

The Burden of Knowledge and the
'Death of the Renaissance Man': Is
Innovation Getting Harder?

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1 Overview

- What happens if innovators face an increasing educational burden as technology progresses?
- Implications for long-run growth
- Testable implications for innovators:
 - Educational attainment
 - Specialization
 - Teamwork
- Time and cross-sectional dimensions
- Empirical evidence using microdata

--◆-- US R&D Workers (Left Axis) --■-- Real US R&D Expenditures (Left Axis) --- US Private Sector MFP growth (Right Axis)

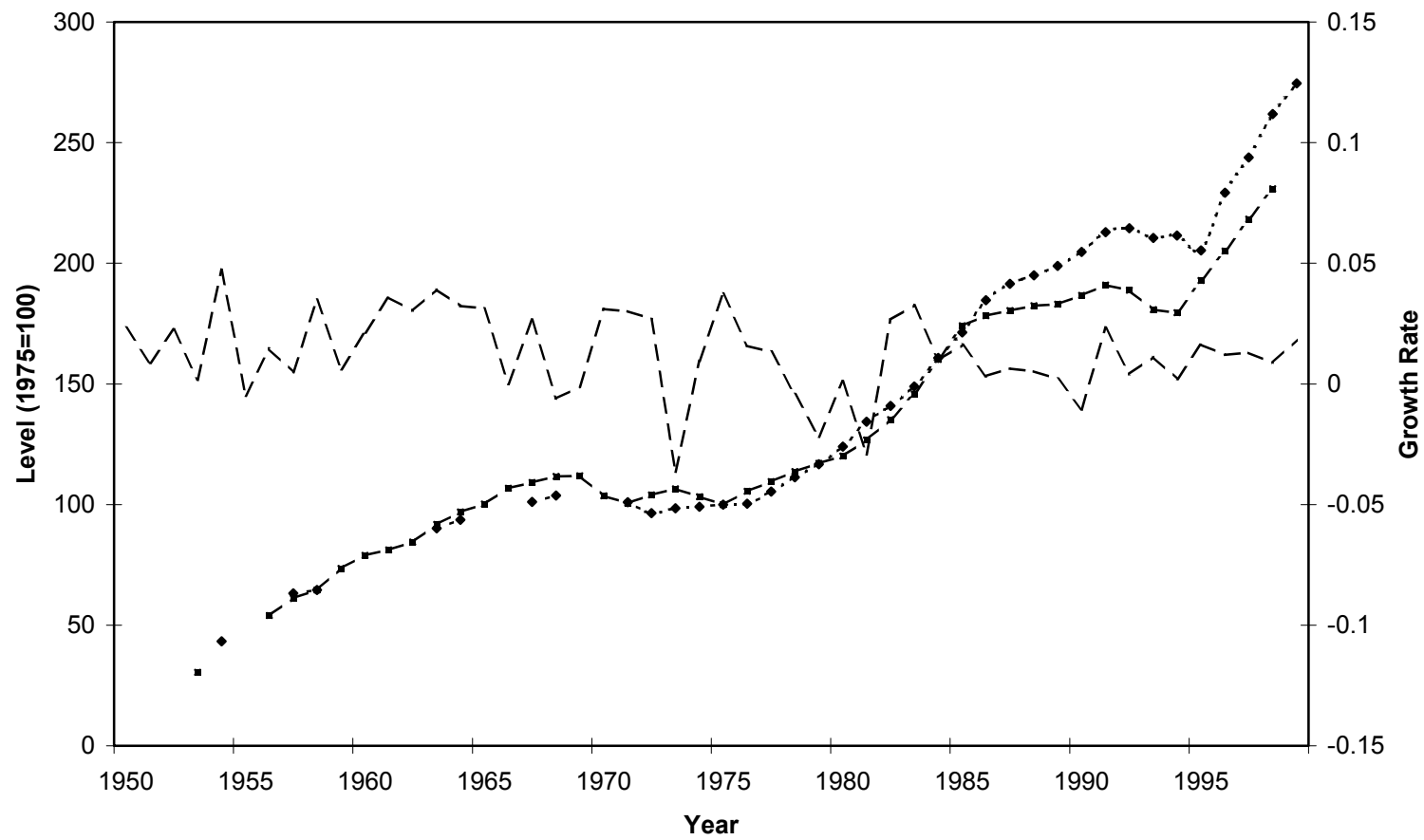
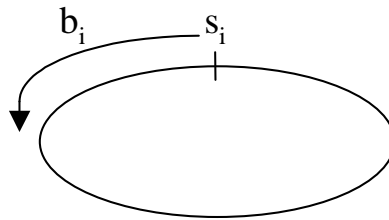


