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The Acquisition and Commercialization of Invention in the American Economy

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Motivation

- Notwithstanding reports of an increase in "open innovation" (Chesbrough, 2003), we do not know the extent to which U.S. firms rely on outside sources OVERALL as a source of invention.
  - There are, however, numerous studies of specific channels through which firms may acquire inventions (e.g., licensing, cooperative ventures and alliances) and of specific sources (e.g., customers, universities).
- Nor do we know the impact of external supply on innovation rates overall, no less how the value and impact of inventions originating from different sources may compare.

The paper

- Provides broad-based evidence on the extent to which innovations introduced by U.S. manufacturers relies upon external sources for their inventions, providing insight into the "division of innovative labor" (DoIL) for the U.S.
  - ***Note: distinction between invention and innovation***
- Estimates importance for innovative performance overall
- Compares incidence, value and impact on innovation of external sources

So what?

- Understanding innovation
  - Potentially expands what we should include among the fundamental determinants of innovation: factors that underpin external supply of invention, and innovation as a distributed process
    - Not just a question of "make-or-buy," but whether firms will innovate to begin with, and thus the overall rate of innovation.
- Social welfare/policy
  - Gains from trade and economies of specialization
  - Decades-long search for the "ideal firm type" for innovation (e.g., large firms, startups, etc.) misguided. If it's having different types of firms and other entities, and the relationships among them, that matter, then policies concerned with innovation should focus more on the "system" rather than any one component.
- Managerial
  - External availability of inventions (versus innovation) also can impact the overall rate of innovation, suggesting need go beyond the typical factors for explaining innovation rates to also consider drivers of external supply schedule.

Project

- A survey of product innovation for firms in mfg and selected service industries in 2010
- Distinguishing between innovation and invention, we focus on firms that commercialize new products (i.e., innovators)
- Surveyed population: All firms, not just innovating firms
  - Challenge: Identifying innovating (not inventing) firms
- Responses focus on:
  - A specific line of business
  - That innovation introduced since 2007 accounting for plurality of 2009 business unit sales (i.e., "most significant" innovation).
- Firms relying upon outside sources report:
  - Sources (suppliers, customers, universities, etc.)
  - Channels through which firms acquire inventions (license, collaborative research, M&A, service contract, informal)
- Outcome measures (e.g., % business unit sales due to innovation).

Data

- Sample frame
  - **Dun and Bradstreet**, stratified by industry (28 3-4 digit NAICS in manufacturing and selected service inds., including software and engineering services), firm size (6 strata) and startup status
    - Over 22,000 firms
    - Oversampled large and startup firms and innovative industries
- **Phone survey**, at line of business: marketing managers or business manager (recall that this is an innovation—not an R&D—survey)
  - Used phone to find knowledgeable respondents
- **6685 responses (30.3% response rate)**
- For paper, we exclude out of population and tiny firms (<10 employees), and **focus on manufacturing**, leaving **5,157 in sample**.
  - Adjusted for nonresponse bias and sampling strategy.

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

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
  - Of all the new or significantly improved products or services you brought to market in [RESPONDENT INDUSTRY] during the three years, 2007-2009, think of the one that accounts for the most revenue.
  - Did your company patent any part of this innovation?
  - Did you introduce this innovation in your industry before any other company?
  - Firms responding yes to either considered "new to the market" innovators.
  - Will refer to **NTM** respondents below as innovators

Innovation rates across surveys: % of resps. intro'ing NTF* or NTM** innovs. (**mfg only**)

Survey	NTF %	NTM %
DoIL (2010)	43	18
BRDIS (2009)	22	na
German CIS (2009)	49	22

- *NTF – New to the Firm
- **NTM – New to the Market
- Validation: At industry level, DoIL NTM rate measure correlated with R&D intensity, patenting, and BRDIS and CIS innovation measures .
  - All r's > 0.70, except with BRDIS RDI, at 0.60

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

*BRDIS NTF and BRDIS RDI r =.35

Examples of innovations in sample industries

Industry	Innovation
Food	Antioxidant chocolates
Food	Live active cheddar cheese with probiotics
Beverage	Vitamins 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

Before examining sources of innovation, first needed to identify who innovates

(Summary statistics weighted to adjust for sampling strategy and nonresponse bias)

Rates of innovation and imitation, patenting and % sales for U.S. mfg.

