Firm Size and Innovation: Evidence from European Panel Data

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MOTIVATION

Whether firm size affects corporate investment and innovation is an important theoretical and empirical question

Several theories (Schumpeter, 1942, Galbraith, 1952, Arrow, 1962, Gilbert and Newberry, 1982,…)

Considerable body of empirical research (see, e.g., the survey by Cohen and Levin, 1989)

But few robust stylized facts:

1. Results are often inconclusive

2. Attention is typically restricted to the 500 or 1000 largest firms in the manufacturing sector

3. Limited empirical analysis of basic research-performance relationship (the basic research premium, Griliches, 1986)

OUR CONTRIBUTION

We develop a new and comprehensive firm-level dataset on patents and academic publications

Two key advantages:

1. Covers a wide distribution of firm size

    - About 10 percent of the innovating firms in our sample have less than 7 employees and less than $1 million in annual sales

2. Provides new systematic data on firm publications (that is, academic publications co-authored by employees of one of our firms)

    - Important as firm publications may be a useful proxy for basic research. Arguably, firms that conduct more basic research are more likely to publish than firms that have a stronger focus on applied research

    - By looking at multiple indicators of innovative activity, we provide a richer and more nuanced view on how firm size and innovation interact

KEY RESULTS

1. Private firms contribute substantially to the advancement of basic scientific knowledge (~ 200k publications were matched to firms)

We then study how the performance-innovation relationship varies with firm size. We find that:

2. The correlation of performance with applied research (patents) is stronger for small firms than for large firms

3. By contrast, the correlation of performance with basic research (academic publications) is stronger for large firms than for small firms

4. Evidence for the “basic research premium”, BUT only for very large firms

7. These results are robust to:

    - Looking at different measures of performance (TFP and growth)
    - Controlling for the quality of patents and academic publications
    - Restricting attention to different subsets of the size distribution

PRESENTATION OUTLINE

- Introduction
- Data
- Innovation-performance relationship and firm size
- Discussion of results
- Summary and future research

DATA - Amadeus, EPO, USPTO and Thomson.

1. **Patents (1979-2005)**
   - Matched patents from the EPO & USPTO to all European firms (~8 million names from Amadeus)
   - Over 15K firms with at least 1 patent between 1979- 2006
2. **Academic Publications (1970-2006)**
   - Matched academic articles published by firms
   - Thomson's ISI Web of Science: publications in "hard" sciences journals
   - ~200k firm publications, many in leading journals (e.g., "Cell", "Journal of the American Medical Association")
3. **Accounting (1995-2005):**
   - Amadeus – 4M private & public European firms (inc. historical data)
   - Detailed accounting information over a wide size distribution (~10 percent of the innovating firms have less than 7 employees and less than $1 million in annual sales)

AN EXAMPLE OF A FIRM PUBLICATION

Clinical study to assess the immunogenicity and safety of a recombinant Pseudomonas aeruginosa OprF-OprI vaccine in burn patients

Full Text | Find it Oxford | Holdings | Go | Print | E-mail | Add to Marked List | Save to EndNote Web | more options

Author(s): Mansouri E, Blome-Eberwein S, Gabelsberger J, Germann G, von Specht BU

Source: FEMS IMMUNOLOGY AND MEDICAL MICROBIOLOGY **Volume:** 37 **Issue:** 2-3 **Pages:** 161-166 **Published:** JUL 15 2003

Times Cited: 6 **References:** 28

Abstract: In a recent clinical trial we evaluated the safety and immunogenicity of a recombinant OprF-OprI vaccine consisting of the mature outer membrane protein I (OprI) and amino acids 190-342 of OprF of Pseudomonas aeruginosa in burn patients and compared the elicited antibodies with antibodies against tetanus as response to a simultaneous immunization given on the day of admission. Safety and immunogenicity of the vaccine had been tested before in healthy human volunteers as published in 1999. In this first clinical trial we immunized eight burn patients suffering from second or third degree burns involving between 35% and 55% of the body surface three times with 100 mug of the OprF-OprI vaccine. The vaccine was found to be very well tolerated. The patients did not show any serious side effects - and in particular no activation of the mediator cascade was observed. None of the subjects showed systemic P. aeruginosa infections during or after the treatment of their burns. The serological tests (ELISA) for detection of antibodies against P. aeruginosa and tetanus toxoid showed seroconversion for seven patients after inoculation. The data indicate that OprF-OprI can be a useful vaccine in the therapeutic management of burn injuries. (C) 2003 Federation of European Microbiological Societies. Published by Elsevier Science B.V. All rights reserved.

