RIETI-NISTEP Policy Symposium

Open Innovation as a Key Driver of Japan's Industrial Competitiveness

Handout

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The Acquisition and Commercialization of Invention in the American Economy

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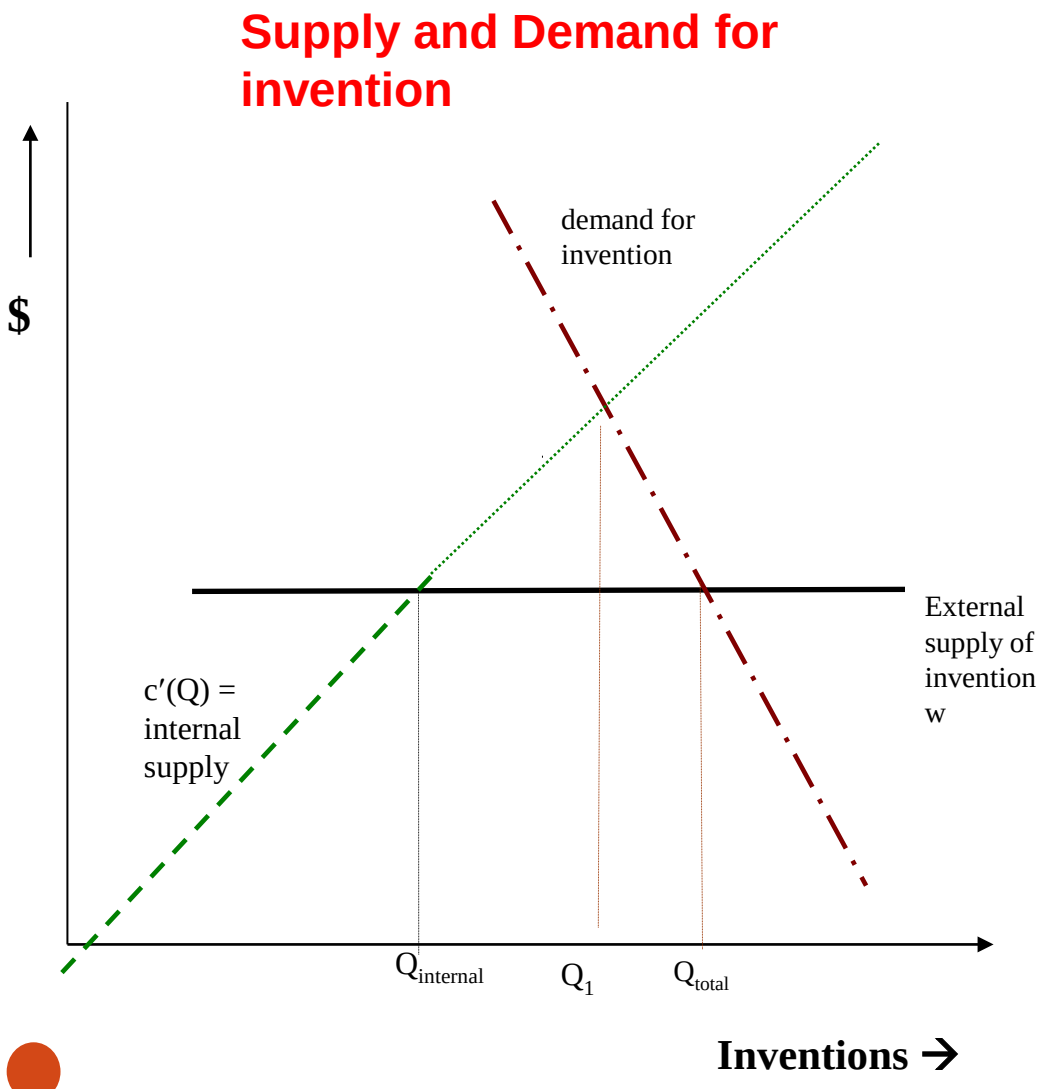
The paper

- Broad-based evidence on the rate of innovation in the U.S. and the extent to which it relies upon external *invention*
  - 5,000 + American manufacturing firms.
  - *Innovation* v *Invention*
  - Sources and channels
- Sample frame: Dun and Bradstreet, stratified by industry (28 3-4 digit NAICS), firm size (6 strata)
- Phone survey: marketing managers or business manager

Motivation

- External sources of invention
  - Neglected till recently
  - Gains from trade and specialization
- Existing literature for U.S. has studied of specific channels (e.g., licensing, coop), or specific sources (e.g., customers, universities).
- No CIS available for U.S.