INDUSTRY (N)	% NOSI	% NTM	Imitation % (NOSI-NTM)	% sales from NOSI	% sales from focal innovation	% NTM pat'd
Food/Bev. (362)	40%	15%	25%	26%	17%	25%
Textiles (210)	38%	18%	20%	20%	14%	54%
Wood (385)	33%	10%	23%	21%	20%	14%
Chemicals (365)	50%	27%	23%	23%	15%	46%
Pharma (128)	63%	36%	27%	33%	30%	59%
Plastics (340)	48%	22%	26%	24%	19%	48%
Minerals (323)	31%	11%	20%	23%	15%	34%
Metals (324)	38%	10%	28%	19%	9%	29%
Fab"d Metals (424)	39%	12%	26%	28%	15%	36%
Machinery (384)	46%	23%	23%	27%	19%	50%
Electronics (146)	76%	38%	39%	39%	25%	58%
Semiconductors(302)	61%	33%	28%	35%	25%	60%
Instruments (135)	60%	44%	16%	28%	24%	52%
Electric Equip (344)	54%	30%	25%	37%	28%	56%
Auto (339)	53%	30%	23%	35%	26%	33%
Med. Equip. (136)	56%	22%	34%	34%	27%	72%
All mfg firms (5157)	**43%**	**18%**	**25%**	**27%**	**20%**	**42%**

Overall

- **43%** report new-to-the-firm (NTF) innovation
- **42%** of those who report innovation report NTM-innovation (i.e, 18% innovate and 25% imitate)
  - Innovation varies across industries
  - Imitation more stable
- Patent propensity:
  - Varies across industries (per priors and CMS)
  - **42%** of innovators patented, and only 6% of imitators patent
- 4% of mfg/ firms licensed technology to others without commercializing new products.
- Will focus on the NTM respondents and call them **Innovators**.

Innovation rates by firm size (wtd. means)

Firm size class	NTF%	NTM%	% Imit.
Large (>1000)	66	43	23
Medium (100-1000)	54	26	28
Small (<100)	40	16	24
All	43	18	25

Small ≠ Startup!
(Only 180 "startups" in sample)

- As expected, large firms have lower "share of revenue from new products" (27% v 20.5%)
- *Skew: Most significant innovation accounts for high revenue share*
  - 24% (out of 27%) for small firm and 12% (out of 20.5%) for large & medium firms

SOURCES of (NTM) INNOVATION

External acquisition by source

- ***"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]**
  - **"SDR" would suggest a conservative bias.**

Manufacturing	
Supplier	**13%**
Customer	**26%**
Other Firm in industry	8%
Consultant/Comm. Lab/Service provider	8%
Independent inventor	8%
University/Govt Lab	5%
Any external source	**49%**

Sources of innovation (wtd. means)

	N	Any External	Supp.	Cust.	Other firm	Consult./ serv prov	Ind. Inventor	Univ.	Special-ist
Food/Beverage	73	0.46	0.33	0.16	0.07	0.01	0.08	0.00	0.08
Textiles	38	0.45	0.30	0.23	0.03	0.03	0.05	0.00	0.08
Wood	60	0.55	0.18	0.34	0.09	0.11	0.01	0.01	0.13
Chemicals	115	0.49	0.15	0.14	0.04	0.13	0.06	0.04	0.20
Pharmaceuticals	39	0.45	0.05	0.07	0.14	0.04	0.04	0.17	0.26
Plastics	95	0.59	0.15	0.29	0.04	0.13	0.15	0.04	0.28
Minerals	44	0.38	0.05	0.18	0.03	0.06	0.09	0.08	0.21
Metals	52	0.48	0.26	0.29	0.11	0.09	0.04	0.07	0.12
Fab'd Metals	71	0.43	0.08	0.31	0.05	0.00	0.05	0.05	0.10
Machinery	111	0.46	0.08	0.34	0.09	0.11	0.07	0.06	0.19
Electronics	58	0.46	0.13	0.15	0.12	0.07	0.05	0.09	0.17
Semiconductors	108	0.58	0.14	0.43	0.10	0.13	0.11	0.10	0.26
Instruments	62	0.47	0.04	0.26	0.09	0.09	0.07	0.02	0.16
Electical Equip.	111	0.44	0.10	0.24	0.05	0.07	0.07	0.05	0.18
Auto	110	0.52	0.11	0.29	0.12	0.05	0.16	0.14	0.24
Misc.	120	0.50	0.08	0.22	0.15	0.11	0.13	0.02	0.22
Medical Equip.	40	0.49	0.17	0.23	0.05	0.13	0.09	0.15	0.32
All MFG.	**1307**	**0.49**	**0.13**	**0.26**	**0.08**	**0.08**	**0.08**	**0.05**	**0.18**

Observations on sources

- **Dependence on external sources is (a) high and (b) stable across industries and firm-size classes**
  - **49% of innovators claim that an outside source created, developed or conceptualized the technology**
  - Customers are most pervasive source across industries.
- More R&D intensive industries rely less upon suppliers and customers (r= -0.25 and -0.30), and more upon universities (r=0.42)
- Customers tend to be source when firms' customers are other firms, not final consumers (r=0.52)
- 2.5% of firms in sample are "startups." But startups are reported to be the source of innovation for 14% of firms acquiring inventions externally, suggesting startups' disproportionate role in the DoIL.