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KeyWords Plus: MEMBRANE PROTEIN-F; HETEROLOGOUS IMMUNOTYPE STRAINS; B-CELL EPITOPES; PROTECTIVE VACCINE; SYNTHETIC PEPTIDES; PORIN PREPARATION; INFECTION; IMMUNIZATION; ANTIBODIES; MODEL

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MATCHING ADDRESS FIELD TO AMADEUS

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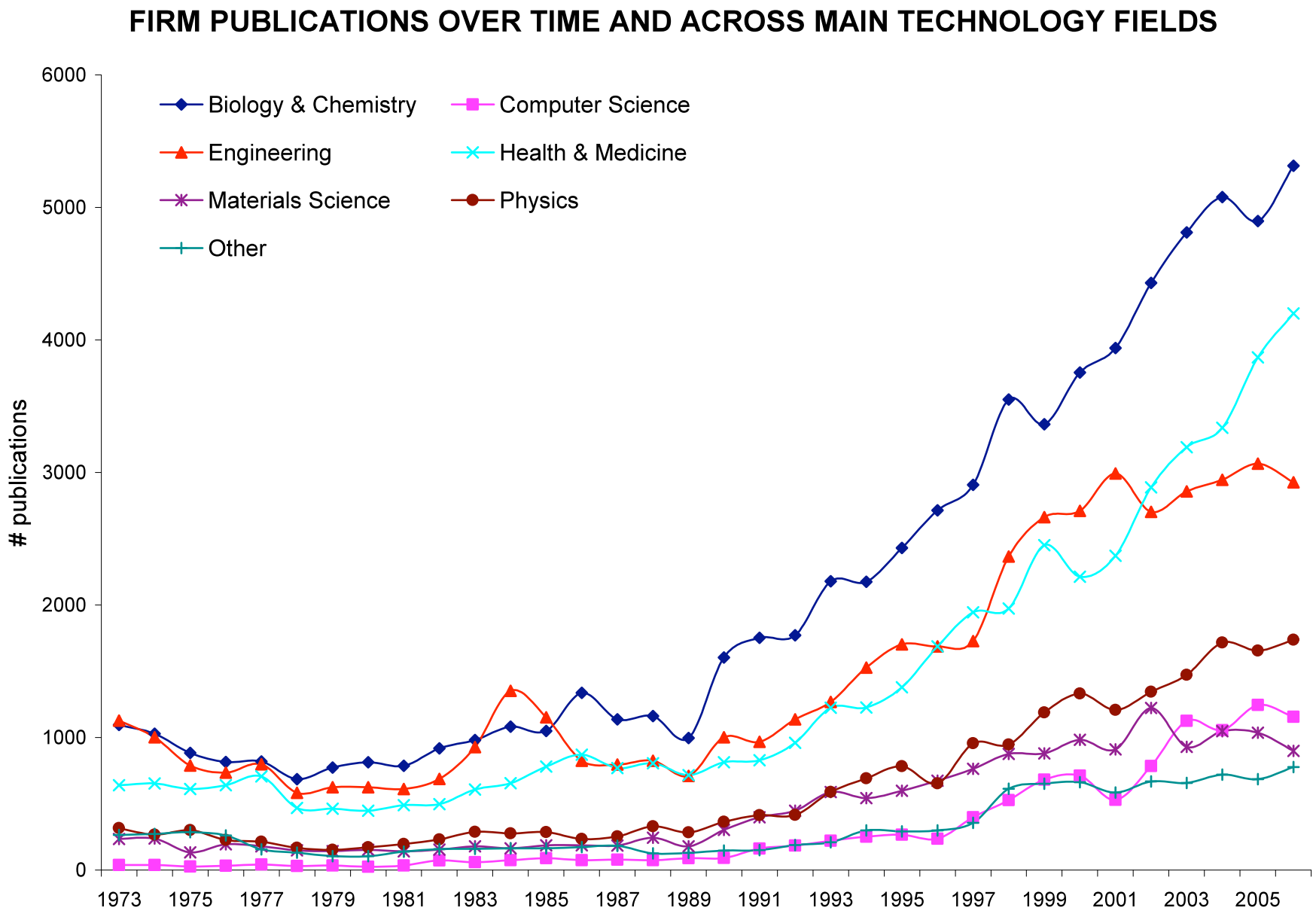
FIRM PUBLICATIONS ACROSS FIELDS AND TIME