Motivation



- Rate of innovation and dependence on external source co-determined.
- 2 Margins: (1) External v No Innovation and (2) Make or Buy
- Firms may be at different margins → technical capability of firm

- Demand curves = derived demand for innovation
  - Depends upon product market competitive conditions …
- External supply curve reflect ability and number of sources
- Internal supply reflects efficiency of internal R&D

Project and data

- A survey of product innovation for US manuf. firms in 2010
  - + selected services, not included for today
- Population: All firms in these industries, not just innovators
- Focus on "most important innovation" for the "main line of business"
  - Firm = Business, (not parent corporation)
- Sample frame: Dun and Bradstreet, stratified by industry (28 3-4 digit NAICS), firm size (6 strata)
  - Oversampled large and startup firms and innovative industries
- Phone survey: marketing managers or business manager (recall that this is an innovation—not an R&D—survey)
- 6685 /22,000 responses (30.3% response rate)
- Today exclude service firms and tiny firms (< 10 employees), leaving 5,157 in sample.

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

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
R^2 any patent application (PATSTAT)	.72	.74
R^2 patent count (PATSTAT)	.54	.47
R^2 forward citation count (PATSTAT)	.56	.49

*BRDIS NTF and BRDIS RDI R^2 =.35

NTF: *In 2009, have you earned revenue from any new or significantly improved goods or services in [THREAD INDUSTRY] introduced since 2007, where "New" means new to your firm*.

NTM: Of all the new or significantly improved products or services you brought to market in [THREAD INDUSTRY] during the three years, 2007-2009, think of the one that accounts for the most revenue. ***Did you introduce this innovation in your industry before any other company?***

Examples of innovations in sample industries

Industry	Innovation
Food	Antioxidant chocolates
Food	Live active cheddar cheese with probiotics
Beverage	Vitamin-enhanced flavoured spring water
Textile	Heat resistant yarn
Textile	New varieties of garments
Paper	Low surface-energy tapes resistant to air, water, detergents, UV light
Paper	Hanging folder with easy slide tab
Petroleum	Non-detergent motor oil
Chemicals	BioSolvents – water based emulsion technology
Pharmaceutical	Oral gallium to prevent bone decay
Pharmaceutical	Inhalation anaesthetics
Plastics	Styrene based floor underlayment
Minerals	Multi-wall polycarbonate recyclable panels
Minerals	Solar glass and coating technologies solar modules
Metals	Solder system & nanofoils
Metals	New water faucets and bath products
Electronics	USB-to-GPIB Interface Adapter
Electronics	20-h IPS Alpha LCD Panel
Semiconductors	Linear voltage regulators
Semiconductors	Phase change memory
Transport Equipment	Improved alcohol sensing system

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	26	17	9	42
Pharma	128	63	28	35	23	13	61
Plastics	340	48	16	31	14	6	42
Minerals	323	31	9	22	21	14	35
Metals	324	38	9	29	14	5	23
Fab Metals	424	39	10	29	28	8	35
Machinery	384	46	20	26	24	14	52
Electronic	146	76	33	43	38	9	58
Semi Con	302	61	27	34	29	18	59
Instrument	135	60	37	23	17	7	54
Elec Equip	344	54	26	28	25	13	53
Auto	339	53	27	25	25	11	34
Med Equip	136	56	22	34	37	31	72
Miscl	510	48	19	29	30	10	45
All mfg	**5157**	**43**	**16**	**28**	**22**	**11**	**42**
Large (> 1000)	1268	66	38	28	26	12	63
Med. Firms	945	54	23	32	24	16	47
Small (< 100)	2944	40	13	27	21	12	36

Overall

- **43%** report new-to-the-firm (NTF) product introduction
- **36%** of new products are innovations -- NTM (i.e., about 16% of all firms innovate and 28% imitate)
  - Innovation varies across industries
  - Imitation more stable
- **42%** patented focal innovation
  - First estimate of patent propensity for U.S.
- **4%** firms licensed technology to others without introducing new products.
- New products account for **22%** of revenue for NTF firms; Focal innovation accounts for **11%** of revenue for NTM
- **40%** of innovators invest in new marketing or sales channels, while **47%** invest in new skills or equipment
  - Only 38% of innovations commercialized using existing complementary capabilities alone
  - *Lack of complementary capabilities apparently not inhibiting innovation?*

