The Sources of Innovation in the U.S. Manufacturing Sector

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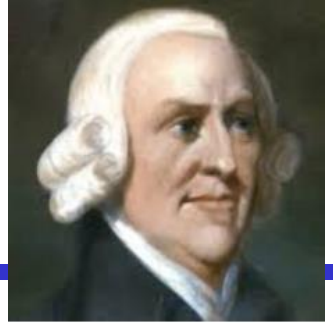
Questions

- **How "open" is innovation?**
  - I.e., How often do firms obtain the inventions underlying their new, commercialized products (i.e., innovations) from outside sources?
- What sources?—Users? Universities? Other firms in the industry? Etc.
- Through what channels?—Licensing? Cooperative relationships? Etc.
- The relative value of inventions across sources?
- How do firm capabilities affect their acquisitions of inventions and knowledge from the outside?
- **So what?**

Start with the last question: Importance?



- The social benefits from a division of labor in the economy have been long understood.
  - First sentence of first chapter of Smith's *The Wealth of Nations*:

> "The greatest improvement in the productive powers of labour…seem to have been the effects of the division of labour."
>
> (*Adam Smith*, 1776)

Benefits of the division of *innovative* labor (DoIL)

- Exploitation of comparative advantage
  - E.g., a firm or institution that invents something may not be the firm most capable of bringing that invention to market.
- Promotion of specialization in invention and commercialization, yielding efficiencies from scale and learning
- Having more metaphorical "minds" working on a problem increases likelihood of success

=> Gains from "trade"

Project

- A survey of product innovation for firms in mfg and selected service industries in 2010
- Focus: innovators--i.e., Firms that commercialize new-to-the-market (NTM) products.
- Population: All firms, not just innovators
  - Challenge: Identifying innovating (not inventing) firms
- Respondents asked to focus on:
  - A specific line of business
  - "Most important innovation"--That innovation intro'd since 2007 accounting for plurality of 2009 business unit sales.

Data

- Sample: > 22,000 firms
- **6685 responses (30.3% response rate)**
- For paper, excluded out of population and tiny firms (< 10 employees), and **focus on manufacturing**, leaving **5,157 in sample**.

Who innovates?

Rates of innovation and imitation, manufacturing industries (wtd)

INDUSTRY	N	% NOSI	% NTM	Imitation % (NOSI-NTM)	% sales from NOSI	% sales from focal innovation	% NTM patented
Food & Bev	362	40	13	27	16	9	24
Text	210	38	15	22	19	15	51
Wood	385	33	8	25	15	7	11
Chem	365	50	24	25	17	9	42
Pharma	128	63	28	33	23	13	61
Plastics	340	48	16	31	14	6	42
Minerals	323	31	9	21	21	14	35
Metals	324	38	9	29	14	5	23
Fab Metals	424	39	10	28	28	8	35
Machinery	384	46	20	24	24	14	52
Electronic	146	76	33	43	38	9	58
Semi Con	302	61	27	33	29	18	59
Instrument	135	60	37	22	17	7	54
Elec Equip	344	54	26	28	25	13	53
Auto	339	53	27	23	25	11	34
Med Equip	136	56	22	33	37	31	72
Miscl	510	48	19	29	30	10	45
All mfg	**5157**	**43**	**16**	**27**	**22**	**11**	**42**
Large (> 1000)	1268	66	38	27	24	10	63
Med. Firms	945	54	23	31	20	15	47
Small (< 100)	2944	40	13	26	19	12	36

1. External Sources of (NTM) Innovation

External sources (asked of all innovators)

- *(For the focal innovation) Did any of the following originate this innovation, that is, create the overall design, develop the prototype or conceptualize the technology?* [Responses not mutually exclusive]

Supplier	14%
Customer	27%
Consultant/ Comm. Lab/ Service provider	8%
Independent Inventor	7%
University/Govt Lab	5%
Other Firm in industry	8%
Any external source	49%

Technology specialists: 17%

Sources of invention by industry (wtd means)