Figure 2.1: Rising Research Intensity, Flat Productivity Growth

2 The Model

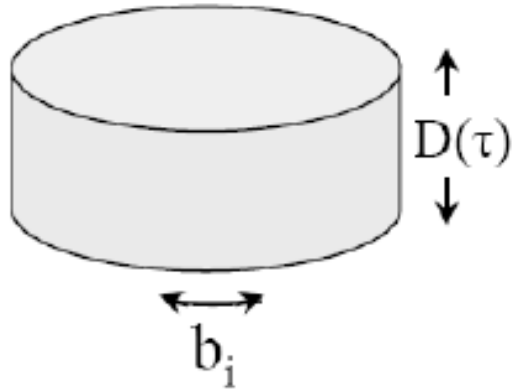
- There is a continuum of fields of knowledge, arranged around a unit circle.



The circle of knowledge

- If one chooses to become an innovator, one must make two additional decisions:
 - (1) Where on the circle to locate oneself (s_i)
 - (2) How broadly to educate oneself (b_i)
- At a point in time, the depth of knowledge at each point s on the circle is $D(t)$.

- An innovator will acquire an amount of knowledge: $b_i D(\tau)$



- Tradeoff:
 - More education costs more to acquire
 - More education makes innovator more productive
- Evolution of tradeoff:
 - Distance to the frontier, $D(t)$, changes
 - Value of knowledge changes

2.1 Steady-state growth

- Ceteris paribus, the greater the rate at which knowledge accumulates, the lower the growth rate. Magnitude of effect depends on importance of broad expertise to innovator productivity.
- Increasing value of new knowledge can offset rising burden of knowledge, preserving steady-state growth
- Depending on parameter values, increasing R&D effort produces either (i) explosive growth, or (ii) becomes a necessary condition for positive steady-state growth.
 - Given that growth is not exploding, model suggests that, without increasing R&D effort, growth will eventually stop.
- Is there a rising burden of knowledge?

2.2 Testable Predictions

- Time series
 - Educational attainment increasing
 - Specialization increasing only if distance to knowledge frontier increasing substantially
 - Team size is increasing if specialization is increasing.
- Cross section (extended model)
 - Greater depth of knowledge within a field => greater specialization, greater teamwork in that field
 - But educational attainment is invariant across fields!

3 Evidence

3.1 Data

- Hall, Jaffe, Tratjenberg (2001) data set
 - All USPTO utility patents, 1975-2000 (2.1 million observations)
 - Technological category of patent, citations, etc
 - Name and address of all inventors listed with a patent
- Age Data: www.AnyBirthday.com
 - Subset of HJT 2001 for which inventors' birth dates were found using www.AnyBirthday.com
 - Produces ages for 56,000 inventors.