Sources of innovation, by firm size (wtd means)

Size	Supp	Cust	Same indust	Consult	Indep Inv	Univ	Any source
Large (>1000)	0.22	0.24	0.08	0.09	0.05	0.07	0.50
Medium (100-1000)	0.11	0.25	0.08	0.07	0.04	0.05	0.46
Small (<100)	0.13	0.27	0.08	0.08	0.10	0.05	0.49
All	0.13	0.26	0.08	0.08	0.08	0.05	0.49

- Large firms especially favor suppliers relative to smaller firms. Thus, it's large firms in less R&D intensive industries that rely more upon suppliers.
- Small firms are more likely to use independent inventors (10%) compared to large firms (5%)

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!

CHANNELS:

Results for those who acquire their inventions from outside the firm

Channels for acquiring innovation by acquiring innovators (wtd.)

	N	M&A	JV/Coop	License	Service Contract	Informal	Market*	Market only*
Food/Beverage	29	0.10	0.76	0.15	0.18	0.14	0.28	0.15
Textiles	10	0.07	0.76	0.20	0.17	0.09	0.34	0.16
Wood	27	0.10	0.50	0.11	0.36	0.39	0.47	0.12
Chemicals	42	0.07	0.68	0.05	0.38	0.33	0.47	0.18
Pharmaceuticals	15	0.43	0.35	0.58	0.07	0.19	0.80	0.47
Plastics	44	0.16	0.68	0.10	0.20	0.30	0.35	0.13
Minerals	15	0.13	0.69	0.12	0.11	0.56	0.36	0.17
Metals	18	0.17	0.65	0.05	0.15	0.42	0.37	0.16
Fabricated Metals	24	0.01	0.60	0.09	0.05	0.68	0.14	0.01
Machinery	37	0.11	0.53	0.07	0.16	0.41	0.33	0.22
Electronics	22	0.13	0.76	0.12	0.16	0.11	0.28	0.12
Semiconductors	44	0.16	0.61	0.16	0.31	0.39	0.42	0.19
Instruments	21	0.06	0.48	0.37	0.12	0.12	0.54	0.40
Electical Equipment	32	0.28	0.59	0.18	0.32	0.37	0.60	0.26
Auto	39	0.11	0.66	0.34	0.18	0.21	0.53	0.29
Miscellaneous	50	0.06	0.64	0.14	0.20	0.36	0.33	0.12
Medical Equipment	15	0.15	0.47	0.16	0.29	0.30	0.56	0.23
All	**484**	**0.10**	**0.61**	**0.14**	**0.20**	**0.36**	**0.37**	**0.16**

Channels for acquiring innovation by firm size
(wtd means)

Size	M&A	Coop	License	Contract	Informal	Mkt. only
Large (>1000)	0.18	0.54	0.22	0.19	0.28	0.24
Medium (100-1000)	0.12	0.67	0.09	0.16	0.28	0.18
Small (<100)	0.08	0.61	0.14	0.21	0.40	0.14
All	0.10	0.61	0.11	0.20	0.36	0.16

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

Share of innovating mfg firms for which invention originates from the outside revisited (Sample: firms reporting source that also reported channel)

Source: / Channels:	Supp	Cust	Firm in same indust	Consult/Comm lab	Indep. Inventor	Univ	Any source
Overall, including all channels	13%	23%	8%	7%	7%	4%	43%
Mkt channels (License, M&A, Service contract) and JV/Coop	11%	18%	6%	7%	7%	4%	35%
Mkt channels only	5%	6%	4%	5%	5%	2%	16%

Observations on channels

- Sourcing from customers relies heavily upon informal or cooperative channels
- Sourcing from "specialists" relies heavily upon purely market channels; not informal channels.
  - Exception: universities which also rely heavily upon cooperative channels
- Use of market channels alone characterize a minority fraction—16%—of the relationships in the DoIL.
- 61% reliance upon cooperative channels suggest pervasive co-invention between focal firm and source, and limitations of purely market channels.

