Killing the Golden Goose? The Decline of Science in Corporate R&D

Ashish Arora[a], Sharon Belenzon[b] and Andrea Patacconi[c]

a. *Fuqua School of Business, Duke University,* and *NBER*
b. *Fuqua School of Business, Duke University*
c. *Norwich Business School, University of East Anglia*

The Golden Age of American Corporate Research?

Motivation

- Modern economic growth is distinguished by the systematic application of science to the problem of economic production. Simon Kuznets, *Modern Economic Growth: Rate, Structure and Spread*. 1966
- Advance of scientific knowledge eventually leads to advances in techniques of production and productivity growth Joel Mokyr 2002 – *Gifts of Athena*
- Private investment in creating new scientific knowledge: Nelson, *JPE*. *1959;* Rosenberg *Res Pol 1990*

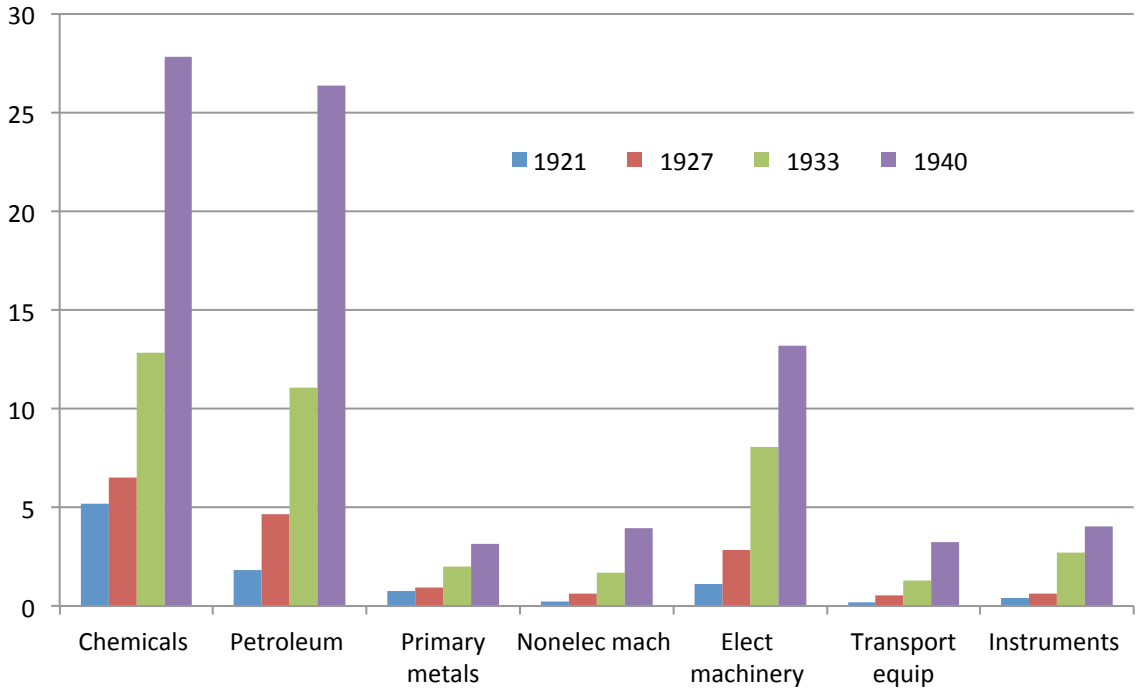
Research question

Are large firms withdrawing from investing in science?

Why?

"I am fully convinced that it has never, is not now, and never will pay commercially, to keep an establishment of professional inventors, or of men whose chief business it is to invent" … the duties of the patent department … (should be) … first and foremost on examining patents or inventions submitted by the public for consideration and second on examining descriptions of inventions forwarded by the company's employees."

T.D. Lockwood, on the "Duties of the patent department", at AT&T, 1885. (cited by Lamoreaux and Sokoloff, 1999)



Scientists and Engineers in Industrial Research Labs in U.S. Manufacturing Firms per thousand (Mowery, 1995)

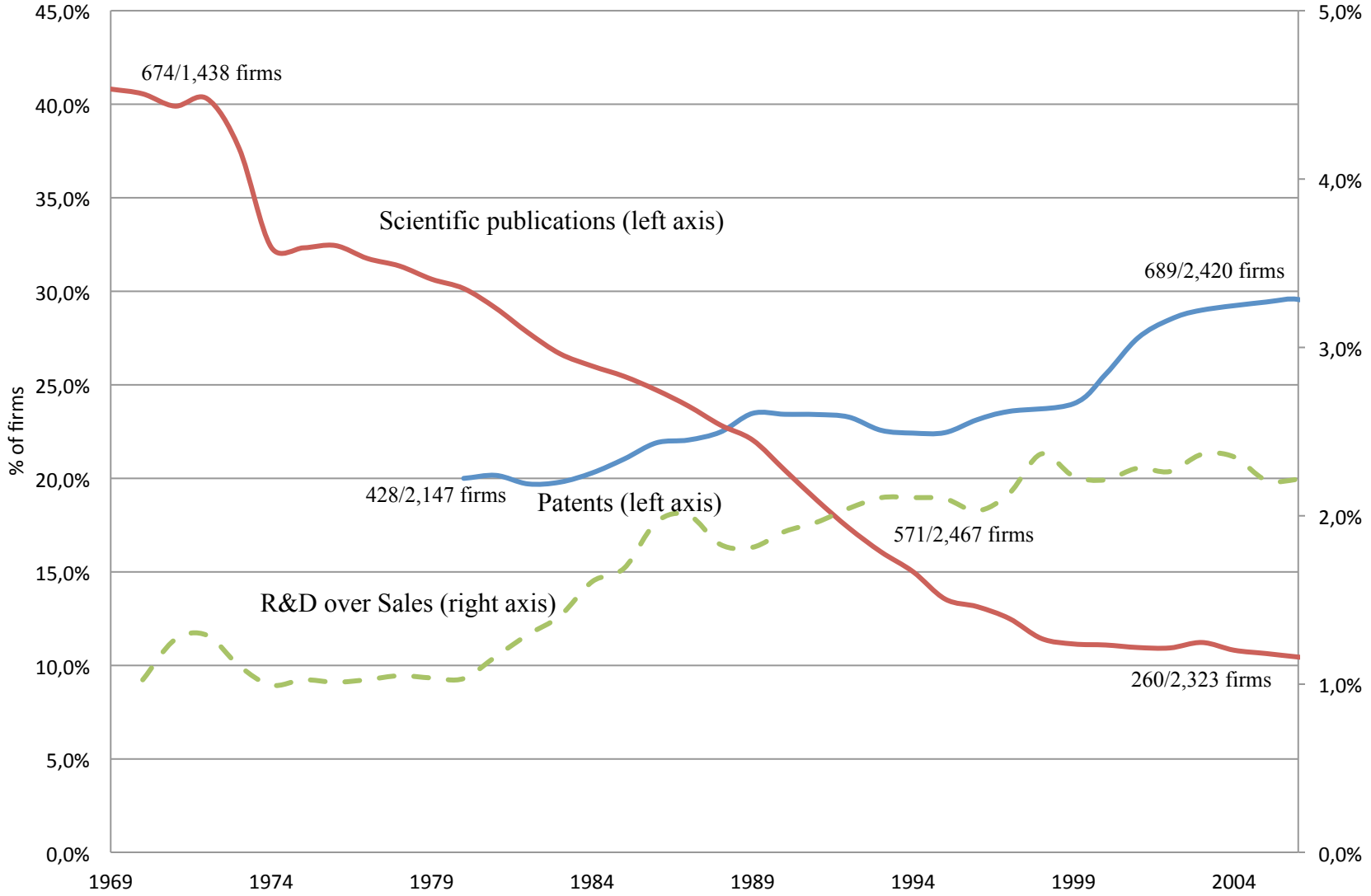
Internal labs for

- materials testing, quality control, trouble shooting production,
- evaluating external technology