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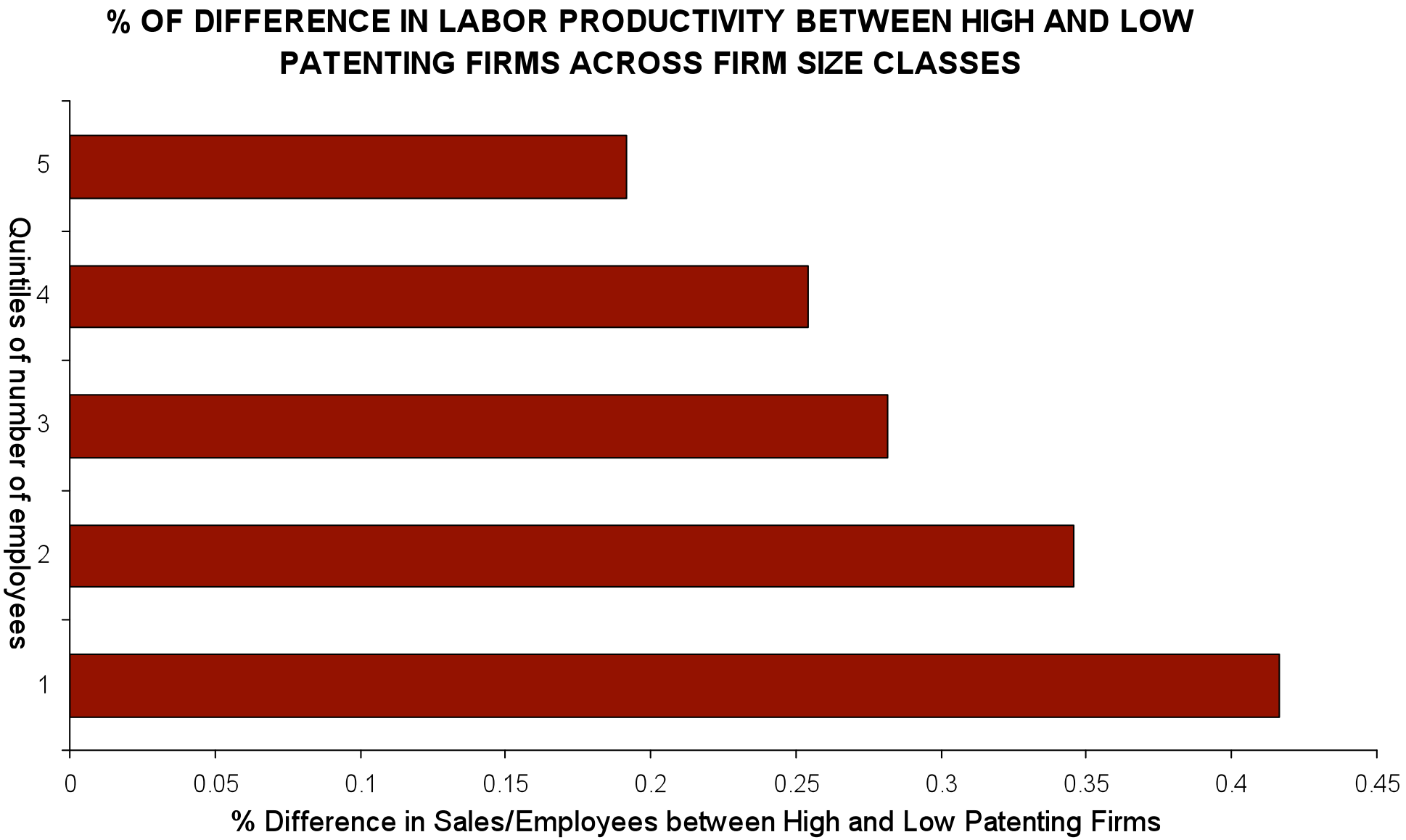
SUMMARY STATISTICS FOR MAIN FIRM CHARACTERISTICS