SOURCES of INNOVATIONS

External sources

- *(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%

Sources of invention by industry, percentage shares

INDUSTRY	N	Any External	Supp (a)	Cust (b)	Other Firm (c)	Consult./ Serv prov (d)	Ind. Inventor (e)	Univ (f)	Specialist (d+e+f)
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%

Did any of the following originate this innovation, that is, create the overall design, develop the prototype or conceptualize the technology?

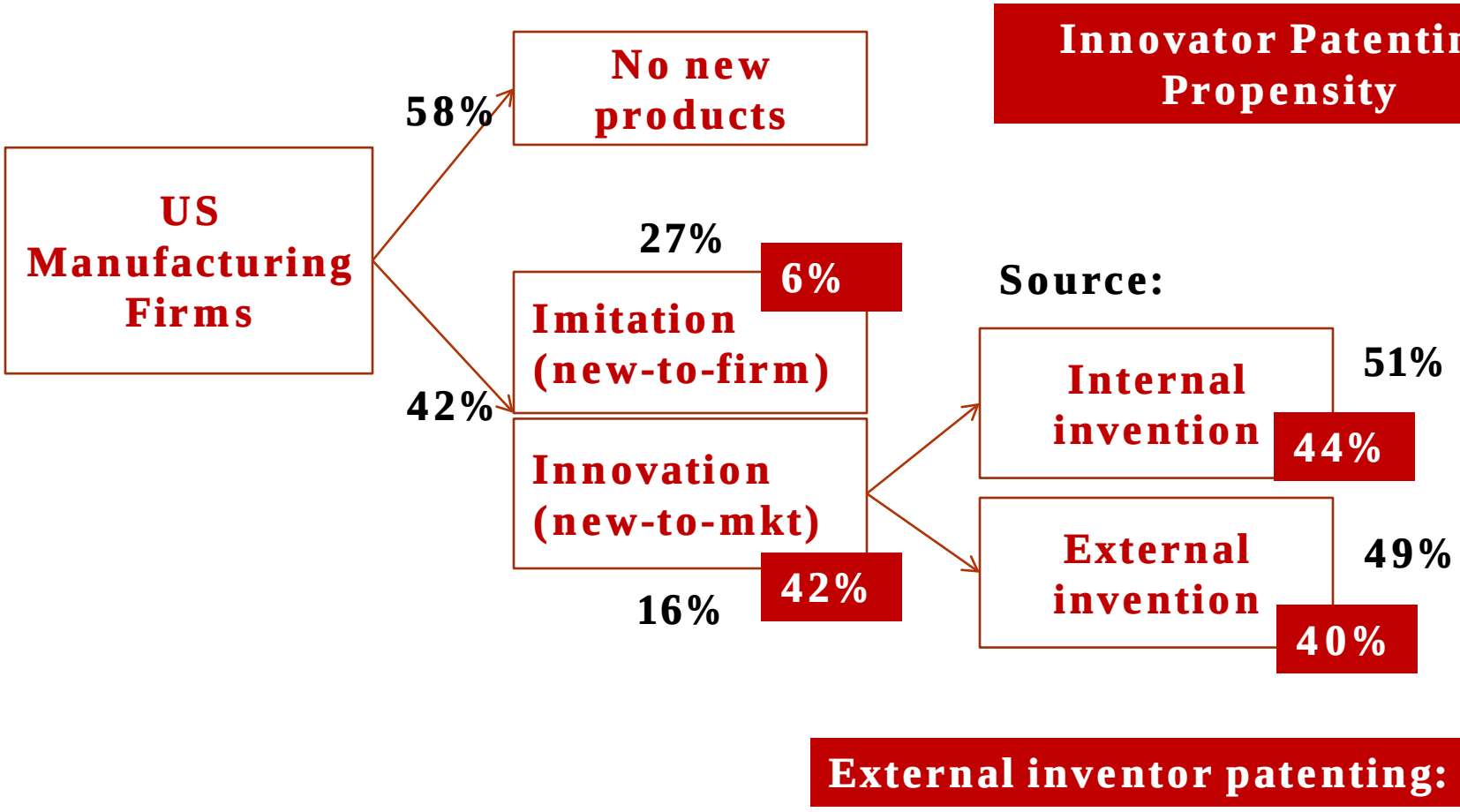
[Responses not mutually exclusive]