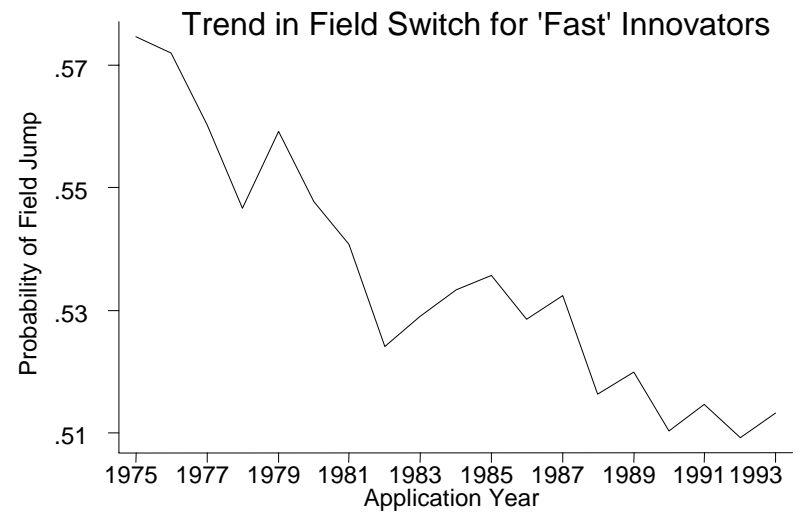
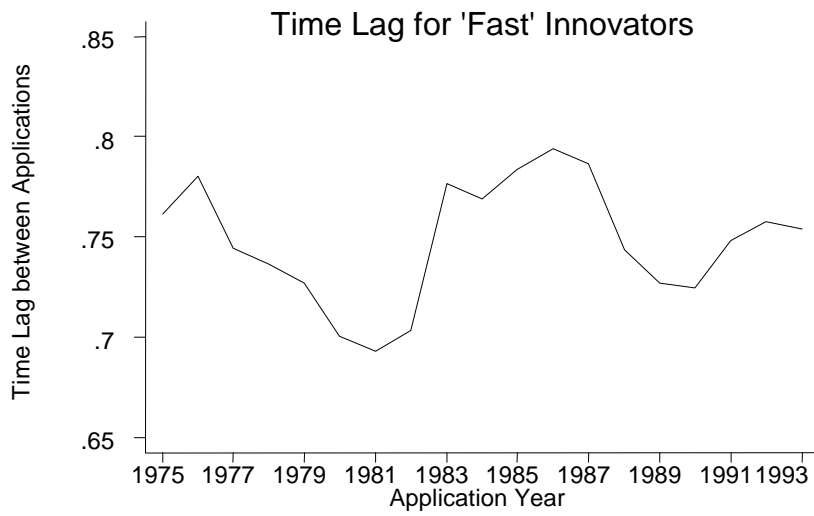
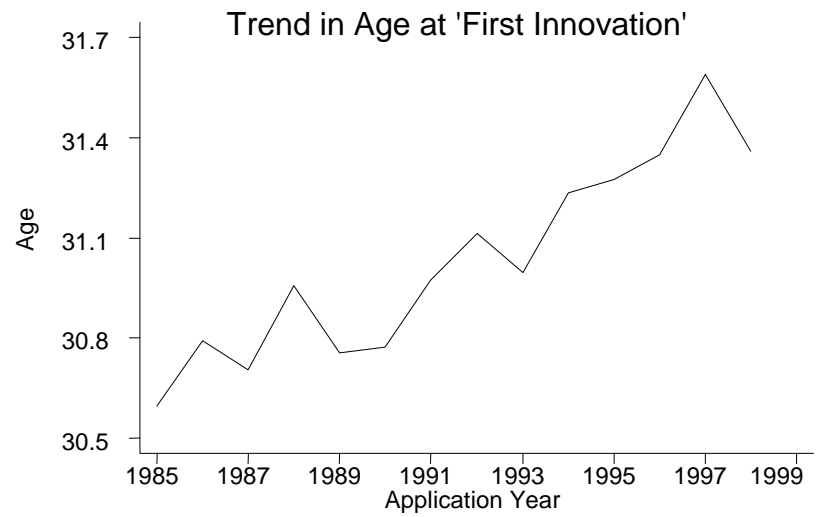
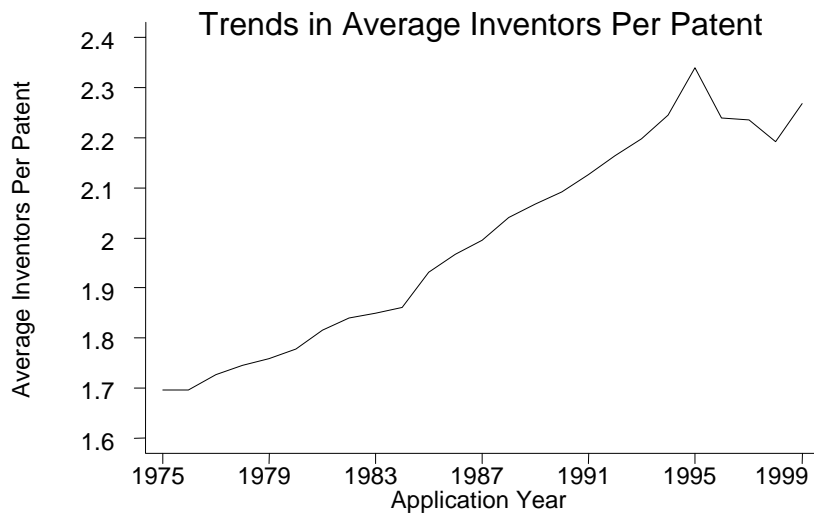