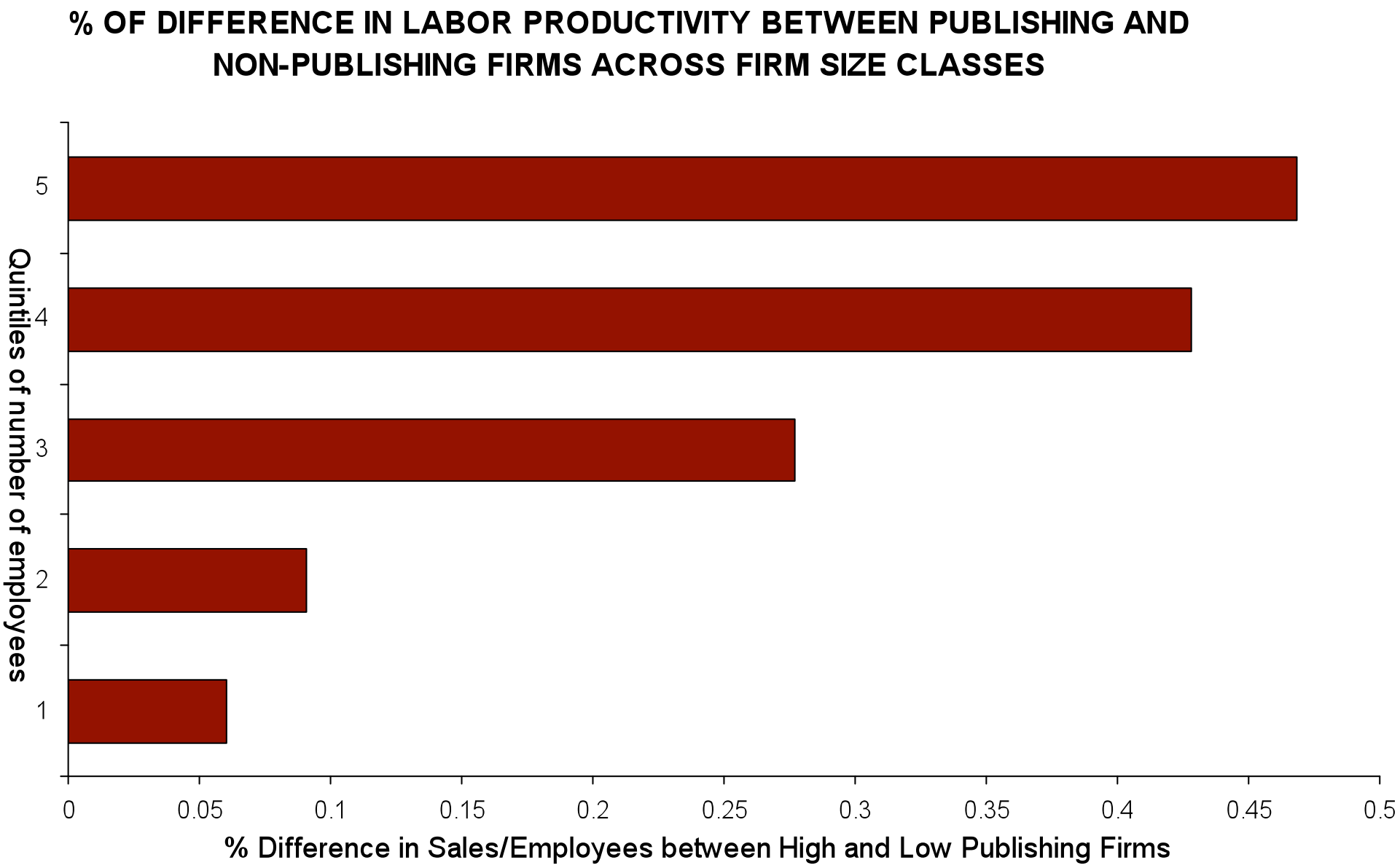
- The estimation sample includes all firms that have either at least one patent between 1979 and 2004, or publish at least one article (in “hard sciences”) between 1970 and 2004

