Persistency and Uncertainty Across the Academic Career

APS 2012

American Physical Society, March Meeting, Boston USA

Alexander M. Petersen

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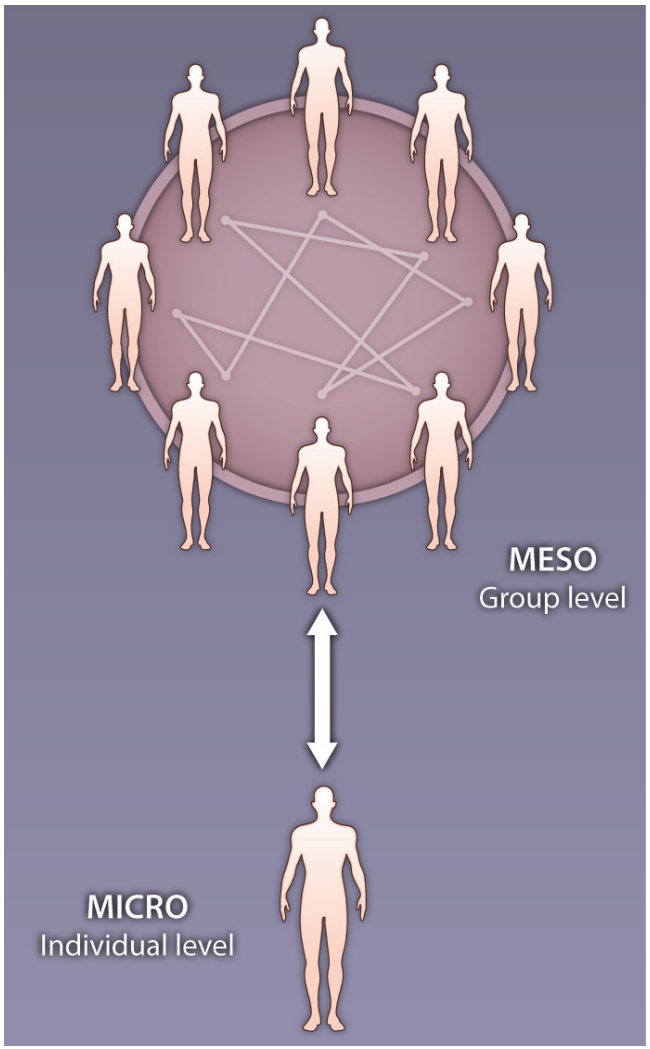
Gene Stanley (Boston University), Massimo Riccaboni (IMT Lucca),
Fabio Pammolli (IMT Lucca), and Sauro Succi (CNR Rome)

Sociophysics: scientists as interacting "atoms"



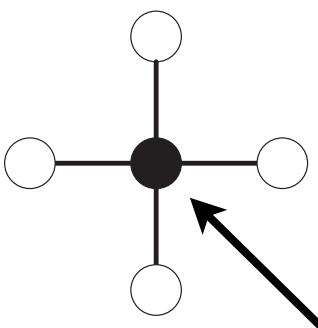
K. Börner, et al. A multi-level systems perspective for the science of team science. Sci. Transl. Med. 2, 49cm24 (2010).

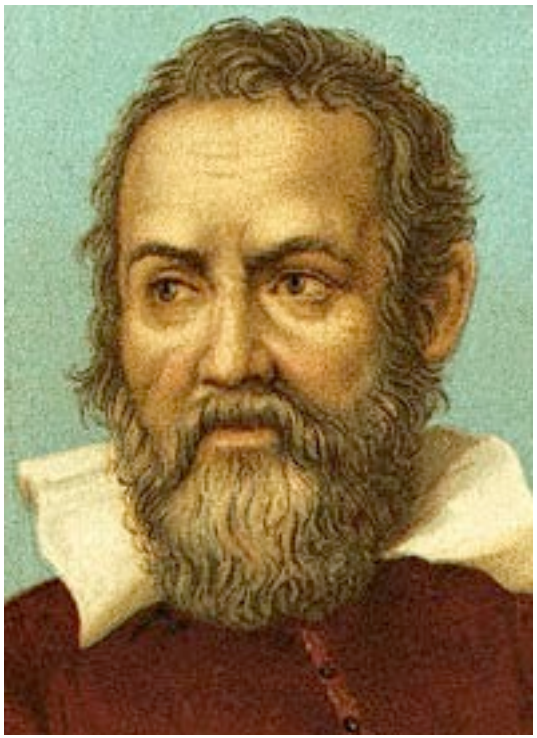
Interactions mediated by social "forces":

- Collaboration (attractive)
- Competition (repulsive)
- Knowledge (an "exchange particle")

Evolution of Science: "In the beginning..."