Sources of invention, by firm size

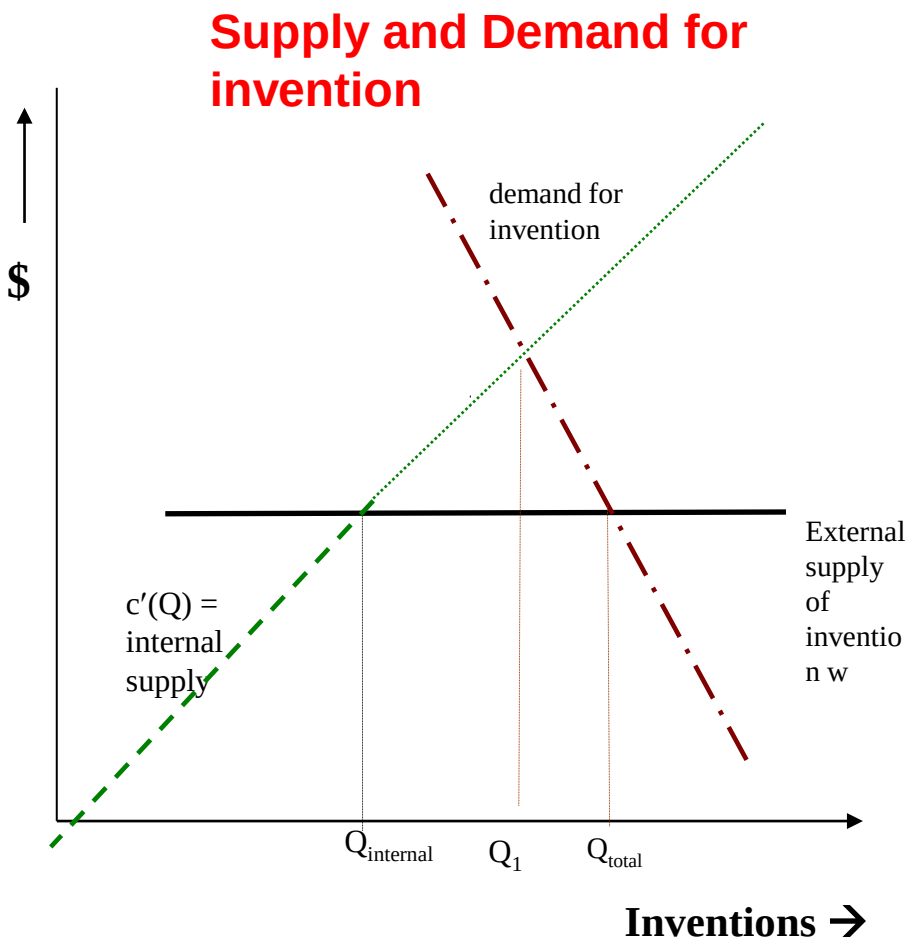
	Any External	Supp	Cust	Other Firm	Consult./ Serv prov	Ind. Inventor	Univ	Specialist
Large (>1000)	51%	22	25	9	7	4	6	14
Medium (100-1000)	48%	12	26	9	8	4	5	16
Small (<100)	49%	13	28	8	8	9	5	18
All	49%	14	27	8	8	7	5	17

- No difference in external dependence by size!
- Large firms favor suppliers and universities relative to smaller firms
- Small firms favor independent inventors (9%) relative to large firms (4%)
- 2.5% of firms in sample are “startups.” But startups are reported to be the source of innovation for 13% of firms acquiring inventions externally

Innovation and the Sources of Invention



External sources and rate of innovation



- Only 34% of externally reliant innovators report they could have obtained from alternate source ➔ (66% x 49% = 33% of innovations not happen without external source)
- Innovation rate drop from 16% to 11% without external source
- Multinomial assumptions → Innovation drop from 16% to 9% without external source
- **Bottom line: Two margins**
- **Not just "make or buy"**
- **Weak firms / small firms more dependent on external source for innovation**

CHANNELS

Channels for acquiring innovation overall and by industry (wtd.)