					Distribution		
Variable	# firms	# Obs	Mean	Std. Dev.	10st	50th	90th
Patents stock	13,087	58,445	6.8	51.5	0.1	0.9	10.9
Publications Stock	6,516	27,657	3.9	28.7	0	0.5	5.7
Sales (`000)	14,251	60,926	435,158	3,933,684	921	21,153	379,236
Employess	17,047	74,321	1,370	10,458	7	126	1,423
Age	16,659	73,876	28	26	5	19	65
Employment growth	17,047	74,321	0.02	0.44	-0.04	0	0.22
Sales Growth	13,741	58,993	0.09	0.53	-0.06	0.09	0.42
Capital (`000)	15,094	64,534	278,911	3,309,300	93	3,822	145,348
Cash flow (`000)	14,341	60,156	43,743	489,349	-523	971	30,371
Capital/Employee (`000)	13,997	61,305	619	30,196	6	37	212
Sales/Employee (`000)	13,088	57,404	263	309	74	176	502

PATENTS–PRODUCTIVITY RELATIONSHIP ACROSS SIZE CLASSES



PUBLICATIONS–PRODUCTIVITY RELATIONSHIP ACROSS SIZE CLASSES



INNOVATION–PRODUCTIVITY RELATIONSHIP AND FIRM SIZE

DEPENDENT VARIABLE: LOG(SALES)

	(1)	(2)	(3)	(4)	(5)	(6)
# Employees$_{t-1}$:	All	All	≤ median (110)	> median (110)	> 75th (435)	> 90th (1600)
log(Employment)$_{t-1}$	0.806***	0.813***	0.837***	0.731***	0.667***	0.626***
	(0.009)	(0.009)	(0.014)	(0.016)	(0.027)	(0.045)
log(Capital)$_{t-1}$	0.186***	0.183***	0.158***	0.237***	0.276***	0.277***
	(0.007)	(0.007)	(0.009)	(0.012)	(0.021)	(0.038)
log(Patents stock)$_{t-1}$	0.052***	0.168***	0.085***	0.044***	0.029***	0.029**
	(0.009)	(0.025)	(0.025)	(0.009)	(0.009)	(0.013)
log(Publications stock)$_{t-1}$	0.030**	-0.037	-0.016	0.048***	0.055***	0.083***
	(0.015)	(0.036)	(0.034)	(0.015)	(0.016)	(0.018)
log(Patents stock)$_{t-1}$ × log(Employment)$_{t-1}$		-0.016***				
		(0.003)				
log(Publications stock)$_{t-1}$ × log(Employment)$_{t-1}$		0.012***				
		(0.004)				

Notes: All regressions include complete sets of country, industry (3-digit SIC) and year dummies. The sample covers the period 1995-2004 and includes all Amadeus firms with at least one patent or one academic publication in "hard" science journals between 1978 and 2005. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. *** significant at 1%.

INNOVATION–GROWTH RELATIONSHIP AND FIRM SIZE

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	log(Employment$_t$/Employment$_{t-1}$)			log(Sales$_t$/Sales$_{t-1}$)		
log(Employment)$_{t-1}$	-0.044***	-0.040***	-0.041***	-0.024***	-0.021***	-0.022***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
log(Patents stock)$_{t-1}$	0.032***	0.078***	0.081***	0.022***	0.060***	0.064***
	(0.003)	(0.011)	(0.012)	(0.003)	(0.010)	(0.011)
log(Publications stock)$_{t-1}$	0.021***	0.026***	0.008	0.009*	0.013**	-0.013
	(0.005)	(0.005)	(0.013)	(0.005)	(0.005)	(0.013)
log(Patents stock)$_{t-1}$ × log(Employment)$_{t-1}$		-0.007***	-0.007***		-0.005***	-0.006***
		(0.001)	(0.001)		(0.001)	(0.001)
log(Publications stock)$_{t-1}$ × log(Employment)$_{t-1}$			0.003**			0.004***
			(0.001)			(0.001)
R^2	0.043	0.045	0.045	0.037	0.038	0.039
Observations	63,164	63,164	63,164	57,779	57,779	57,779
Number of firms	14,195	14,195	14,195	13,354	13,354	13,354

Notes: All regressions include complete sets of country, industry (3-digit SIC) and year dummies. The sample covers the period 1995-2004 and includes all Amadeus firms with at least one patent or one academic publication in "hard" science journals between 1978 and 2005. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. ** significant at 5%; *** significant at 1%.

