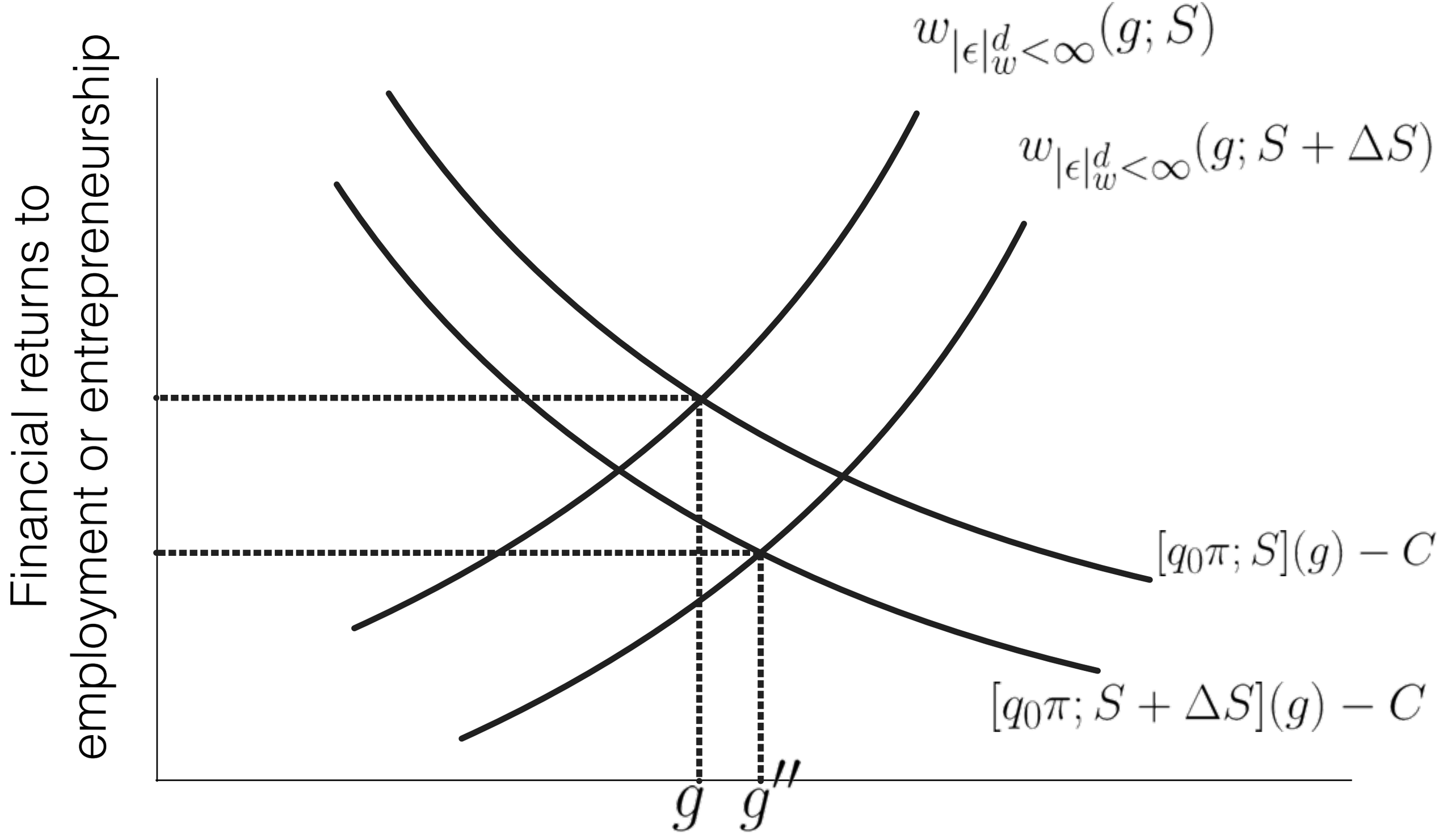
g

Fraction of engineers pursuing entrepreneurship

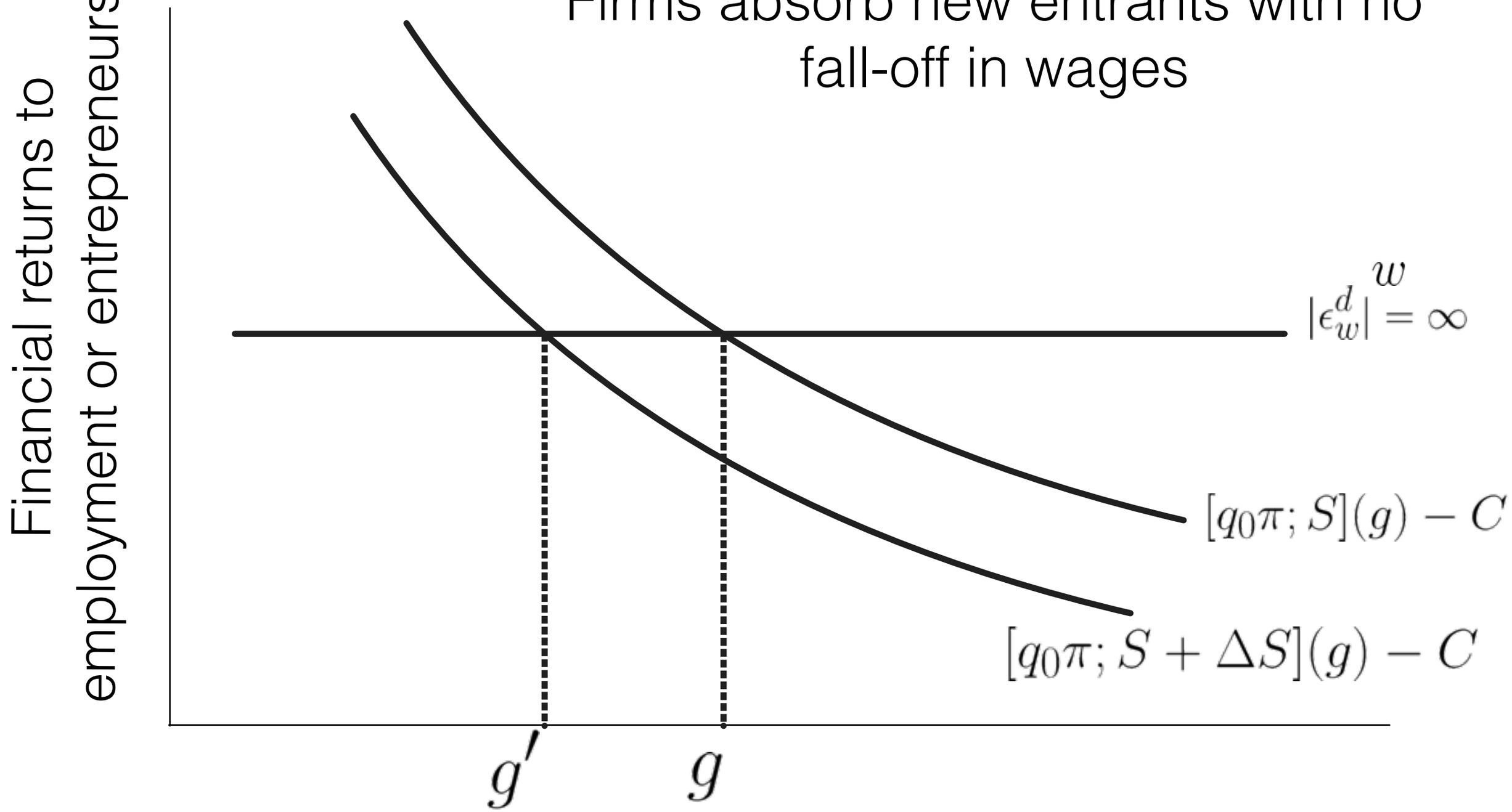
Supply of engineers

Proposition 2. *An increase in the supply of engineers: (1) lowers the wages of engineers (2) lowers the retained equity of entrepreneurs. (3) lowers expected profits (4) raises realized profits (5) lowers the startup probability of success and (6) has an ambiguous effect on entrepreneurship.*

	w Employee wages	**e** Retained equity	**q_0** Startup success probability	**π** Profits	**g** Entre-preneurial fraction
S↑ Supply of engineers	↓	↓	↓	↑	Ambiguous