INDUSTRY	N	JV / Coop R&D	M&A	License	Service Contract	Informal	Market*	Market only*
Food & Bev	26	73	11	17	20	15	32	17
Text	10	76	7	20	17	9	34	16
Wood	23	54	12	5	45	32	50	15
Chem	38	67	6	5	35	29	44	18
Pharma	13	40	39	56	8	17	82	43
Plastics	32	61	25	9	27	36	45	13
Minerals	15	69	13	12	11	56	36	17
Metals	14	64	19	3	17	46	39	18
Fab Metals	22	58	0	9	5	72	14	0
Machinery	35	53	11	6	17	42	34	22
Electronic	19	83	5	3	19	12	22	3
Semi Con	37	64	15	15	30	43	37	16
Instrument	19	41	6	42	14	14	60	45
Elec Equip	27	62	19	21	36	42	55	22
Auto	37	67	11	33	18	21	53	29
Med Equip	13	45	15	17	30	31	57	24
Miscl	43	63	3	13	20	33	33	14
All mfg	423	61	10	13	21	37	37	16

Channels for acquiring innovation by firm size

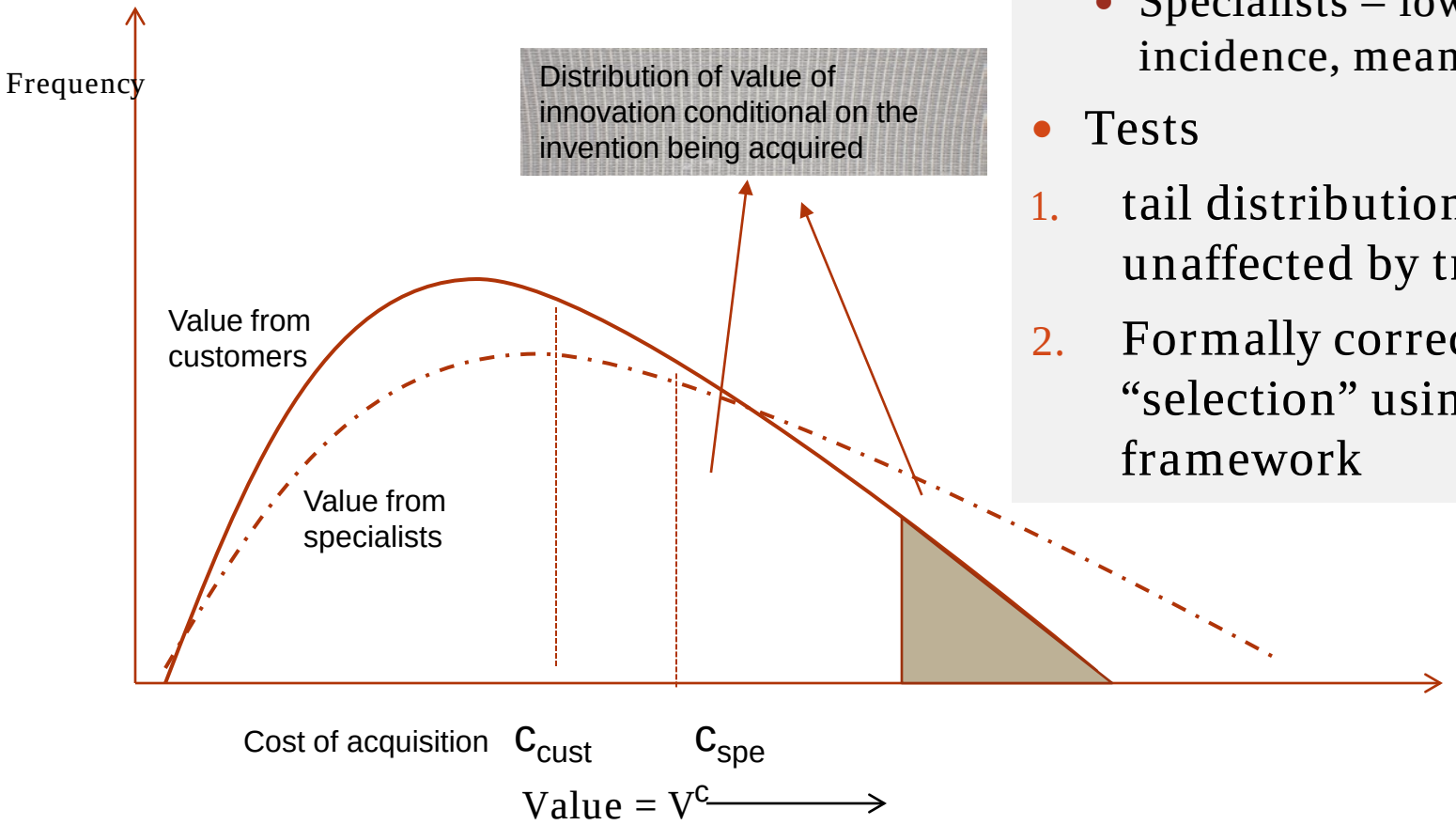
Size	JV	M&A	Lic	Contract	Informal	Market	Market only
Large (>1000)	53	18	21	21	29	47	24
Medium (100-1000)	66	13	10	17	27	36	19
Small (<100)	60	8	13	23	41	36	14
All	61	10	13	21	37	37	16