Figure 1: Basic Time Trends

3.2 Other Evidence

- Age
 - Age at which Nobel Prize winning research and great technological inventions is performed rises by 6 years over 20th Century, with large drop in presence of great inventions early in life-cycle. (Jones 2005)
 - Lengthening doctorates, rise of post-doctorates (Jones 2005, NRC 1990, Tilghman et al, 1998)
- Teamwork in sciences
 - Steep upward trends in journal coauthorship across all scientific fields, 1981-1999 (Adams, 2004)
 - Numerous field-specific studies show rising coauthorship trends going back as far as 1900

4 Conclusions

- Model provides parsimonious explanation for a range of descriptive evidence.
- Increasing specialization and increasing teamwork despite increased educational attainment are consistent with rising burden of knowledge.
- A rising burden of knowledge has negative implications for long-run growth.

Table 1: Age Trends among Great Innovators

	Dependent Variable: Age at Great Achievement	
	Nobel Prize Winners	Great Inventors
Year of Great Achievement (in 100's)	5.83 ^{***} (1.37)	4.86 ^{**} (2.31)
Number of observations	544	286
Time span	1873-1998	1900-91
Average age	38.6	39.0
R ²	0.032	0.016

NOTES:

(i) This table borrows from Jones (2004). Age trends are measured in years per century. Standard errors are given in parentheses.

(ii) Nobel Prize winners include all winners in Physics, Chemistry, Medicine, and Economics. Great inventors are taken from technological almanacs listing the great inventions of the 20th century.

** Indicates 95% confidence level. *** Indicates 99% confidence level.

Table 2: Trends in Inventors per Patent

		Dependent Variable: Inventors per Patent						
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Application Year		.0293 (.0001)	.0261 (.0001)	.0262 (.0001)	.0251 (.0001)	.0244 (.0002)	.0306 (.0002)	.0180 (.0003)
Foreign Patent		--	.444 (.002)	.416 (.002)	.141 (.004)	.146 (.004)	US Only	Foreign Only
Technological Field Controls	Broad	--	Yes	--	--	--	--	--
	Narrow	--	--	Yes	Yes	Yes	Yes	Yes
Assignee Code		--	--	--	Yes	Yes	Yes	Yes
Number of Observations		2,016,377	2,016,377	2,016,377	2,016,377	1,506,956	1,123,310	893,067
Period		1975-1999	1975-1999	1975-1999	1975-1999	1975-1996	1975-1999	1975-1999
Mean of Dependent Variable		2.03	2.03	2.03	2.03	1.97	1.82	2.29
Per-decade Trend as % of Period Mean		14.4%	12.9%	12.9%	12.4%	12.4%	16.8%	7.9%
R ²		.02	.08	.10	.12	.13	.12	.10

Table 3: Trends in Age at First Innovation

		Dependent Variable: Age at Application						
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Application Year		.0657 (.0095)	.0666 (.0095)	.0671 (.0095)	.0671 (.0099)	.0687 (.0097)	.0530 (.0107)	.0584 (.0109)
Technological Field Controls	Broad	--	Yes	--	--	--	--	--
	Narrow	--	--	Yes	Yes	Yes	--	Yes
Assignee Code		--	--	--	Yes	Yes	--	Yes
Team Size		--	--	--	--	-.0630 (.0273)	--	-.0348 (.0306)

Number of observations		6,541	6,541	6,541	6,541	6,541	5,102	5,102
Period		1985- 1999	1985- 1999	1985- 1999	1985- 1999	1985- 1999	1985- 1999	1985- 1999
Age Range		25-35	25-35	25-35	25-35	25-35	23-33	23-33
Mean of Dependent Variable		31.0	31.0	31.0	31.0	31.0	29.3	29.3
Per-decade Trend as % of Period Mean		2.1%	2.1%	2.2%	2.2%	2.2%	1.8%	2.0%
R ²		.007	.010	.020	.020	.021	.005	.018