WHY AMAPAT? US COMPUSTAT AND LARGE EUROPEAN FIRMS

DEPENDENT VARIABLE: LOG(SALES)						
	(1)	(2)	(3)	(4)	(5)	(6)
	US Compustat firms			Large European firms (> 1600 Employees)		
$\log(\text{Employment})_{t-1}$	0.676***	0.674***	0.671***	0.607***	0.621***	0.622***
	(0.028)	(0.029)	(0.029)	(0.050)	(0.054)	(0.054)
$\log(\text{Capital})_{t-1}$	0.314***	0.314***	0.315***	0.289***	0.289***	0.289***
	(0.025)	(0.025)	(0.025)	(0.042)	(0.042)	(0.042)
$\log(\text{Patents stock})_{t-1}$	-0.010	-0.022	0.008	0.030**	0.087	0.084
	(0.007)	(0.024)	(0.031)	(0.014)	(0.058)	(0.063)
$\log(\text{Publications stock})_{t-1}$	0.022***	0.021**	-0.043	0.081***	0.083***	0.096
	(0.008)	(0.009)	(0.049)	(0.019)	(0.019)	(0.100)
$\log(\text{Patents stock})_{t-1}$ × $\log(\text{Employment})_{t-1}$		0.001	-0.002		-0.006	-0.007
		(0.002)	(0.003)		(0.006)	(0.006)
$\log(\text{Publications stock})_{t-1}$ × $\log(\text{Employment})_{t-1}$			0.007			-0.001
			(0.005)			(0.010)
R^2	0.951	0.951	0.951	0.854	0.854	0.854
Observations	21,416	21,416	21,416	4,793	4,793	4,793
Number of firms	1,502	1,502	1,502	1,020	1,020	1,020

Notes: All regressions include complete sets of country, industry (3-digit SIC) and year dummies. The sample covers the period 1995-2004 for European firms and includes all Amadeus firms with at least one patent or one academic publication in "hard" science journals between 1978 and 2005. For the US, the sample covers the period 1980-2001 and includes only firms with at least one patent or publication over the period 1969-2005. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. ** significant at 5%; *** significant at 1%.

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DISCUSSION OF RESULTS

Why should basic and applied research exhibit such markedly different patterns?

Internal capital markets

- A key benefit of having an active internal capital markets (usually correlated with firm size) is headquarters' superior ability to reallocate scarce resources across projects, relative to external investors [Stein (1997)]
- Large firms should therefore perform better than small firms when the amount of asymmetric information between headquarters and external investors is large (e.g., when the variance of the project is large)
- Furthermore, headquarters owns and controls the project in which it invests and therefore has stronger incentives to improve its quality [Gertner, Scharfstein and Stein (1994)]
- To the extent that basic research is more uncertain, harder to evaluate and more sensitive to monitoring than applied research, this yields the pattern of results that we observe in the data

DISCUSSION OF RESULTS (CONT'D)

2. Financial Constraints

- Basic research is often more risky than applied research and its returns accrue further in the future
- Plausible that financial constraints are more severe in basic research. Firms will invest first in applied research and only then in basic research

3. Nelson's (1959) diversification hypothesis

- Nelson argued that a broad technological base may be necessary to find use for the uncertain outcome of an R&D project
- This is especially important when research is close to the basic-science end of the spectrum

SUMMARY

- We develop a novel firm-level database on patents and academic publications, covering a wide distribution of firm size
- Key findings:
  1. Private firms contribute substantially to the advancement of basic scientific knowledge (~ 200k publications were matched to firms)
  2. The correlation of performance with applied research (patents) is stronger for small firms than for large firms
  3. By contrast, the correlation of performance with basic research (academic publications) is stronger for large firms than small firms
  4. Evidence for the “basic research premium”, but only for very large firms
- We discuss possible explanations for our empirical findings, including internal capital markets, cash constraints and diversification

FUTURE RESEARCH

- Main limitation of our analysis is that it only highlights correlations, without showing causality. Future work should try to disentangled the channels through which the innovation-performance relationship varies with firm size
- A natural place to start would be the rich cross-industry and cross-country variation in our data
- For instance, we could test for financial constraints by using different measures of industry external dependence (Rajan-Zingales), cash flow, age, etc
- The determinants of open science: incentives for scientists (Stern, 2004) and signaling (Hall and Ziedonis, 2001)