- Small firms favor informal channels.
- Big firms favor licensing and M&A
- Medium firms favor cooperative channels

- Customer-inventions favor informal and cooperative channels
- “Specialists” favor market channels
- Market channels usually involve JV/ Cooperative R&D as well

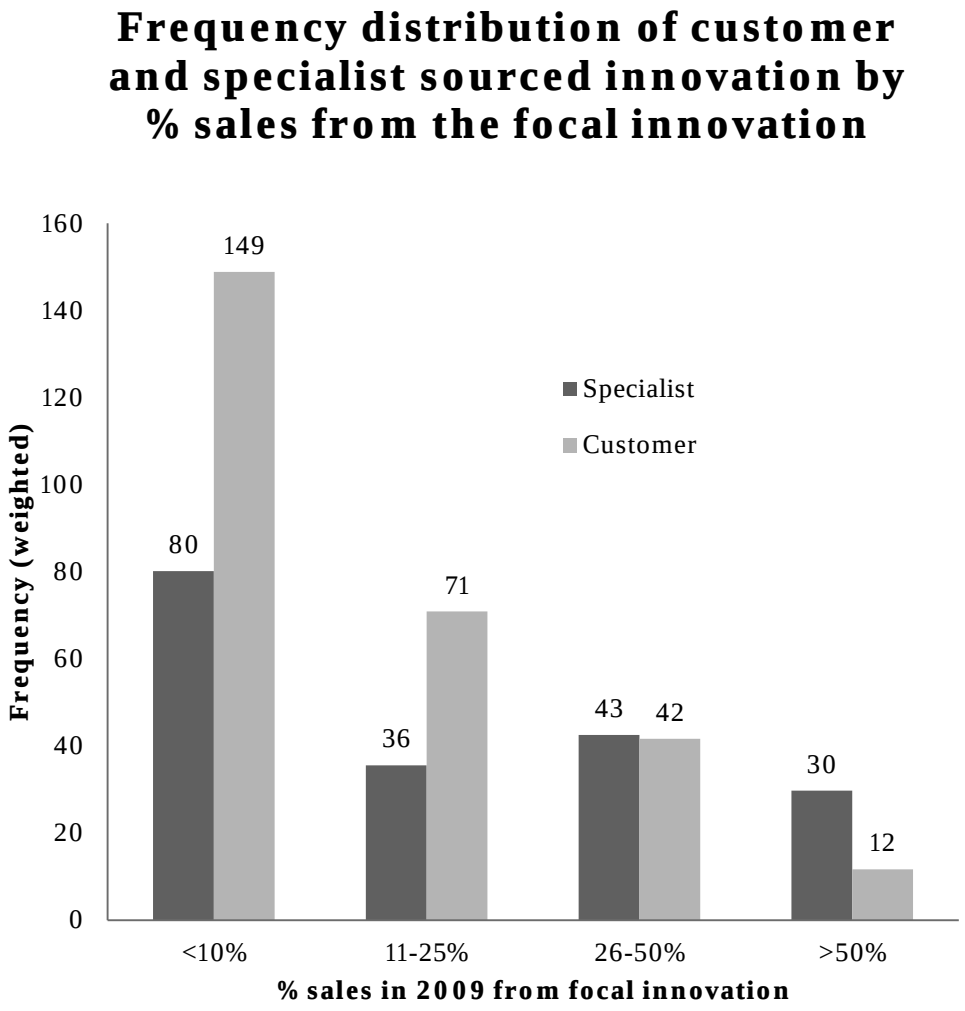
Value of inventions by source

- Are high-value “lead user” inventions typical?
  - Recall: Customers more frequent
  - But incidence ≠value.
- Are innovations from customers more incremental? or Cheaper to acquire?
  - Are lead users typical of customer-sourced innovation?
- Important details
  - Universities, independent inventors and R&D service providers/consultants are “technology specialists”
  - Reference category = pure internal innovations



- 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" using MNL framework



- Tail Distribution Test: Innovations with > 50% of revenue: Specialist are 2.5X more frequent than customers
- Innovations with < 10% of revenue: Customers 1.9X more frequent than specialist

➔ Customer innovations are probably less valuable

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

Value of inventions by source: MNL approach with sample selection correction

	% firm sales from focal innovation	% firm sales from focal innovation greater than 50% = 1	% firm sales from focal innovation *(Selection correction)*	(% firm sales from focal innovation greater than 50%) = 1 *(Selection correction)*
Customer	-3.29** (1.40)	-0.07** (0.02)	-3.21** *(1.48)*	-0.07** *(0.02)*
Supplier	0.82 (1.79)	0.07** (0.03)	0.97 *(1.99)*	0.06** *(0.03)*
Other Firm	3.01 (2.19)	-0.02 (0.03)	3.20 *(2.48)*	-0.04 *(0.04)*
Specialists	6.22** (1.64)	0.08** (0.03)	6.30** *(1.71)*	0.07** *(0.03)*
Ln (Empl)	-4.10** (1.07)	-0.06** (0.02)	-4.10** *(1.07)*	-0.06** *(0.02)*
Ind. FE's (45)	*Yes*	*Yes*	*Yes*	*Yes*
Controls	*Parent size, Age*	*Parent size, Age*	*Parent size, Age*	*Parent size, Age*
Ln (share of source in ind)			-0.21 *(1.21)*	-0.01 *(0.02)*