1930s onwards invest in "experiments" and creation of new products and processes

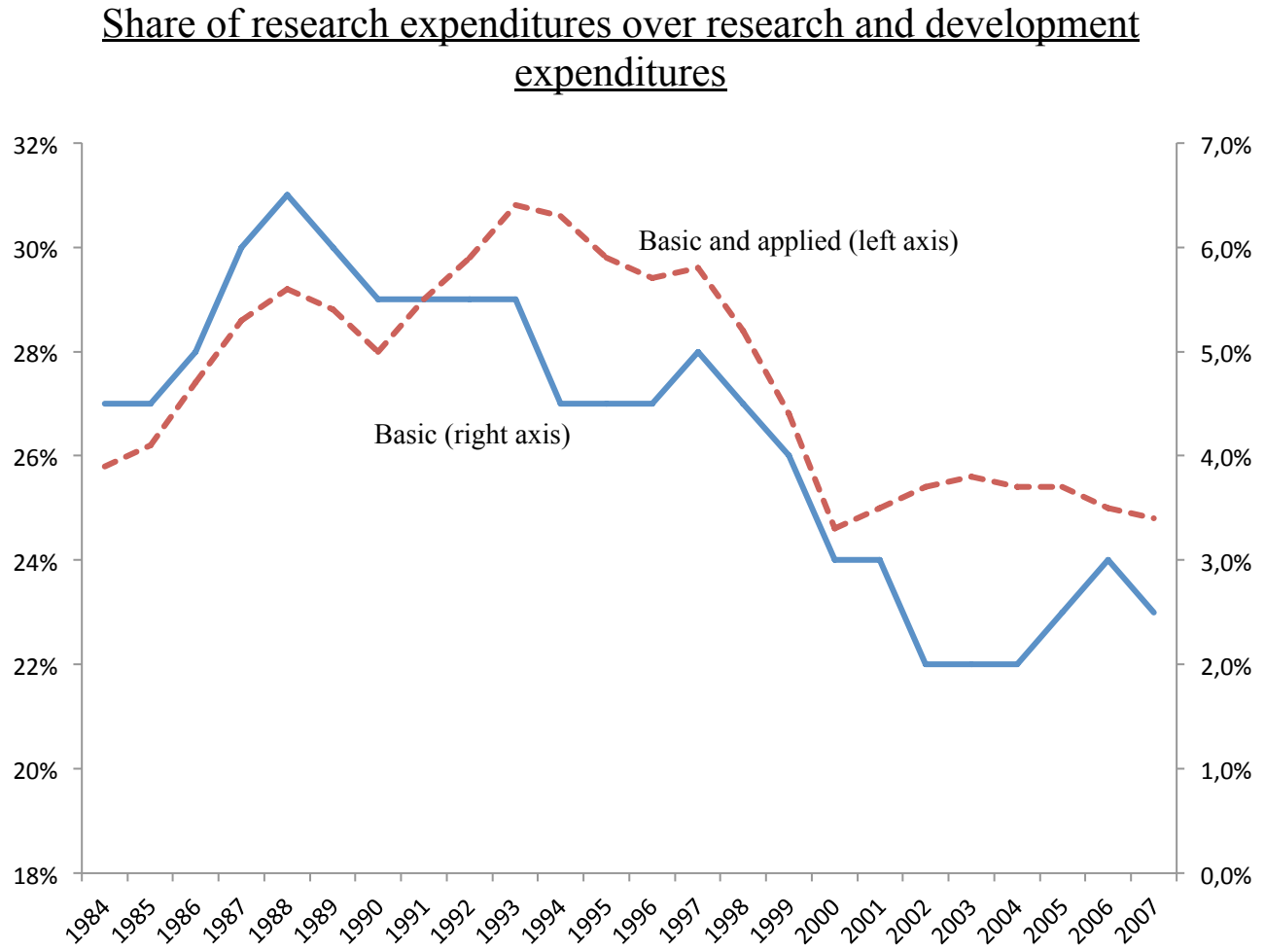
1983 private sector spent more on research than Federal government

Figure 1: Over time, firms are investing less in science but more in technology



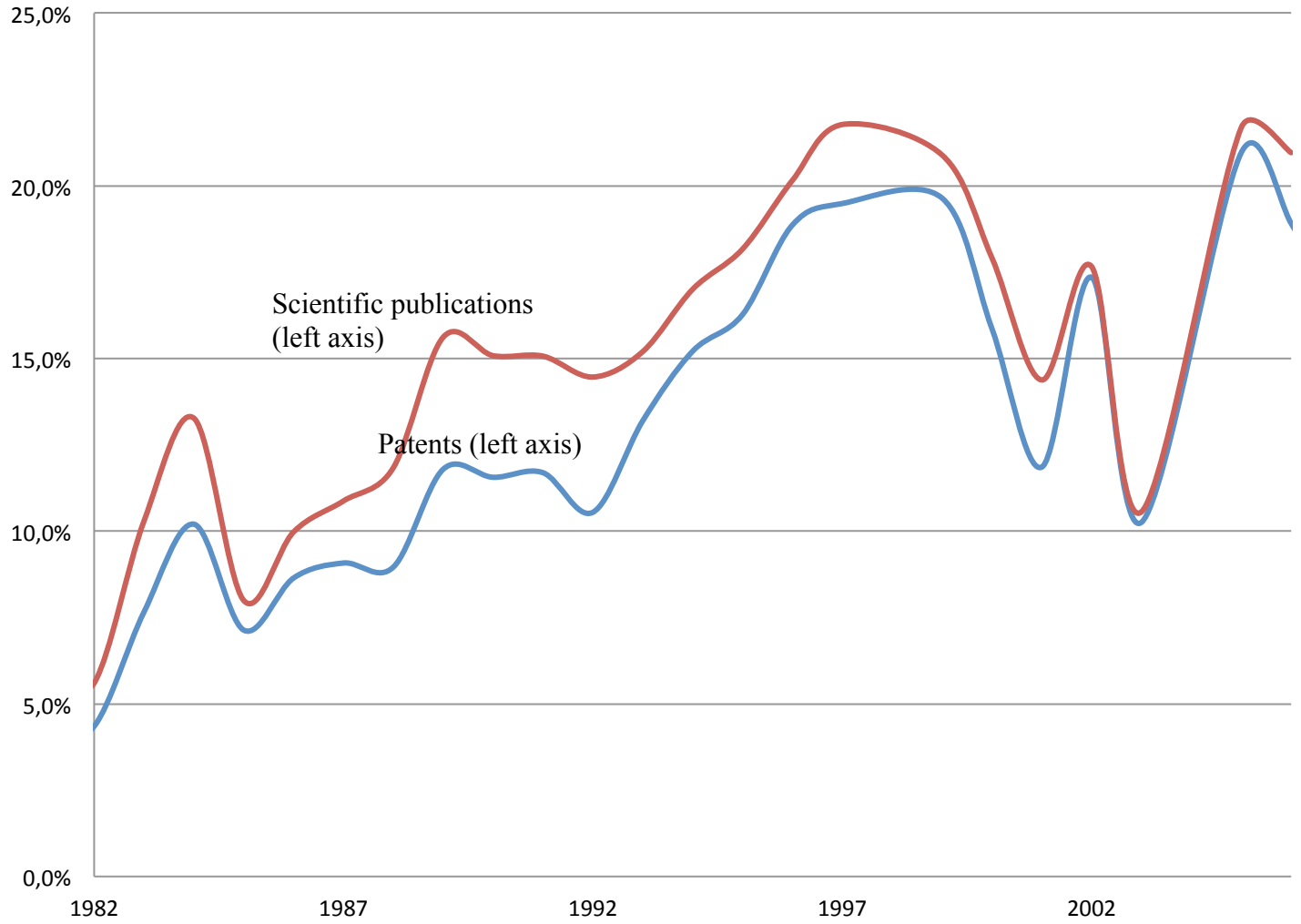
Note: This figure presents the share of publishing and patenting firms of all Compustat firms with at least one year with non-zero R&D expenditures, over time. Data source: Compustat, Web of Science, PatStat.