INDUSTRY	N	Any External	Supp	Cust	Other Firm	Consult./ Serv prov	Ind. Inventor	Univ, Gov't	Specialist
Food & Bev	63	46	34	15	8	1	5	0	6
Text	33	50	32	26	4	3	6	0	9
Wood	52	52	22	27	11	14	1	0	15
Chem	102	49	17	15	5	10	3	5	16
Pharma	30	50	2	9	17	6	6	19	30
Plastics	74	53	11	28	5	11	16	4	27
Minerals	36	49	6	23	3	8	12	10	27
Metals	44	49	29	30	11	11	4	7	13
Fab Metals	60	48	10	38	6	0	4	3	7
Machinery	98	49	7	36	10	12	7	6	21
Electronic	50	45	11	17	10	8	6	5	14
Semi Con	91	62	16	49	9	13	8	9	23
Instrument	53	48	5	26	7	11	9	1	19
Elec Equip	98	44	12	26	4	8	7	4	17
Auto	101	52	11	28	12	6	17	15	25
Med Equip	36	49	18	22	4	13	9	15	32
Miscl	106	46	8	20	13	10	9	2	18
All mfg	1127	49	14	27	8	8	7	5	17

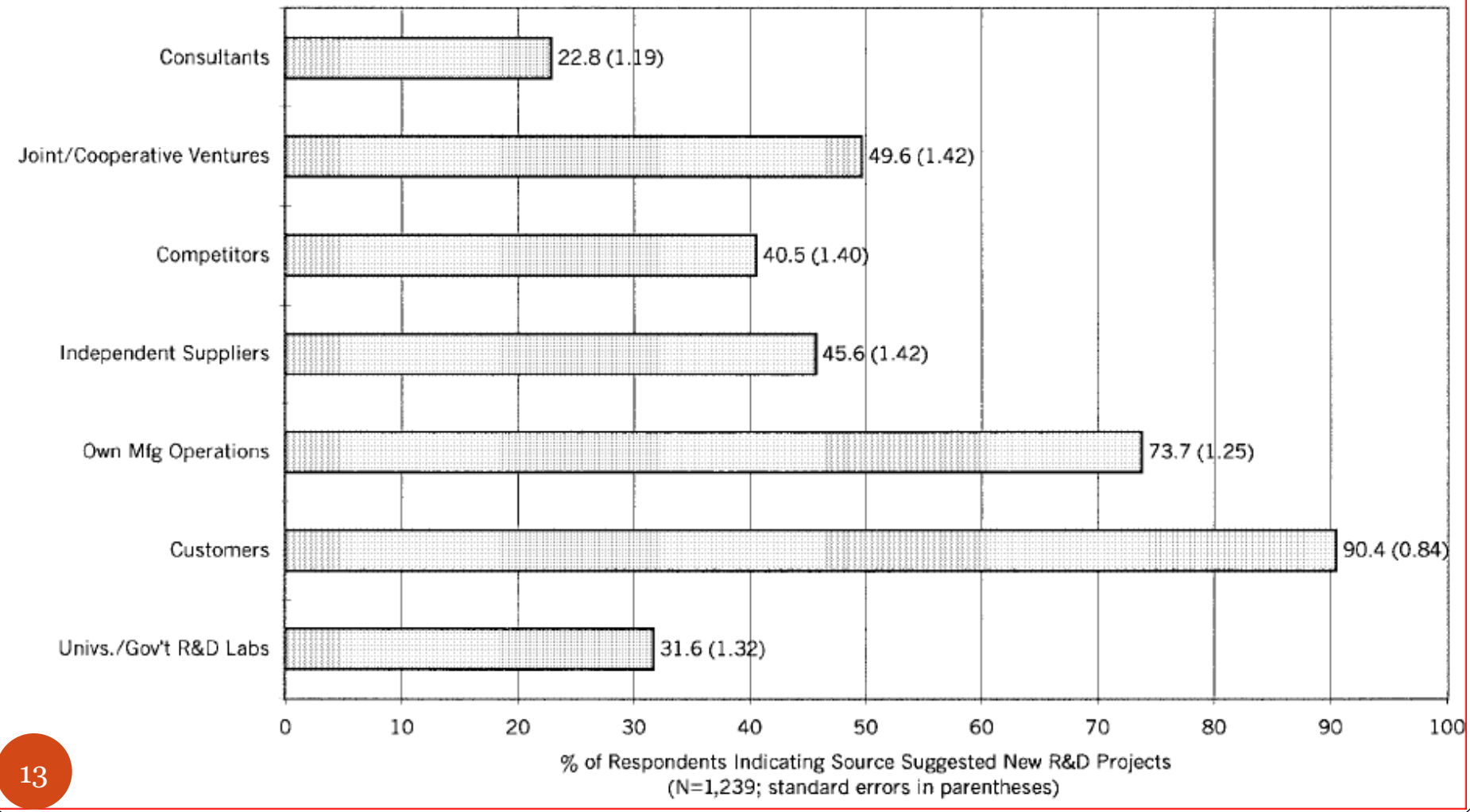
Observations on sources

- **Dependence on external sources high and stable across industries and firm-size classes**
  - **49% of innovators claim that an outside source created, developed or conceptualized the technology**
- Customers (27%) most pervasive source
  - Tend to be source when firms' customers are other firms, not final consumers
- More R&D intensive industries rely less upon suppliers and customers (r= -0.30 and -0.49), and more upon universities (r=0.40)

Detour: Public research (Cohen et al., 2002)