Financial returns to employment or entrepreneurship
$w_{|\epsilon|_w^d<\infty}(g;S)$
$w_{|\epsilon|_w^d<\infty}(g;S+\Delta S)$
$[q_0\pi;S](g)-C$
$[q_0\pi;S+\Delta S](g)-C$
g
g''
Fraction of engineers pursuing entrepreneurship

Highly elastic labor demand =
Firms absorb new entrants with no fall-off in wages



Supply of engineers and entrepreneurship

- New entrant engineers will not necessarily “split” into occupations at same proportions as existing engineers

- If engineer labor demand is highly elastic, new entrants will be biased towards employment and vice-versa if demand is highly inelastic

Stock of ideas

Proposition 3. *An increase in the stock of startup ideas: (1) raises the wages of engineers, (2) raises the retained equity of entrepreneurs, (3) raises expected profits, (4) lowers realized profits, (5) raises the startup probability of success, and (6) has an ambiguous effect on entrepreneurship.*

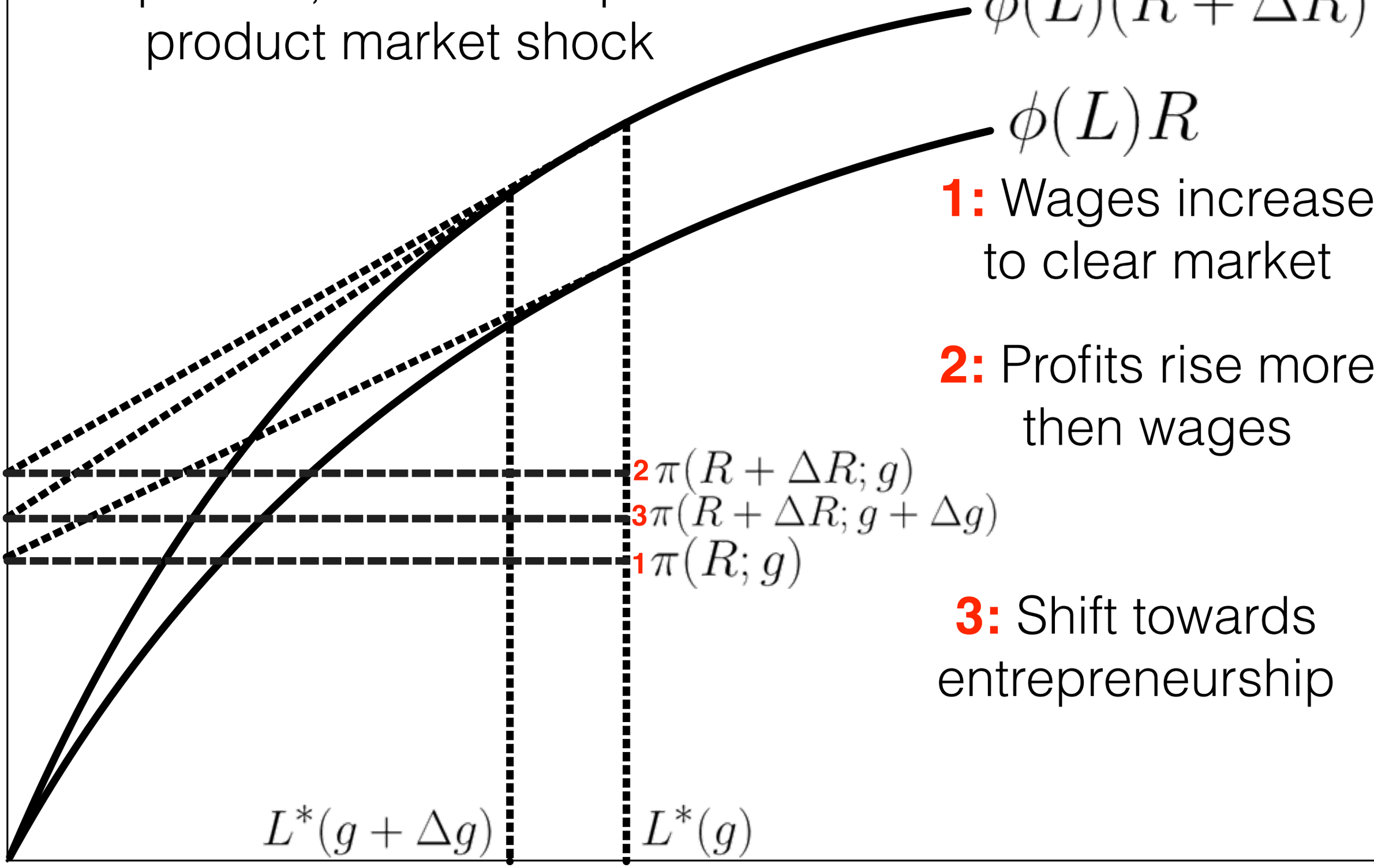
	w Employee wages	**e** Retained equity	**q_0** Startup success probability	**π** Profits	**g** Entre-preneurial fraction
κ↑ Stock of Ideas	↑	↑	↑	↓	Ambiguous