N	930	930	930	930
R^2	0.21	0.15	0.21	0.15

Other indicator of innovation value, by source:
Selection corrected estimates

	Innovator invests equip or skills	Innovator invests in sales channel	Firm increased market share = 1	Firm has patented innovation
Customer	-0.03 *(0.04)*	-0.008 *(0.04)*	-0.06* *(0.04)*	-0.10** *(0.03)*
Supplier	-0.19** *(0.05)*	0.01 *(0.04)*	0.07 *(0.05)*	-0.10** *(0.05)*
Other Firm	0.01 *(0.06)*	0.04 *(0.06)*	-0.05 *(0.06)*	-0.08 *(0.06)*
Specialists	0.14** *(0.05)*	0.10** *(0.04)*	0.14** *(0.05)*	0.29** *(0.04)*
Ln (Empl)	0.06** *(0.03)*	0.05* *(0.03)*	0.04 (0.03)	0.11** *(0.03)*
Ind. FE's	*45*	*45*	*45*	YES
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	1015	1020	919	1022
R^2	0.14	0.16	0.13	0.25

Interpretation

- The value of customer-sourced inventions is lower than specialist-sourced inventions, but costs of commercialization and acquisition are also lower.
  - Costs: economic proximity reduces search and contracting costs; lower sales and marketing costs
  - Value: inventions incremental,
    - Industrial customers disinclined to the changes in existing equipment, personnel, or even organizations required by more significant invention by the focal firm (i.e., supplier).
- Specialists—Higher value but higher cost
  - Search and contracting costs → higher cost
  - not tied to existing products → higher value

Conclusions

- Reliance on external sources is high
- Sources of external invention from within the industrial chain (suppliers, customers) are important in all industries; "Specialists" disproportionately more in hi-tech industries
- Collaboration is major channel for acquiring invention; Market-based channels (e.g., licensing, M&A) are more relevant to high-tech industries.
- External sources: Customer inventions are low value relative to specialists, but even lower cost.
- High reported patent propensity by innovators
- Patents also used by sources, especially specialists and used in market channels.

Thank you