Figure 2: Same pattern is evident using NSF data



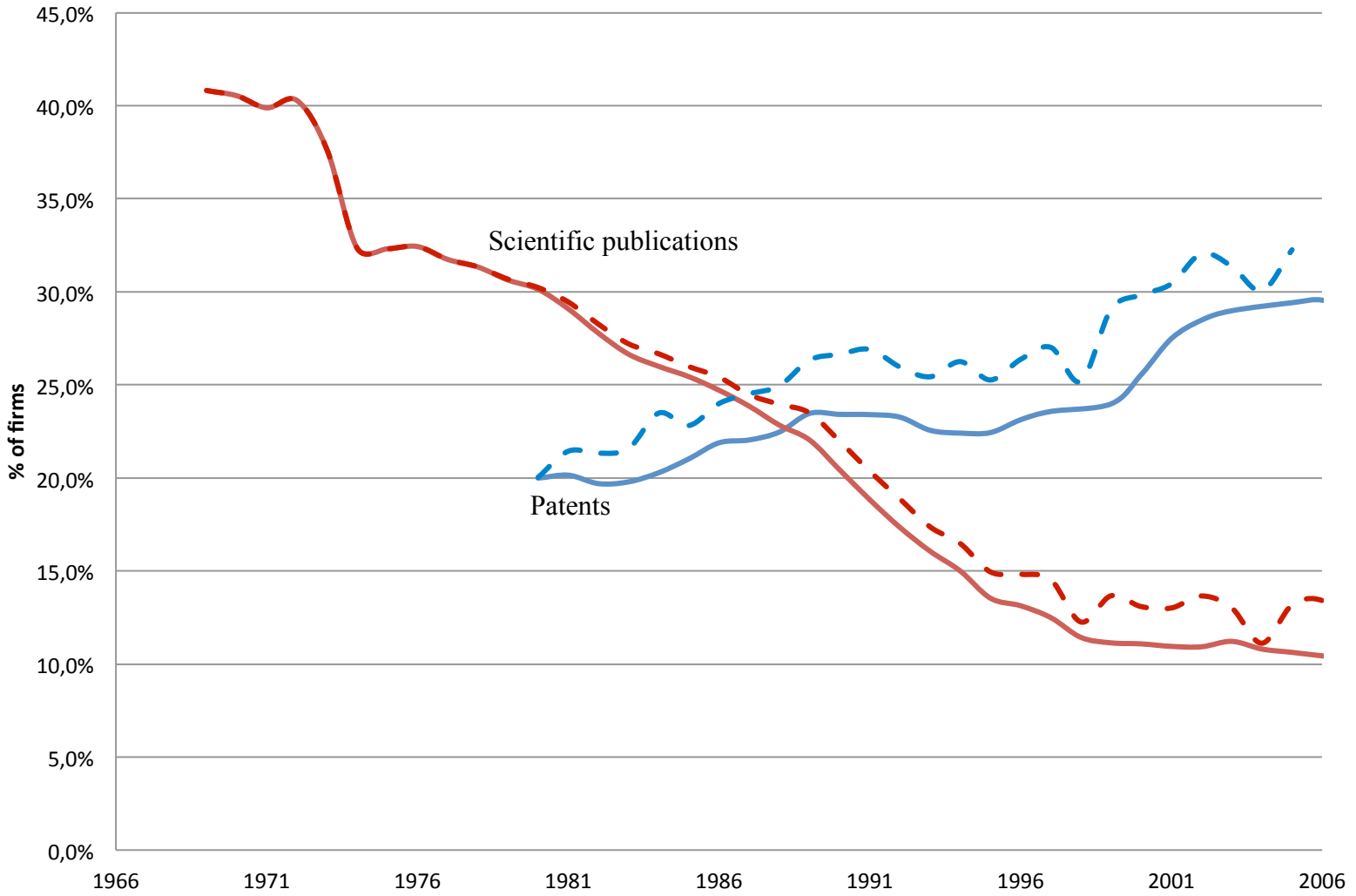
Data source: National Science Foundation/Division of Science Resources Statistics, Survey of Industrial Research and Development: 2007.

Figure 3: Over time, firms rely more on external knowledge



Note: This figure presents the share of publishing firm that acquire targets with scientific publications, and the share of patenting firms that acquire targets with patents, over time (3-year moving average). The dotted line plots the share of firm scientific articles that are coauthored with an external scientist. Data source: SDC Platinum, Web of Science, PatStat.

Figure 4: The basic trends remain - firms are moving away from research and towards development



Note: This figure combines internal and acquired publications and patents. The dashed lines present the combined shares.
Data source: Compustat, SDC Platinum, Web of Science, PatStat.

Main findings

- 1980-2007: Large firms are withdrawing from science
  - Less production of internally generated research
  - Decline in the stock market value of scientific capabilities
  - Decline in the price paid for scientific capabilities in M&A

Stylized fact 1: Large firms invest less in science

Not likely to reflect mere changes in publication behaviour

Stylized fact 2: Investors (and managers) pay for the fruit of science (patents)...

Stylized fact 3: ... but not for the golden goose itself (the firm's scientific capabilities)

Stylized fact 4: Results are present in broad range of industries

Stylized fact 5: Science continues to be useful for invention

Why are large firms withdrawing from science?

1. Science is becoming less useful for invention

- Gordon (2012)
- Distinguish between production of science and use of science
- Absorptive capacity is less important if external science is more accessible over time (better "packaging")

✖

2. Difficulties in managing science internally

- Hounshell and Smith (1988), Kay, 1994; Dasgupta and David, 1994; Argyres and Silverman, 2004; Pisano, 2006; Arora et al., 2014

3. Globalization

- Two competing views: escaping competition via more innovation/science (e.g., Aghion et al., 2005; Bloom et al., 2012), vs. falling margins (Schumpeterian effect)

✓

4. Increasing firm's focus

- Nelson (1959). Investment in science is more profitable in diversified firms

✓

5. Changes in American institutions

- Regulatory changes affecting American publicly-listed firms (Sarbanes-Oxley Act, 2002)
- Commercialization of research in American universities (Bayh–Dole Act , 1980)
- Short-termism in American stock markets

✖

Which mechanisms are supported?

- Decline in corporate science is likely to be linked to:

  (3) Cost-based competition due to greater globalization (Schumpeterian effect)

  (4) Shrinking firms' scope

- It is less likely that the decline in corporate science is linked to:

  (1) Science being less useful for innovation

  (5) American-specific (regulatory) changes

Data and Results

Data: Compustat, Web Of Science, USPTO, EPO, SDC Platinum

1. U.S. Compustat. Investment and stock market value for R&D performing publicly-listed firms.
2. Scientific publications. Publications by firms (312k)
   - Automatic and manual match of Compustat and SDC to Thomson Web of Science (affiliation field)
   - Testing mechanism (5): Match to European firms (public and private)
3. Patents. Match USPTO and EPO patents to Compustat and SDC Platinum (M&A data)
4. Acquisitions. 29,752 acquisitions from Thomson SDC for the period 1985-2007
   - Deal value, shares acquired, assets, sales, industry
   - Include deals where deal value and target assets are available
   - 2.5k publications and 115k patents
   - Track post-acquisition behavior

Measures of science

1. **Firm publications**: scientific publications in “hard-science” journals
   - Generate a list of more important journals by field. Remove publications in trade journals and conference proceedings
   - Match journal name to CHI database to classify as basic/ applied
   - Information on journal impact factor
   - Article specific quality measure: number of citations it receives
2. **Patent citations to science**: The use of science in invention
   - The number of citations a patent makes to scientific publications in “hard-science” journals
   - Include only citations to leading journals in “hard-science”

Summary statistics for main variables

TABLE 1. SUMMARY STATISTICS FOR MAIN VARIABLES

				Distribution		
VARIABLES	No. Obs.	Mean	Std. Dev.	10th	50th	90th
Panel A: Compustat firms						
Market value ($, mm)	11,304	5,920	20,278	33	677	12,208
$Assets_{t-1}$ ($, mm)	11,304	3,017	9,681	24	397	7,328
$Sales_{t-1}$ ($, mm)	11,304	3,410	9,805	35	677	12,208
Publication stock	11,304	58	389	0	0	20
Publication flow	11,304	10	58	0	0	8
Patent stock	11,304	174	664	2	19	314
Patent flow	11,304	26	101	0	2	46

- Our sample includes Compustat R&D performing firms for the period 1980-2007, and all acquisitions by Compustat firms over the period 1985-2007 (from SDC Platinum)
- 28% of Compustat firms publish at least one article over the sample period
- Publishing firms are larger ($4.3B in sales vs. $2.8B) and more valuable ($8.8B vs. $4.4B), but grow more slowly (7.7% vs. 10.9%)