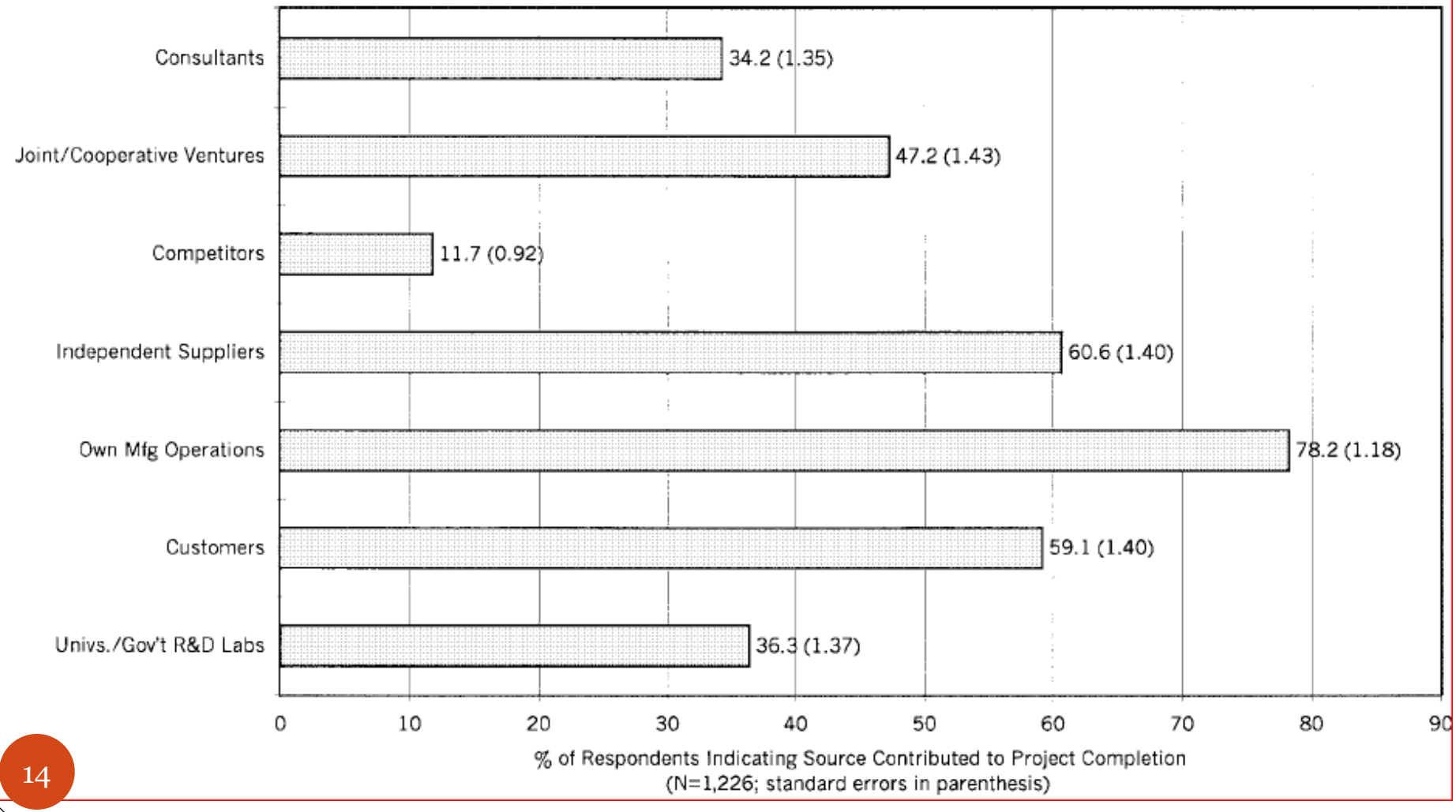
Inventions ≠ knowledge

Figure 1 Information Sources Suggesting New Projects



Public research: Provides frontier research and also a repository of expertise, techniques, etc.

Figure 2 **Information Sources Contributing to Project Completion**



Back to inventions

2. CHANNELS

For those who acquire their inventions from outside the firm

(responses not mutually exclusive)

Channels for acquiring inventions

	N	M&A	Lic.	Contract	JV/ Coop	Infor-mal	Mkt.	Mkt. only
All	423	10%	13	21	61	37	37	16

Observations on channels

- Market-based channels comprise just over a third of inventions acquired from outside sources.

  => DoIL spans more than market transactions

- Almost two-thirds of exchanges rely on non-market channels, especially cooperative efforts, suggesting pervasive co-invention between focal firm and source and limitations of purely market channels.
- While sourcing from customers relies heavily upon informal or cooperative channels, sourcing from "specialists" relies heavily upon market channels.

3. Value of inventions across sources

Value of inventions by source