Size of the product market

Proposition 4. *An increase in the size of the product market: (1) raises the wages of engineers, (2) raises the retained equity of entrepreneurs, (3) lowers the startup probability of success, (4) raises expected profits, (5) raises realized profits, and (6) increases the fraction of engineers pursuing entrepreneurship.*

	w Employee wages	**e** Retained equity	**q_0** Startup success probability	**π** Profits	**g** Entre-preneurial fraction
C↑ Startup costs					
S↑ Supply of engineers					
κ↑ Stock of Ideas					
R↑ Size of product market	↑	↑	↓	↑	↑

Before engineers adjust occupations, consider a positive product market shock



1: Wages increase to clear market

2: Profits rise more then wages

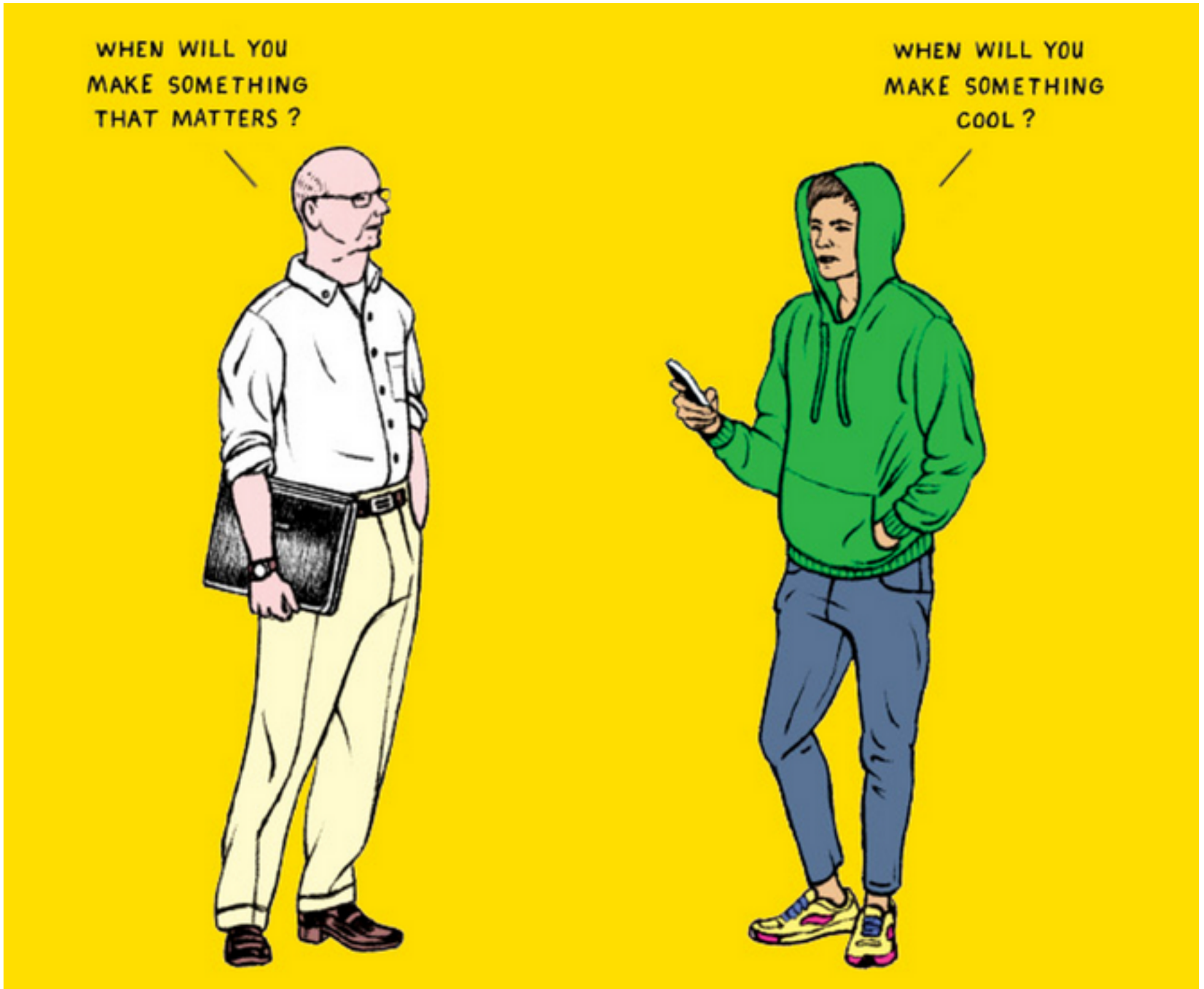
3: Shift towards entrepreneurship

Number of engineer-employees per firm

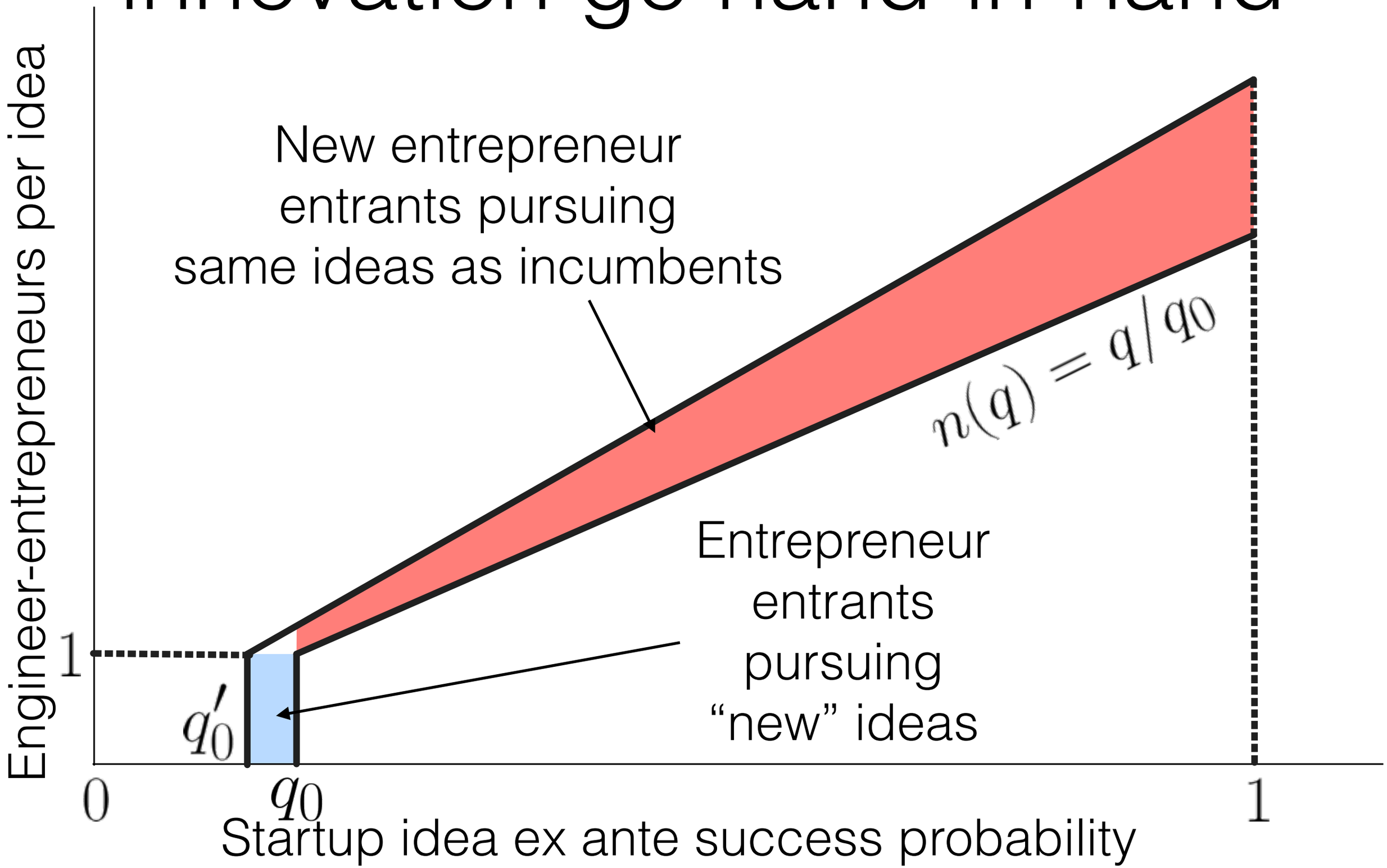
Comparative statics & Silicon Valley FAQs