Large firms are withdrawing from investing in internal science over time

TABLE 2. RESEARCH AND THE STOCK MARKET VALUE OF R&D PERFORMING FIRMS

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Pubs /R&D	Patents/ R&D	R&D/ Sales	ln(*Market value*)		
VARIABLES					1980-1997	1998-2007
Time trend	-0.042**	-0.037**	0.004	0.091*		
	(0.006)	(0.006)	(0.006)	(0.046)		
Time trend × ln(*Publication Stock*)$_{t-1}$				-0.002**		
				(0.0008)		
Time trend × ln(*Patent Stock*)$_{t-1}$				0.004**		
				(0.001)		
ln(*Publication Stock*)$_{t-1}$				0.074**	0.066**	0.024
				(0.014)	(0.024)	(0.027)
p-value for difference in estimates:					*p-value* <0.01	
ln(*Patent Stock*)$_{t-1}$				0.066**	0.095**	0.153**
				(0.014)	(0.023)	(0.023)
Dummy for Research Lab					0.217*	0.058
					(0.091)	(0.076)
p-value for difference in estimates:					*p-value* <0.01	
ln(*Assets*)$_{t-1}$				0.306**	0.266**	0.372**
				(0.017)	(0.026)	(0.038)
ln(*R&D Stock*)$_{t-1}$				0.066**	0.049**	0.076**
				(0.014)	(0.018)	(0.015)
ln(*Sales*)$_{t-1}$	-0.403**	-0.229**	-0.167**	0.488**	0.522**	0.422**
	(0.049)	(0.049)	(0.045)	(0.019)	(0.033)	(0.042)
Firm fixed-effects	Yes	Yes	Yes	No	No	No
R^2	0.918	0.852	0.845	0.842	0.853	0.818
Observations	11,304	11,304	11,304	11,304	5,288	6,016

- Publications intensity (cited-weighed flow of publications over R&D stock) and patents intensity are falling over time (within-firms)
- From (1), between 1980 and 2007, publications intensity fell by 66% of average publications intensity value
- R&D intensity remains stable over time
- Stock market value of research (publications, dummy for whether the firm has a research lab) falls over time, but the value of development (patents) rises

Results reflect decline in corporate investment in basic research rather than changes in publication norms

Dependent variable:	Flow of scientific publications		Share basic	ln(Market value)
Publications:	Basic	Applied	All	All
Time trend	-0.005**	-0.001	-0.023**	0.086*
	(0.002)	(0.003)	(0.008)	(0.046)
Time × ln(*Basic publication stock*)$_{t-1}$				-0.019*
				(0.001)
Time × ln(*Applied publication stock*)$_{t-1}$				0.001
				(0.001)
ln(1+*Basic publication stock*)$_{t-1}$				0.071**
				(0.014)
ln(1+*Applied publication stock*)$_{t-1}$				-0.024
				(0.015)
Time trend × ln(*Patent stock*)$_{t-1}$				0.005**
				(0.001)
ln(1+*Patent stock*)$_{t-1}$				0.064**
				(0.013)
ln(*R&D stock*)$_{t-1}$	0.013**	0.034**	-0.214**	0.071**
	(0.006)	(0.011)	(0.055)	(0.005)
ln(*Sales*)$_{t-1}$	0.015	0.032**	0.117**	0.489**
	(0.009)	(0.013)	(0.067)	(0.019)
ln(*Assets*)				0.308**
				(0.017)
R^2	0.944	0.871	0.935	0.853
Observations	11,304	11,304	4,955	11,304

- If publications are falling because disclosure is becoming more costly, we should observe a similar decline in applied journal publications
- But, results are driven only by basic journal publications
- Similar results if weight by impact factor journal – decline is greater in high impact journals
- Better patentability should encourage disclosure rather than secrecy

Note: We distinguish between basic and applied scientific publications as indicated by the CHI journal database. Publications are classified as basic if they are published in journals with a CHI level of 4, and as applied if they are published in journals with a CHI level of 1. Publications and patents are always weighed by citations.

Withdrawal from research is evidence in all industries, but less so in Biotechnology and Chemicals

TABLE 3. INVESTMENT IN RESEARCH BY INDUSTRY, OVER TIME

	(1)	(2)	(3)
Dependent variable:	Publications /R&D	Patents/ R&D	R&D/ Sales
Time trend	-0.037**	-0.049**	-0.001
	(0.003)	(0.003)	(0.003)
Time trend ×:			
Dummy for Biotechnology (1,465)	0.016**	-0.020**	0.028**
	(0.005)	(0.006)	(0.006)
Dummy for Chemicals (3,025)	0.015**	0.004	-0.002
	(0.004)	(0.004)	(0.004)
Dummy for Pharmacueticals (1,604)	-0.021**	-0.010	-0.004
	(0.005)	(0.007)	(0.006)
Dummy for Electronics (4,590)	-0.005	0.019**	-0.007
	(0.004)	(0.005)	(0.004)
Dummy for I.T. (3,391)	-0.011**	0.002	-0.001
	(0.004)	(0.005)	(0.004)
Dummy for Semiconductors (2,013)	-0.024**	-0.005	0.013**
	(0.004)	(0.005)	(0.004)
Dummy for Tellecommunications (2,064)	0.007	0.029**	0.013**
	(0.005)	(0.005)	(0.004)
Firm fixed-effects	Yes	Yes	Yes
R^2	0.919	0.854	0.845
Observations	11,304	11,304	11,304

- Firms (Compustat) are classified into technology areas based on the distribution of their patents by technology fields
- Publications and patents intensity fell in all technology areas
- Biotechnology experienced a smaller decline in publications intensity, but a greater decline in patenting intensity

Consistent stock market value patterns across industries

TABLE 4. RESEARCH AND STOCK MARKET VALUE BY INDUSTRY, OVER TIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	ln(*Market value*)						
VARIABLES	Biotech	Chemi-cals	Pharma	Elect-ronics	I.T.	Semicon-ductors	Telle-comm
Time trend × ln(*Publication Stock*)$_{t-1}$	-0.001	-0.002*	-0.003*	-0.003**	-0.003**	-0.003*	-0.005**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Time trend × ln(*Patent Stock*)$_{t-1}$	0.005**	0.004**	0.007**	0.006**	0.007**	0.004*	0.009**
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
ln(*Publication Stock*)$_{t-1}$	0.134**	0.154**	0.139**	0.114**	0.157**	0.068**	0.136**
	(0.021)	(0.017)	(0.022)	(0.016)	(0.018)	(0.022)	(0.020)
ln(*Patent Stock*)$_{t-1}$	-0.035	-0.002	-0.086**	0.034	-0.038	0.148**	-0.065*
	(0.027)	(0.024)	(0.029)	(0.021)	(0.025)	(0.036)	(0.031)
Time trend	-0.009	0.012	0.005	0.024*	0.020*	0.034**	0.013
	(0.013)	(0.009)	(0.015)	(0.008)	(0.009)	(0.012)	(0.011)
ln(*Assets*)$_{t-1}$	0.315**	0.453**	0.320**	0.349**	0.310**	0.274**	0.228**
	(0.041)	(0.028)	(0.041)	(0.023)	(0.026)	(0.034)	(0.031)
ln(*R&D Stock*)$_{t-1}$	0.021	0.053**	0.070	0.012	0.007	0.063**	-0.006
	(0.016)	(0.012)	(0.018)	(0.007)	(0.009)	(0.017)	(0.011)
ln(*Sales*)$_{t-1}$	0.418**	0.323**	0.390**	0.543**	0.579**	0.505**	0.677**
	(0.042)	(0.030)	(0.037)	(0.026)	(0.029)	(0.035)	(0.034)
R^2	0.846	0.828	0.833	0.836	0.816	0.851	0.836
Observations	1,465	3,025	1,604	4,590	3,391	2,013	2,064

- ❑ Stock market value of publications is falling in all industries, except for Biotechnology
- ❑ Stock market value of patents is rising in all industries

Withdrawal from science over time is also evident in the value of acquired firms

TABLE 5. RESEARCH AND TARGET'S FIRM VALUE OVER TIME

Dependent variable: ln(*Target's firm value*)