- We examine relationship between provenance of "most significant innovation" and indicators of value, featuring:
  - Share of business unit sales due to that innovation
  - Whether respondent invests in new personnel/equipment to commercialize
- Other indicators of value
  - Whether innovating firm patents the innovation
  - Whether firm's market share increases
  - Develops new distribution channel to commercialize
- Important details
  - Correcting for selection
  - Reference category = internal innovations

Relationship between indicators of invention value and source (cont'd)

	Log of % firm sales from focal innovation (Sample Selection correction)	(% firm sales from focal innovation greater than 50%) = 1 (Sample Selection correction)
Customer	-0.19** (0.07)	-0.07** (0.02)
Supplier	0.03 (0.10)	0.05* (0.03)
Other Firm	-0.13 (0.12)	-0.04 (0.04)
Specialists	0.34*** (0.09)	0.07** (0.03)
Ln (Empl)	-0.32** (0.06)	-0.07*** (0.02)
R&D	0.43*** (0.14)	0.09** (0.04
Ind. FE's (45)	Yes	Yes
Controls	Parent size, Age	Parent size, Age
Ln (share of source)	-0.05 (0.07)	-0.01 (0.02)
N	927	927
R^2	0.19	0.15

Relationship between indicators of invention value and source (Selection corrected estimates)