What can we say about the relative value and cost of inventions from different sources? -- customers vs. "technology specialists"

- Recall: Customers win on incidence
- But incidence≠value.
- Will compare costs and value of inventions originating from customers vs. "technology specialists."
- Related question: Are high-value "lead user" inventions typical?

Value of inventions by source

- We examine relationship between provenance of "most significant innovation" and indicators of value
  - Share of business unit sales due to that innovation
  - To commercialize the product, does respondent invest in new personnel/equipment or develop new distribution channels?
  - Does firm patent the innovation?
- Important details
  - Universities, independent inventors and R&D service providers/consultants are "technology specialists"
  - Reference category = pure internal innovations
  - **Control for selection.**

Value of inventions by source

(Reference category=internal invention; standard errors in paren.)

	% BU sales from focal innovation	Innovator invests in distribution channels or personnel/equip
Customer	**-4.74** *(1.58)***	**-0.00 *(0.03)***
Supplier	1.76 *(2.07)*	-0.02 *(0.05)*
Other Firm	-0.27 *(2.53)*	0.03 *(0.06)*
Specialists	**6.14** *(1.83)***	**0.18** *(0.04)***
BU Size (Ln (Empl))	-5.00** *(1.26)*	0.07** *(0.03)*
Ind. FE's (45)	*Yes*	*Yes*
Controls	*Parent size, Age*	*Parent size, Age*
Seln. Corr. (Ln (share of source))	-1.26 *(1.40)*	0.00 *(0.03)*
N	1080	1185
R^2	0.16	0.13

Indicator of net value

(net of commercialization cost)

	Innovator has patent on invention	Innovator has patent on invention
Customer	**-0.13** (0.03)**	**-0.11** (0.03)**
Supplier	-0.09* (0.04)	-.06 (0.04)
Other firm	-0.06 (0.05)	-0.03 (0.05)
Specialist	**0.25** (0.04)**	**0.27** (0.04)**
Ln(Employment)	0.09** (0.03)	0.09 (0.03)
Industry FE (45)	*YES*	*YES*
Controls	*Parent firm size, Age*	*Parent firm size, Age*
Seln. Corr. (Ln (share of source)		0.05 (0.03)
N	1164	1164
R^2	0.22	0.22

Interpretation

- **While customers are a more common source of invention than specialists, their inventions are of lower value than those from specialists.**
- But incidence, which should reflect value of innovation net of costs of acquisition and commercialization, is highest for customers.
- These results together therefore imply that the **value of customer-sourced inventions is lower, but costs of commercialization and acquisition lower still.**
  - **Thus, customer sourced inventions tend to be more incremental—not of the type originating from "lead-users"**

Why? Customers vs. specialists

- Customers—Lower value and much lower cost
  - Costs lower due to economic proximity that mitigates search and contracting costs
  - Value lower because inventions more incremental, and, in turn, commercialization costs also lower
    - Customers anchoring on existing products
    - Industrial customers—the main the source of customer inventions—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
  - Value higher because specialists not tied to existing products, will often compete on value and thus more likely to offer significant inventions.

Contribution of external supply to innovation rate

- Reductions in innovation rates (% of firms that innovate) if a source or all sources of external supply were eliminated.
- Use a multinomial logit framework to compute contribution of sources to innovation rate

Contribution to innovation rate, overall and by source
(% reduction in rate if source not available)

Customer	**17.6% (1.47)**
Supplier	8.1% (0.85)
Other Firm	4.4% (0.62)
Specialist	10.8% (0.95)
All external	**43.4% (2.06)**
Internal	46.7% (2.02)

- Customers contribute more to innovation rate than suppliers or specialists
- **Overall innovation rate would drop 43%; that is, the percent of firms that innovate would drop from 18% to 10%, if all external sources were unavailable**

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 contribute in hi-tech industries, and for smaller innovators
- Collaboration is major channel for acquiring invention; Market-based channels (e.g., licensing, M&A) are more relevant to high-tech industries

Conclusions

- The incidence of acquiring inventions from customers is highest of all the sources, but customer inventions are low value relative to specialists.
- Overall innovation rate in the mfg sector would be substantially lower absent external sources
- To think about the determinants of innovation, we need to think more about what might drive the external availability of inventions.
  - Adopt a more "system-wide" perspective, focusing on the range of entities and the relationships across them.

Comments, Questions, Suggestions?

Thank you

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