	(1)	(2)	(3)	(4)	(5)
	All Years	1985-1997	1998-2007	Innovating targets	Excluding IT
Time trend × ln(*Publication stock*)$_{t-1}$	-0.018**			-0.017**	-0.019**
	(0.005)			(0.005)	(0.005)
Time trend × ln(*Patent stock*)$_{t-1}$	0.003**			0.002	0.003**
	(0.001)			(0.001)	(0.001)
ln(1+*Publication stock*)$_{t-1}$	0.292**	0.169**	-0.043	0.266**	0.314**
	(0.064)	(0.040)	(0.069)	(0.062)	(0.065)
p-value for difference in estimates:		*p-value* <0.01			
ln(1+*Patent stock*)$_{t-1}$	0.039**	0.069**	0.072**	0.033*	0.041**
	(0.012)	(0.008)	(0.011)	(0.015)	(0.012)
ln(*Assets*)	0.592**	0.586**	0.595**	0.649**	0.598**
	(0.007)	(0.010)	(0.010)	(0.019)	(0.007)
ln(*Sales*)	0.167**	0.177**	0.157**	0.077**	0.168**
	(0.007)	(0.009)	(0.010)	(0.016)	(0.007)
Time trend	0.018**			0.011*	0.019**
	(0.003)			(0.005)	(0.003)
Two-digit industry dummies	Yes	Yes	Yes	Yes	Yes
Country target dummies	Yes	Yes	Yes	Yes	Yes
Acquisition year dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.654	0.678	0.633	0.646	0.661
Observations	26,884	14,990	11,894	4,684	25,004

- ❑ The implied value of research (publications) by acquired firms falls over time, but the implied value of development (patents) rises
- ❑ Results are robust to including only target firms that either patent or publish, and to excluding acquisitions in information technology (1999-2001 IT "bubble" years)
- ❑ *Not paying anymore for the golden goose*.

Note: The sample includes all SDC Platinum deals with non-missing information on target firm value, assets and sales. The sample period is 1985–2007.

Decline in publications activity post-acquisition in the second half of our sample

TABLE 6. PUBLICATIONS IN THREE-YEAR WINDOW AROUND ACQUISITION YEAR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	Flow of scientific publications						Flow of patents		
	Count			Weigh by citations			Count		
Acquisition year:	All	1985-1996	1997-2004	1985-2004	1985-1996	1997-2004	All	1985-1996	1997-2004
Post-acquisition dummy	-0.079** (0.023)	0.013 (0.025)	-0.198** (0.041)	-0.298 (0.200)	0.902** (0.248)	-1.839** (0.326)	1.171** (0.467)	2.036** (0.629)	0.184 (0.698)
Firm fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	0.57	0.57	0.58	6.1	5.6	6.7	8.6	6.6	10.3
R^2	0.865	0.901	0.819	0.614	0.640	0.590	0.953	0.911	0.97
Observations	19,475	10,615	8,860	19,475	10,615	8,860	22,369	11,040	11,329

For each target firm, we identify post-acquisition publications by (1) continued publications under the original target firm name, or (2) publications by authors from the target firm under the acquirer name.
About 20% of post-acquisition publications are of the latter category.

Why are large firms withdrawing from science?

1. Science is becoming less useful for invention

- Gordon (2012)
- Distinguish between production of science and use of science
- Absorptive capacity is less important if external science is more accessible over time (better "packaging")

✖

2. Difficulties in managing science internally

- Hounshell and Smith (1988), Kay, 1994; Dasgupta and David, 1994; Argyres and Silverman, 2004; Pisano, 2006; Arora et al., 2014

3. Globalization

- Two competing views: escaping competition via more innovation/science (e.g., Aghion et al., 2005; Bloom et al., 2012), vs. falling margins (Schumpeterian effect)

✓

4. Increasing firm's focus

- Nelson (1959). Investment in science is more profitable in diversified firms

✓

5. Changes in American institutions

- Regulatory changes affecting American publicly-listed firms (Sarbanes-Oxley Act, 2002)
- Commercialization of research in American universities (Bayh–Dole Act , 1980)
- Short-termism in American stock markets

✖

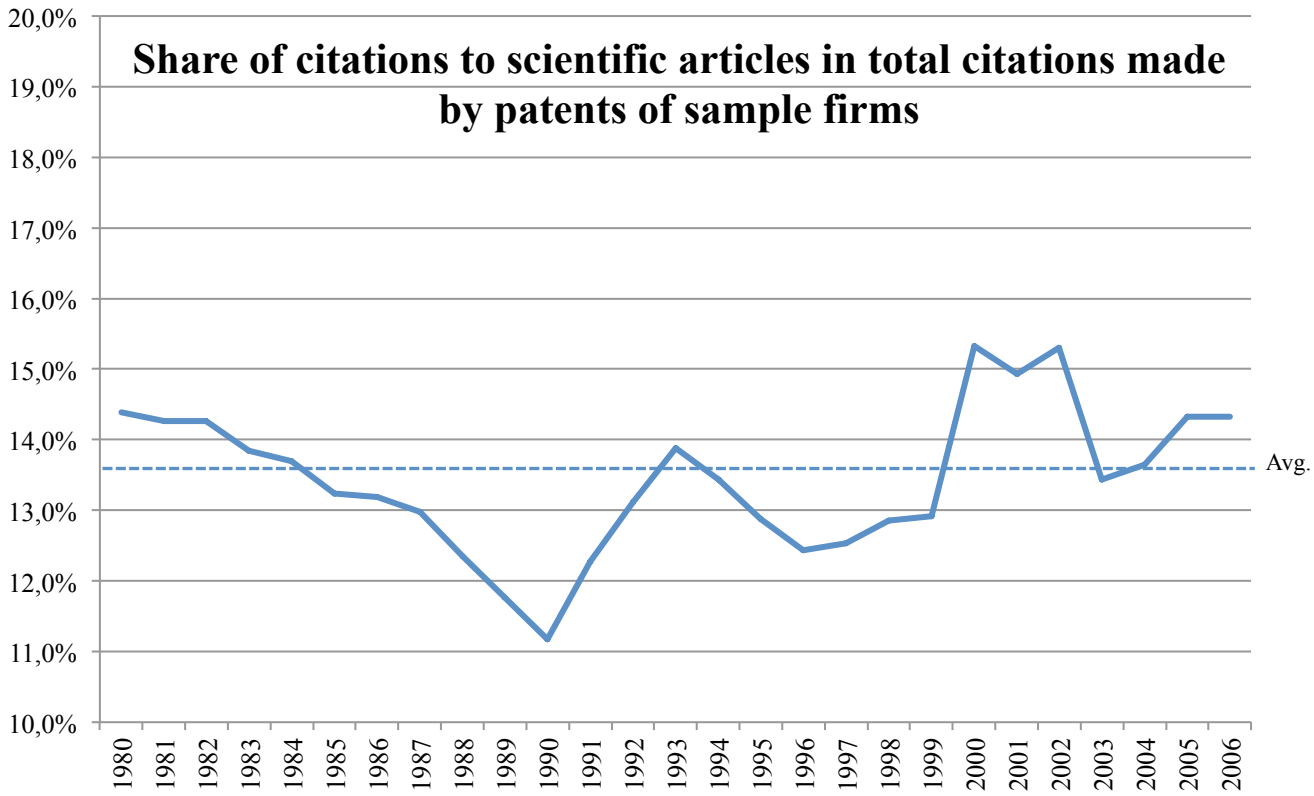
Testing mechanism (1): If science is becoming less useful for research, inventions build less upon science – Not supported

TABLE 7. USE OF SCIENCE IN INNOVATION: CITATIONS BY PATENTS TO SCIENTIFIC PUBLICATIONS

Dependent variable: *Number of patent citations to science*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	All	Publishing firms	Non-publishing firms	Pharma and Biotech	Chemicals	Electronics	Telecom and IT
Time trend	0.001	0.021	-0.017	0.045	0.016	0.046**	-0.001
	(0.015)	(0.017)	(0.020)	(0.055)	(0.040)	(0.014)	(0.014)
Cites made	0.089**	0.089**	0.089**	0.122**	0.100**	0.079**	0.133**
	(0.011)	(0.015)	(0.013)	(0.044)	(0.029)	(0.012)	(0.017)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.582	0.497	0.596	0.621	0.637	0.485	0.526
Observations	11,304	4,411	6,893	2,138	3,275	5,023	4,041