	Innovator invests equip or new skills	Innovator invests in sales channel	Firm has patented innovation	Innovator increased mkt share (=1)
Customer	-0.03 (0.04)	-0.00 (0.04)	-0.08** (0.03)	-0.05 (0.04)
Supplier	-0.19***(0.05)	0.01 (0.05)	-0.11** (0.05)	0.07 (0.05)
Other Firm	0.00 (0.06)	0.02 (0.06)	-0.08 (0.06)	-0.06 (0.06)
Specialists	0.14***(0.05)	0.10** (0.04)	0.28*** (0.04)	0.14*** (0.05)
Ln (Empl)	0.06* (0.03)	0.05* (0.03)	0.11*** (0.03)	0.03 (0.03)
R&D	-0.02 (0.07)	-0.03 (0.07)	0.18***(0.06)	0.16**(0.07)
Ind. FE's	45	45	45	45
Controls	Parent size, Age	Parent size, Age	Parent size, Age	Parent firm size, Age
Ln (share of source)	-0.08** (0.03)	-0.02 (0.03)	0.03 (0.04)	-0.03 (0.03)
N	1012	1017	1019	916
R^2	0.14	0.16	0.26	0.13

Interpretation

- The value of customer-sourced inventions is lower than specialist-sourced inventions
- Why?
  - Conjecture: Customer-sourced inventions incremental
    - Customers anchor on existing products
    - Industrial customers disinclined to change existing equipment, personnel or organization due to more significant innovation
  - Specialists' inventions less constrained by existing products
  - Costs: Economic proximity to customers reduces search and contracting costs relative to tech specialists

4. What distinguishes the firms that participate in this “division of innovative labor”?

Different capabilities: technical v. commercialization capabilities

- Using a constructed measure of firm "technical capability" (i.e., think of inventive vs. commercialization capability), we learned that:
  - Firms with **less** technical capability are the main participants in the DoIL.
    - I.e., More likely to acquire and commercialize outside inventions than firms with greater technical capability that have an "inside option."
  - Firms with greater technical capability more likely to use externally available "raw" knowledge (e.g., from universities) to invent internally.

Conclusions

- Reliance on external sources of innovation pervasive.
- Management: Highlights importance of search function, and "absorptive capacity"--ability to evaluate and use external knowledge and inventions, as well as ability to manage ties with external entities.
- Policy: Adopt more "systems" perspective, focusing not only on nodes (e.g., big firms, startups, universities, etc.) as engines of growth, but means of supporting relationships across them.
  - Consider policies that strengthen those relationships (e.g., patents, transparency in markets for technology, support for cooperative ties, etc.)

Thank you

Innovation: Definitions

- New to the Firm (**NTF**) innovators
  - "In 2009, have you earned revenue from any new or significantly improved goods or services in [INDUSTRY] introduced since 2007, where "new" means new to your firm.
    - Simple resale of goods purchased from others or purely aesthetic changes excluded.
- New to the Market (**NTM**) innovators
  - Asked **NTF** innovators to consider any of those new products were: 1) were the first in the market; or 2) patented . Firms responding yes to either considered "new to the market" innovators.
  - Will refer to **NTM** respondents below as innovators

Validating Innovation Measures: Industry Correlations across Measures

External Indicators	ACS NTF	ACS NTM
BRDIS NTF	.72	.76
Europe-wide CIS NTM	.71	.72
BRDIS R&D Performers	.72	.72
CIS Innovative Activity	.70	.68
BRDIS RDI*	.59	.52
Rs' any patent application (PATSTAT)	.72	.74
Rs' patent count (PATSTAT)	.54	.47
Rs' forward citation count (PATSTAT)	.56	.49