- Is there a tech bubble? Are startups overvalued? Is too much money chasing too few deals?
- Is there too little entrepreneurship? Too much?
- Are startups pursuing innovative ideas?
- What should our public policy be on worker visas, STEM education, equity crowdfunding, land-use policy, R&D funding etc.?

Debates "about" q_0



Duplicative effort & innovation go hand-in-hand



Concluding thoughts

- Model offers many testable predictions about measurable things
    - On measurement: new datasets on startups, their competitors, valuations, success rates and so on
- Ideas and engineers come out strong as complements (the ratio of engineers to ideas is important in the model)
- Some changes in model parameters are consistent with observed changes in Silicon Valley (e.g., rising wages, higher valuations, more entrepreneurship)
- Concerns about amount of entrepreneurship - need for nuance
    - Open question: Is the amount of entrepreneurship socially efficient?

Thank you

Title: “A Theory of Silicon Valley”
Presented at: Duke Strategy Conference
Author: John J. Horton, NYU Stern
Draft: http://www.john-joseph-horton.com/papers/sv.pdf

Back-up slides

What about importance of risk aversion?

- Software startups have little downside risk (e.g., un-securitized loans from VCs)

- Many startup founders are young and have little assets, inconsistent with risk-aversion story (youth do have lower labor market opportunity costs though)

- Stints back & forth between employment and entrepreneurship are common place

- Very little evidence that startup founders try to diversify away from large ownership stakes

- Not clear is matters much for the comparative static results anyway

Why not something dynamic?

- Time from startup to success is remarkably compressed (particularly for failures)

- A “regular” career has time for many stints

What about big companies?

- Some innovation by big companies, of course
- But acquisition of promising startups seems to be an increasingly common strategy
    - Possible reason: lack of enormous growth potential inhibits quasi-rent needed to secure extraordinary efforts from employees

Ideas take purposeful effort to develop. Where is this?

- Many ideas are “dry cleaners” ideas:
    - Business ideas that make use of general purpose technologies or a shifted technological landscape
- There are other sources of ideas
    - Academic research, government research. Corporate R&D that spills
- Software VCs generally don’t fund research

What about other costs to scaling a company?

- This would affect levels but not comparative statics.