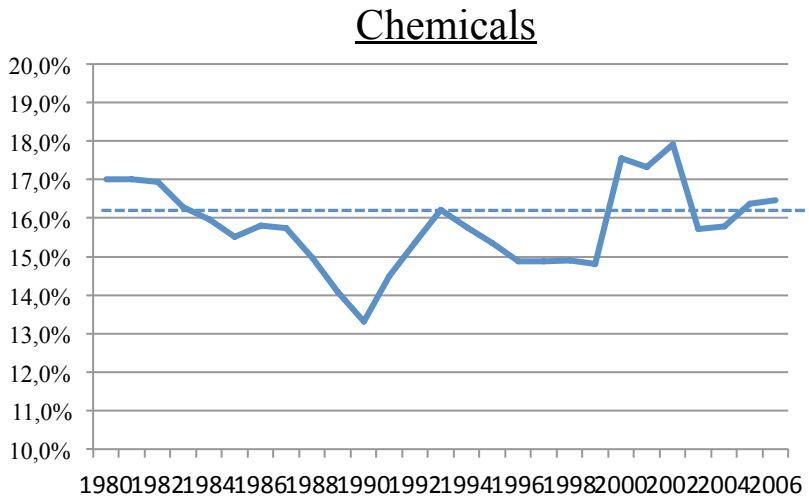
- We include only citations to articles in "hard science" journals, excluding trade journals
- The average (firm-year) citations to scientific articles by patents are stable over time: Inconsistent with declining use of science.

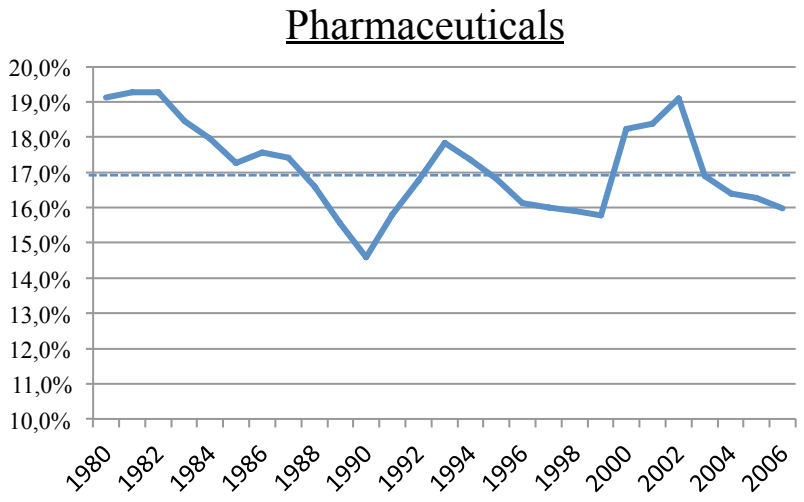
Figure 5: The use of science is stable over time (measured by patent citations to science)



Note: This figure plots the ratio between the citations a patent makes to hard science articles over the sum of citations that patent makes to other patents and to hard science articles. The sample includes all patenting Compustat firms.

Figure 5(b): A Similar time trends is evident in discrete technologies





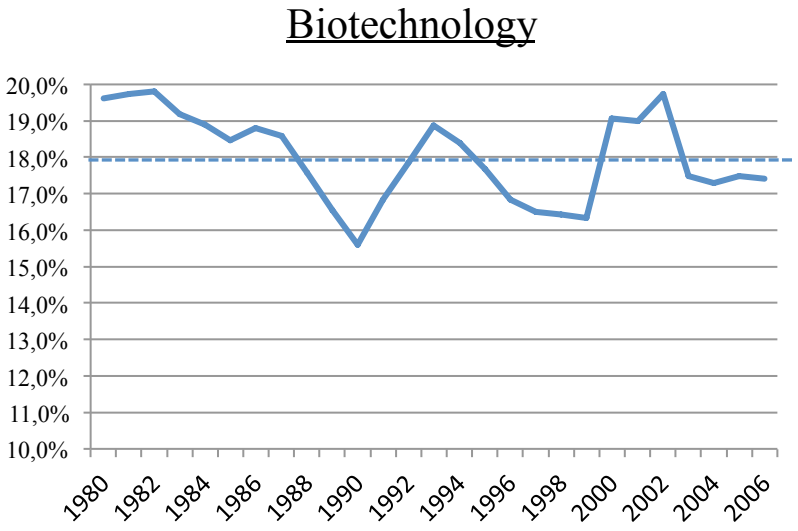
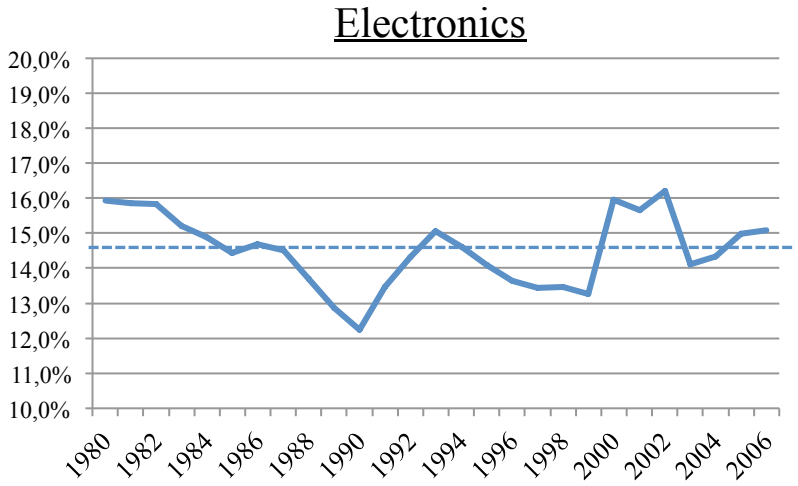
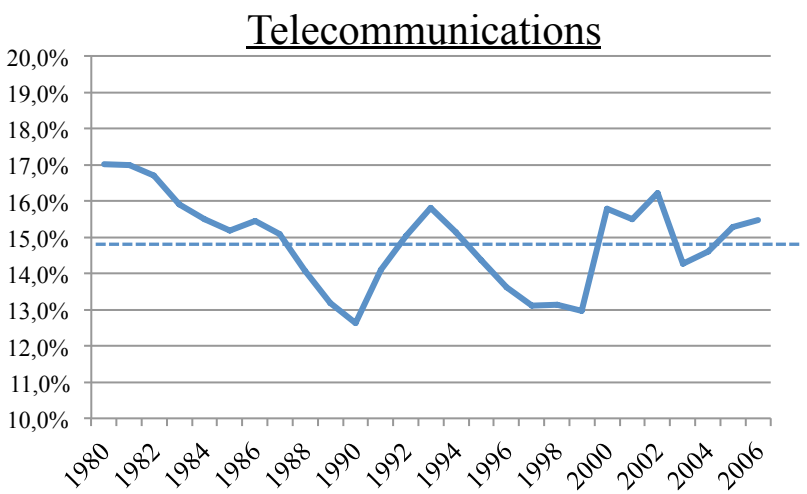
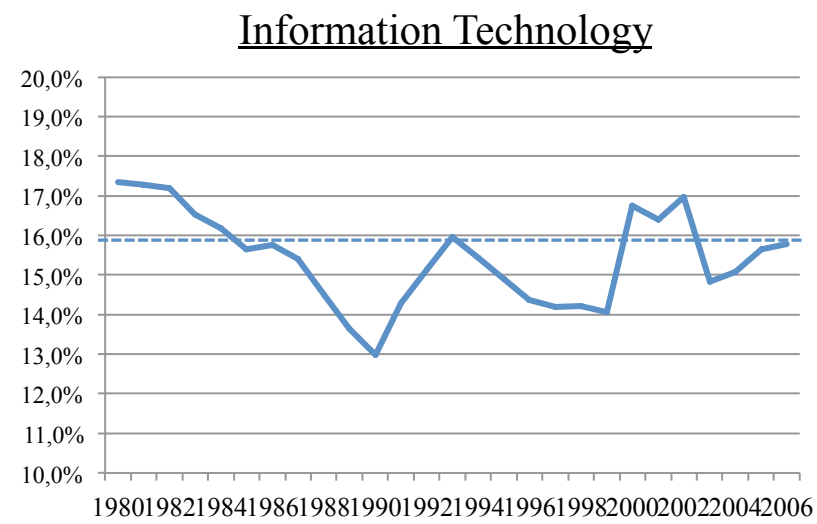
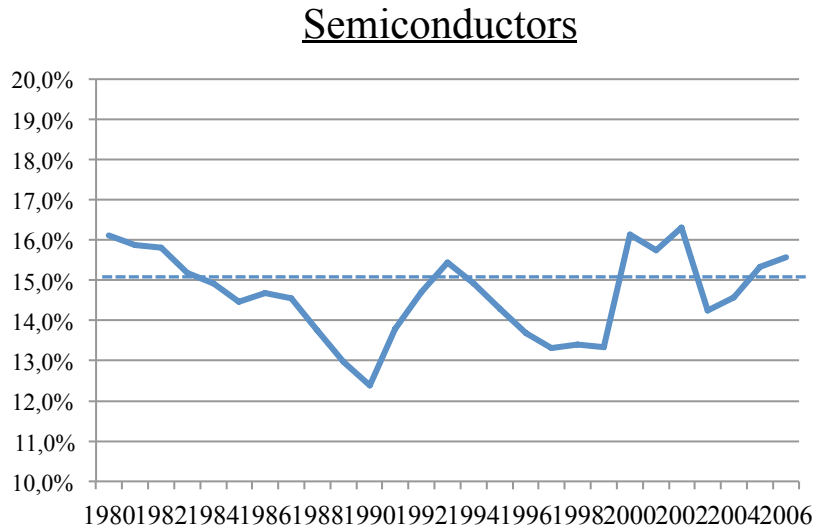