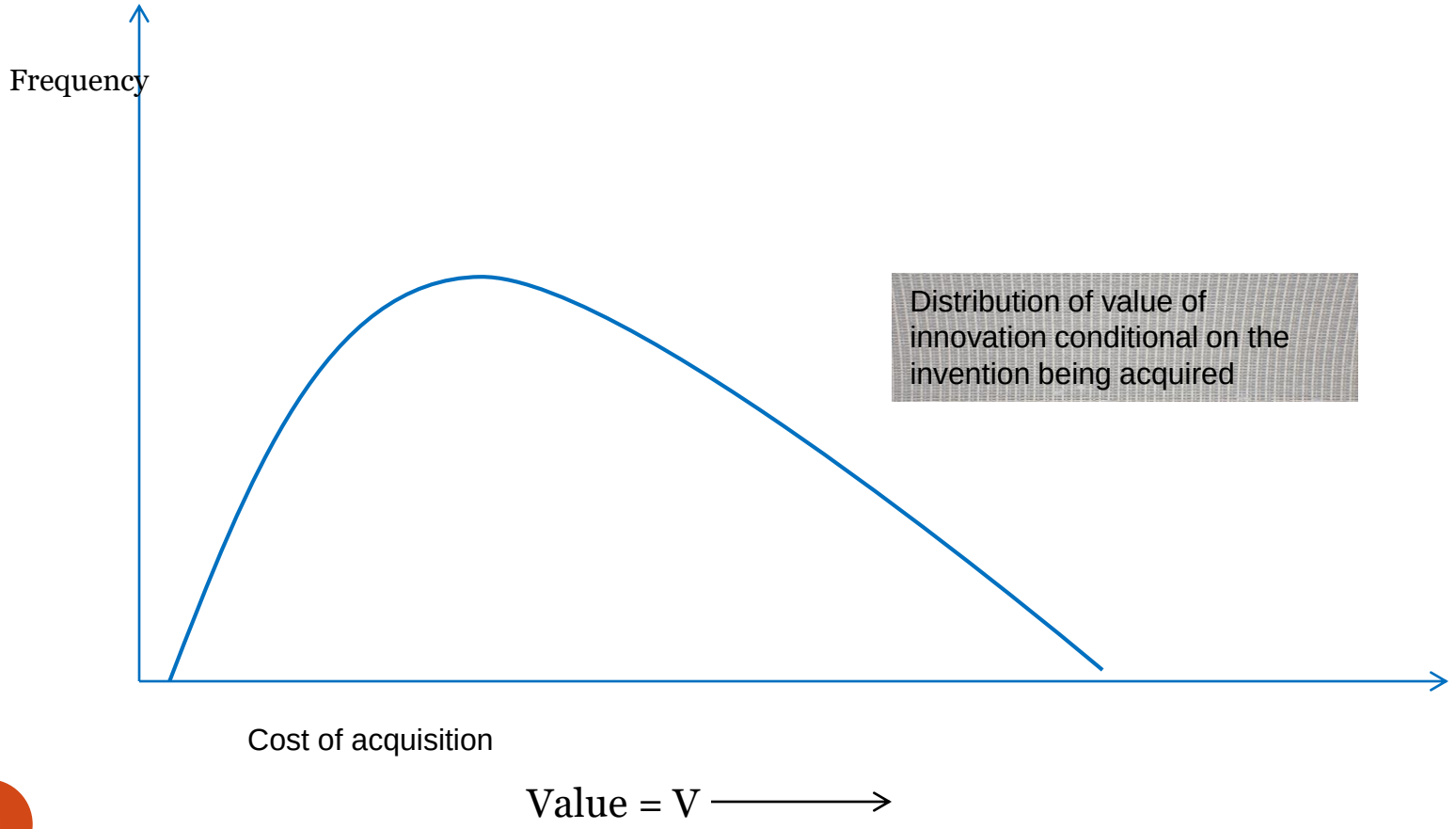
Other aggregate patterns

- Startups were the source for 1/7th of the cases
- In about 25% of cases, source had a patent
  - Source may not be in same sector!

Non-respondent bias tests

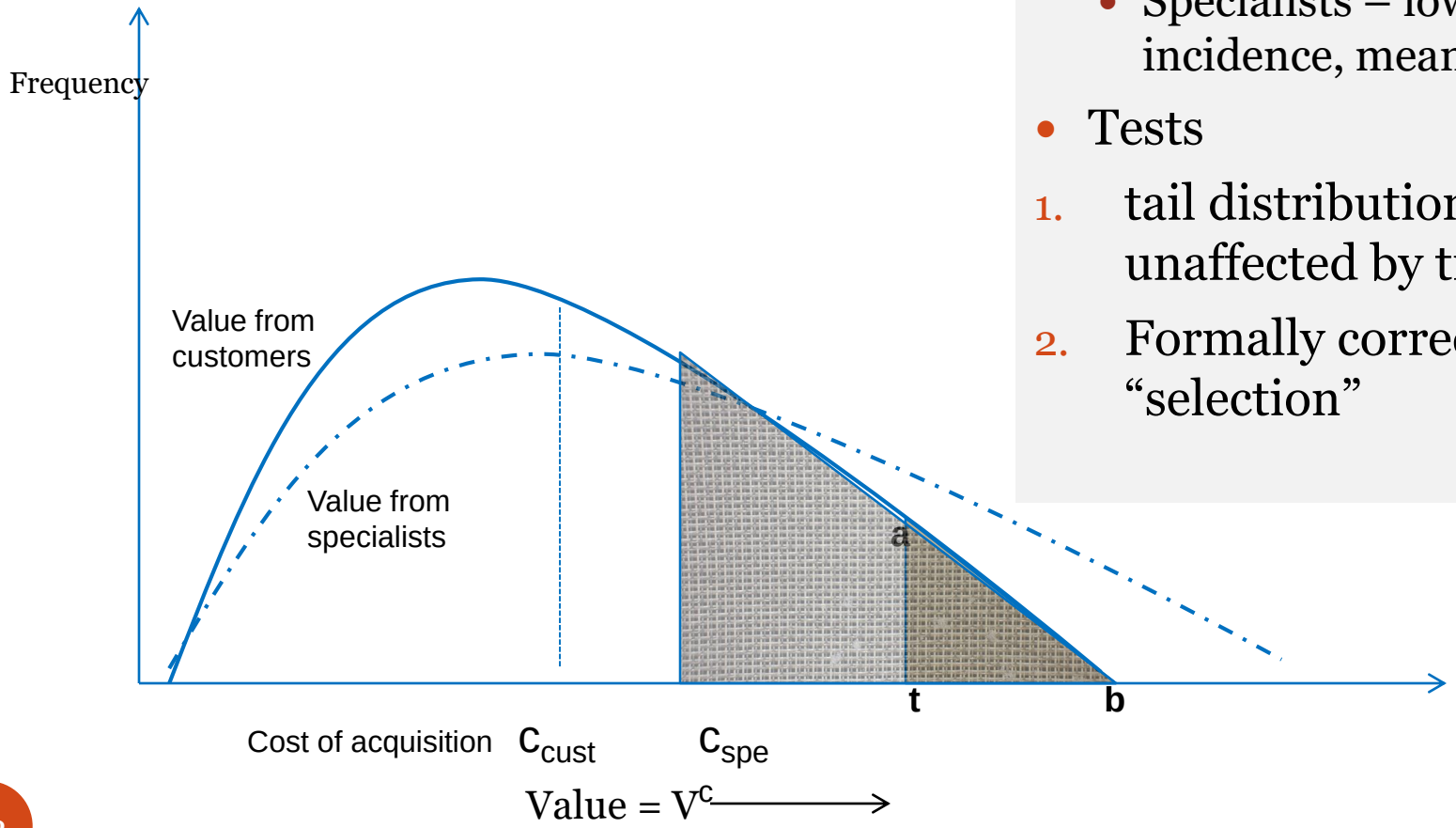
- Compared D&B data for respondents and non-respondents
  - Sample is representative of population on:
    - Firm age, being multiproduct, region, or likelihood to export.
  - Lower response rates for:
    - Large firms, especially Fortune 500 firms (about 20% response rate)
    - Pharmaceuticals also had a low response rate (still over 20%)
- Used Census data to construct industry and size class post-sampling weights to correct for response bias