Figure 5(c): And similar time trends is also evident in complex technologies









Testing Mechanisms (1) Value indicators are also inconsistent with the declining use of science

TABLE 8. TESTING MECHANISMS (A): DECLINING USE OF SCIENCE (*cont'd*)

	(1)	(2)	(3)	(4)
Dependent variable:	ln(*Market value*)		ln(*Acquisition value*)	
VARIABLES				
Time trend × ln(*Publication Stock*)$_{t-1}$	-0.002**	-0.002**	-0.018**	-0.017**
	(0.0008)	(0.0008)	(0.005)	(0.005)
Time trend × ln(*Patent Stock*)$_{t-1}$	0.004**	0.004**	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
ln(*Publication Stock*)$_{t-1}$	0.074**	0.072**	0.292**	0.278**
	(0.014)	(0.014)	(0.064)	(0.063)
ln(*Patent Stock*)$_{t-1}$	0.066**	0.063**	0.039**	0.034**
	(0.014)	(0.014)	(0.012)	(0.012)
Time trend × *Cites to science*		-0.001**		-0.002**
		(0.0004)		(0.0007)
Cites to science		0.039**		0.047**
		(0.010)		(0.013)
ln(*Assets*)$_{t-1}$	0.306**	0.303**	0.592**	0.591**
	(0.017)	(0.017)	(0.007)	(0.007)
ln(*R&D Stock*)$_{t-1}$	0.066**	0.059**		
	(0.014)	(0.005)		
ln(*Sales*)$_{t-1}$	0.488**	0.503**	0.167**	0.168**
	(0.019)	(0.019)	(0.007)	(0.007)
Time trend	0.091*	0.088*		
	(0.046)	(0.046)		
R^2	0.842	0.844	0.654	0.655
Observations	11,304	11,304	26,884	26,884

- ❑ Declining value of publications in both stock market value and acquisition value remain robust when controlling to patent citations to science
- ❑ The value of more scientific patents (patents that make more cites to science) fell over time

And also corporate inventions are not relying on older science over time

Dependent variable: *Average publication year of cited science*					
	(1)	(2)	(3)	(4)	(5)
Variables	Within-industries	Within-industries	Within-firms	Within-firms	Pharma and Biotech
Time trend	0.974**	0.977**	1.001**	1.007**	0.983**
	(0.012)	(0.015)	(0.018)	(0.024)	(0.036)
ln(*Patent stock*)$_{t-1}$	-0.122*	0.123*	0.012	0.011	0.278
ln(*Publication stock*)$_{t-1}$	0.224**	0.254**	0.317*	0.353*	0.249
	(0.036)	(0.071)	(0.158)	(0.191)	(0.208)
Time trend × ln(*Publication stock*)$_{t-1}$		-0.002		-0.002	0.002
		(0.004)		(0.005)	(0.006)
	(0.063)	(0.063)	(0.107)	(0.107)	(0.209)
ln(*Sales*)$_{t-1}$	-0.058	-0.058	-0.668**	-0.672**	-0.548**
	(0.055)	(0.055)	(0.131)	(0.132)	(0.172)
Industry fixed effects	Yes	Yes	-	-	-
Firm fixed effects	No	No	Yes	Yes	Yes
R^2	0.580	0.580	0.691	0.691	0.786
Observations	6,251	6,251	6,251	6,251	1,789

- ❑No exhaustion: Average age of cited papers stable
- ❑Absorptive capacity: publishing firms cite more recent science in their patents
  - ❑No decline over time
- ❑Similar results across fields
- ❑*Have not matched to "own" research as yet*

Testing mechanism (2): Increased globalization is associated with lower investment in research

TABLE 10. GLOBALIZATION AND INVESTMENT IN RESEARCH, 1998-2007

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	ΔPubs		ΔPats	ΔR&D	ΔCapx
ΔChinese import penetration		-1.725**	2.635**	-0.431*	-1.989**
		(0.563)	(0.716)	(0.244)	(0.403)
Time trend	-0.011**	0.001	-0.063**	-0.010**	0.003
	(0.005)	(0.007)	(0.009)	(0.003)	(0.005)
ΔR&D stock	0.042*	0.038*	0.397**		
	(0.019)	(0.019)	(0.055)		
ΔSales				0.474**	0.854**
				(0.031)	(0.053)
R^2	0.002	0.005	0.038	0.260	0.337
Observations	4,354	4,354	4,354	4,354	4,354

Note: Chinese import data is for the period 1998-2007. Changes are computed at the 3-year window.

- Average 3-year change in Chinese import penetration is 2.2%, with a 90th pct. of 6.5%, and 99th pct. of 13.3%
- Increase in Chinese import penetration is associated with a decline in research (publications), but with increased development (patents)

Two-standard deviation increase in Chinese import is associated with a decline of almost 100% (!) of the sample mean

And globalization is also associated with declining value of research capabilities