Distribution of the value of innovations and selection

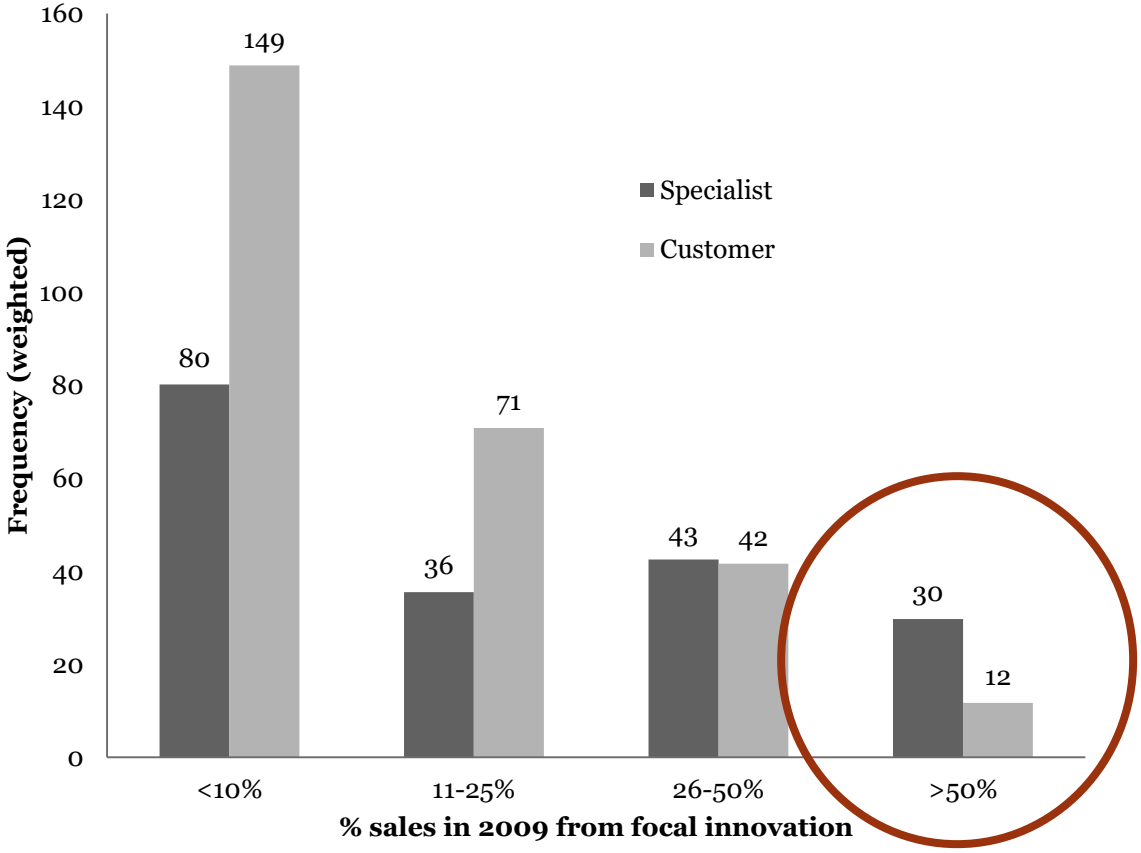


- Higher cost source ➔ lower share, higher average sales
  - Customer – high incidence, low average value
  - Specialists – lower incidence, mean high value
- Tests

1. tail distribution unaffected by truncation
2. Formally correct for "selection"



Frequency distribution of customer and specialist sourced innovation by % sales from the focal innovation



Comparing the tails of distribution of observed % sales from focal innovation

- Innovations with > 50% of revenue are the top decile
  - Specialist are 2.5X more frequent than customers
  - Customers 1.9X more frequent in commercially less valuable innovations
- ➔ Customer innovations are probably less valuable
- Apply multinomial logit framework to formally "correct" for unobserved differences in cost

Non-respondent bias tests

- Compared D&B data for respondents and non-respondents
  - Sample is representative of population on:
    - Firm age, being multiproduct, region, or likelihood to export.
  - Lower response rates for:
    - Large firms, especially Fortune 500 firms (about 20% response rate)
    - Pharmaceuticals also had a low response rate (still over 20%)
- **Census data employed to construct industry and size class post-sampling weights to correct for response bias**