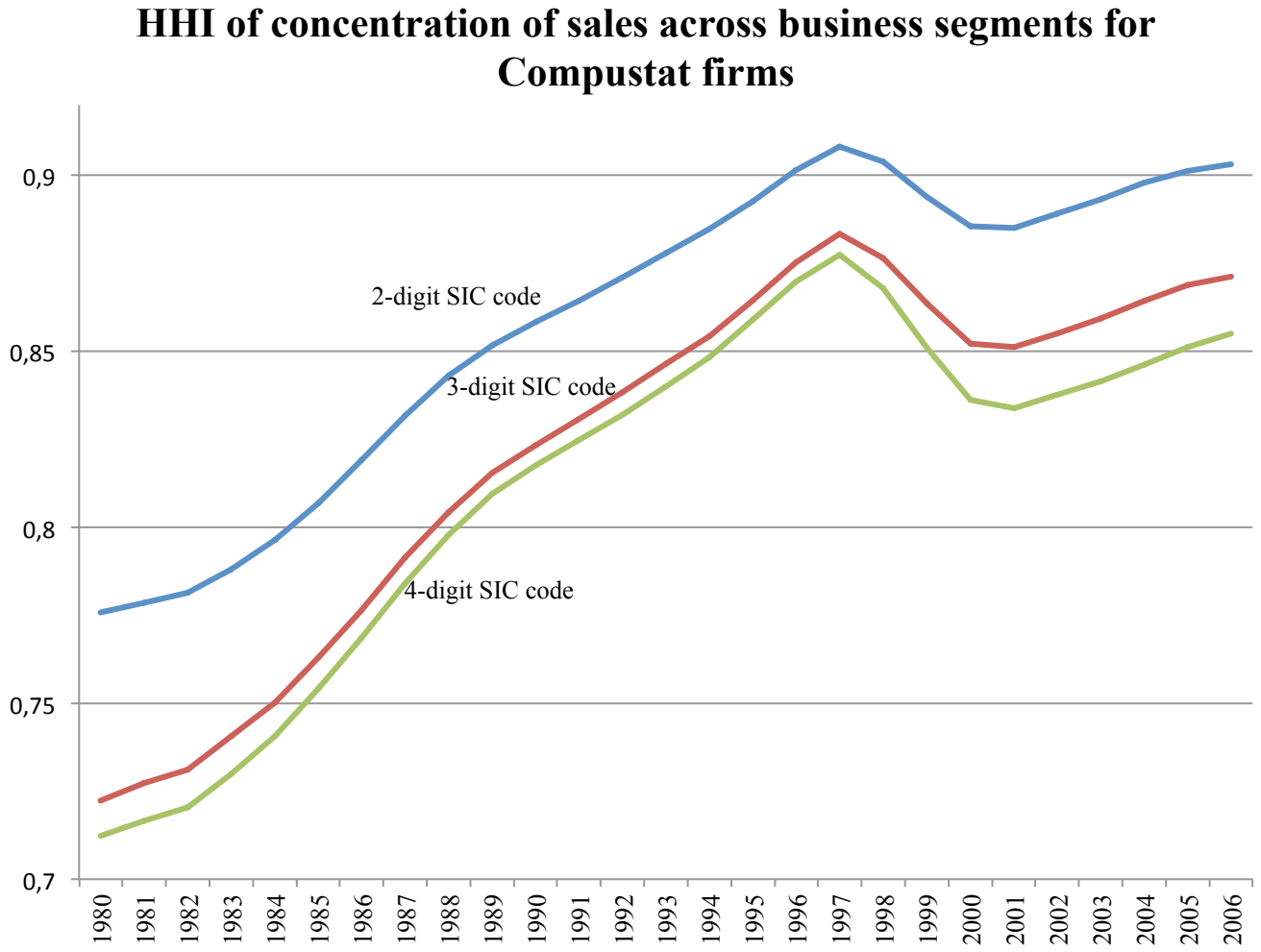
TABLE 11. GLOBALIZATION AND MARKET VALUE

Dependent variable: ln(*Market value*)	(1)	(2)	(3)
		Chinese import	
		High (75^{th} pct.)	Low (25^{th} pct.)
ΔChinese import penetration × ln(*Publication stock*)$_{t-1}$	-0.803**		
	(0.330)		
ΔChinese import penetration × ln(*Patent stock*)$_{t-1}$	-0.018		
	(0.323)		
Time trend × ln(*Publication stock*)$_{t-1}$		-0.010**	0.001
		(0.003)	(0.001)
Time trend × ln(*Patent stock*)$_{t-1}$		0.010**	0.001
		(0.002)	(0.002)
ln(*Publication stock*)$_{t-1}$	0.084**	0.065	0.086**
	(0.015)	(0.042)	(0.022)
ln(*Patent stock*)$_{t-1}$	0.153**	0.031	0.068**
	(0.016)	(0.033)	(0.028)
ln(*R&D stock*)$_{t-1}$	0.096**	0.065**	0.154**
	(0.010)	(0.018)	(0.013)
Time trend		0.174	0.175*
		(0.118)	(0.099)
ΔChinese import penetration	-0.372**		
	(1.290)		
R^2	0.789	0.805	0.873
Observations	3,540	1,755	2,077

- ❑ Consistent with the globalization mechanism, the stock market value of publications drop with increased Chinese import (with no change in the value of patents)
- ❑ And, the declining value of publications is evident only in the industries that were mostly exposed to Chinese import

Note: In column 1, the estimation period is 1998–2007. In columns 2 & 3, the estimation period is 1980–2007. All regressions include lagged logged assets and sales.

Figure 6: The scope of large American firms has declined over time



Note: This figure presents HHI measures of sales concentration by business segments for all Compustat firms (3-year moving average). Data source is Compustat's line of business data.

Testing mechanism (3): Shrinking firms' scope associated with lower benefits from investing in science

TABLE 12. NARROWER FIRM SCOPE

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	ΔPubs	ΔPats	ΔR&D	ln(*Market value*)	
				ΔHHI SIC>0	ΔHHI SIC≤0
ΔHHI SIC	-0.323*	-0.113	-0.060		
	(0.145)	(0.097)	(0.048)		
Time trend	-0.022	-0.006			
	(0.016)	(0.004)			
ΔR&D stock	0.240	0.378**			
	(0.161)	(0.062)			
ln(*Sales*)$_{t-3}$	0.107**	0.036**	0.002		
	(0.040)	(0.015)	(0.007)		
ΔSales			0.391**		
			(0.039)		
Time trend × ln(*Publication stock*)$_{t-1}$				-0.004**	-0.001
				(0.001)	(0.001)
Time trend × ln(*Patent stock*)$_{t-1}$				0.006**	0.004**
				(0.001)	(0.001)
ln(*Publication stock*)$_{t-1}$				0.109**	0.051**
				(0.020)	(0.020)
ln(*Patent stock*)$_{t-1}$				0.030	0.077**
				(0.023)	(0.018)
R^2	0.039	0.113	0.282	0.887	0.827
Observations	7,573	7,573	7,558	2,609	6,653

Note: Changes are at the three-year window. HHI is based on Compustat line-of-business data. All regressions include industry dummies. Columns 4-5 include controls for assets, R&D stock and sales.

- ❑ Between 1980 and 2007, HHI of sales concentration by industry segments fell by 18%
- ❑ HHI of sales concentration by industry segments for publishing firms is 11% lower than for non-publishing firms
- ❑ Moving from the lowest to the highest deciles of shrinking scope is associated with a drop of 87% of sample average decline in publications
- ❑ Value of publications is declining for firms that narrow their scope over time

Testing mechanism (4): America specific effects (regulatory changes of American institutions): Not supported.

TABLE 13. INVESTMENT IN SCIENCE BY EUROPEAN FIRMS

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	*Flow of publications*				
	All	Non-missing sales	Public *vs.* private	Sample years >10	First pub< 1980
Time trend	-0.046**	-0.111**	-0.045**	-0.066**	-0.212**
	(0.011)	(0.030)	(0.011)	(0.015)	(0.050)
ln(*Sales*)		0.322**			
		(0.137)			
Time trend × *Dummy for pubilc*			-0.012		
			(0.024)		
Firm fixed-effects	Yes	Yes	Yes	Yes	Yes
R^2	0.724	0.676	0.724	0.722	0.719
Observations	38,018	15,135	38,018	11,451	2,999

- ❑ European firms display similar reductions in investment in science.
- ❑ From Column 1, in a 10-year period, publishing drops by 39% of sample average.
- ❑ From Column 5, from 1980 to 2007, publications dropped by 56%

Note: Match publications and patents to all European firms (Amadeus, private and public). 58k articles by 3,642 firms, and 210k patents (USPTO) by 10,053 firms. 31% of innovating firms (patenting or publish) publish at least once. Financial data is available only from 1997, not for all firms. R&D is never reported.

Conclusions

- Our results indicate that large firms are withdrawing from research
  - Large firms are investing less in research, and the stock market value of research is declining
  - Same patterns are reflected in acquisitions price: Managers are less willing to pay for scientific capability, and acquired entity reduces publication after acquisition
  - Also consistent with evidence in the literature on the increase in alliances and licensing, as well as qualitative evidence on the decline in corporate research
- Possible mechanism may be linked to cost-based competition and shrinking firms' scope, but not to a decline in the use of science or to American-specific effects
- But other possible explanations remain
  - Division of innovative labor

Conclusions (*cont'd*)

- Pessimistic interpretation: Private research is in decline
  - Established companies can no longer emulate firms such as DuPont, AT&T or Merck
  - Increased importance of public funding?
- Less pessimistic interpretation: Established firms source inventions from outside
  - Reallocation of research from large corporate labs to more efficient organizations
  - Even so, if acquirers will not pay for scientific research, startups might have to invest to convert their research commercially

Next steps

- Update the data for 2014.
  - Examine the effect of the 2008 financial crisis on research
  - Fall of the financial sector triggers more investment in research?
- Who benefits from corporate research (publications) and how those benefits change over time?
- Textual match between firm publications and their patents.
  - Examine how commercialization strategies of science have changed over time