Association networks in the early scientific labor system





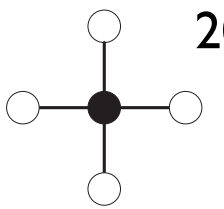
Galileo Galilei

Noble patron (king, wealthy aristocrat, Pope)

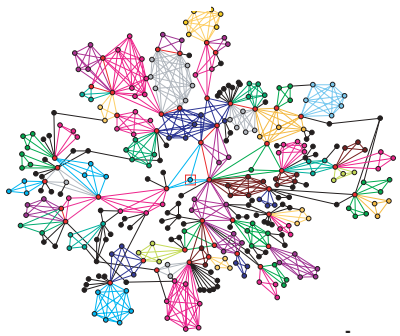
Paul A. David. *The Historical Origins of 'Open Science': An essay on patronage, reputation, and common agency contracting in the scientific revolution.* Capitalism and Society 3(2): Article 5 (2008).

Emerging trends in Science

- emergence of small-world collaboration networks with the increasing role of team-work in science



200+ years



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S. Wuchty, B. F. Jones, B. Uzzi. The increasing dominance of teams in production of knowledge. Science 316, 1036-9 (2007)

Chait RP, ed. The Questions of Tenure. (Harvard University Press, Cambridge USA, 2002).

- organizational shifts in the business structure of research universities
- shifts away from tenure towards shorter-term contracts + bottle neck in the number of tenure-track positions available
- redefining the role of teaching -vs- research faculty
- shifts in the competitive aspects of science, universities, and scientists: reputation tournaments in omnipresent competition arenas

CITATION IMPACT 9 DECEMBER 2011 VOL 334 **SCIENCE**

Saudi Universities Offer Cash In Exchange for Academic Prestige

Two Saudi institutions are aggressively acquiring the affiliations of overseas scientists with an eye to gaining visibility in research journals

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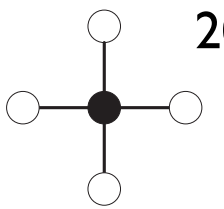

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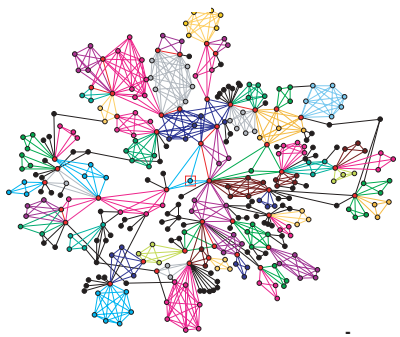

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... articles on the academic labor market

280 | NATURE | VOL 472 | 21 APRIL 2011

RETHINKING PHDS

Fix it, overhaul it or skip it completely — institutions and individuals are taking innovative approaches to postgraduate science training.

Chait RP, ed. The Questions of Tenure. (Harvard University Press, Cambridge USA, 2002).

ACADEMIA

The changing face of tenure

Although still highly desirable, tenure is not as prevalent as it was in some places — and that may not be a bad thing.

NOVEMBER 2010 | VOL 468 | NATURE | 123

NATURE | VOL 472 | 21 APRIL 2011

Issues & Perspectives

Academia's Crooked Money Trail

Science Careers From the journal *Science*

10.1126/science.caredit.a1200001

Undergraduates also carry an increasing share of the load, she adds: Their tuition, often paid with student loans, rises as more funds go to research. Their teachers, meanwhile, increasingly are cut-rate adjuncts rather than the famous professors the recruiting brochures boast about.

UNITED STATES

Mid-career crunch

Some senior scientists feel neglected by the National Institutes of Health's grant formula.

17 MARCH 2011 | VOL 471 | NATURE | 399

1. Empirical Facts

Persistency and Uncertainty

Can a quantitative picture of career dynamics shed light on the saying: *"publish or perish"* ?

Longitudinal career data:

Set A: 100 most-cited physicists, average h-index $\langle h \rangle = 61 \pm 21$

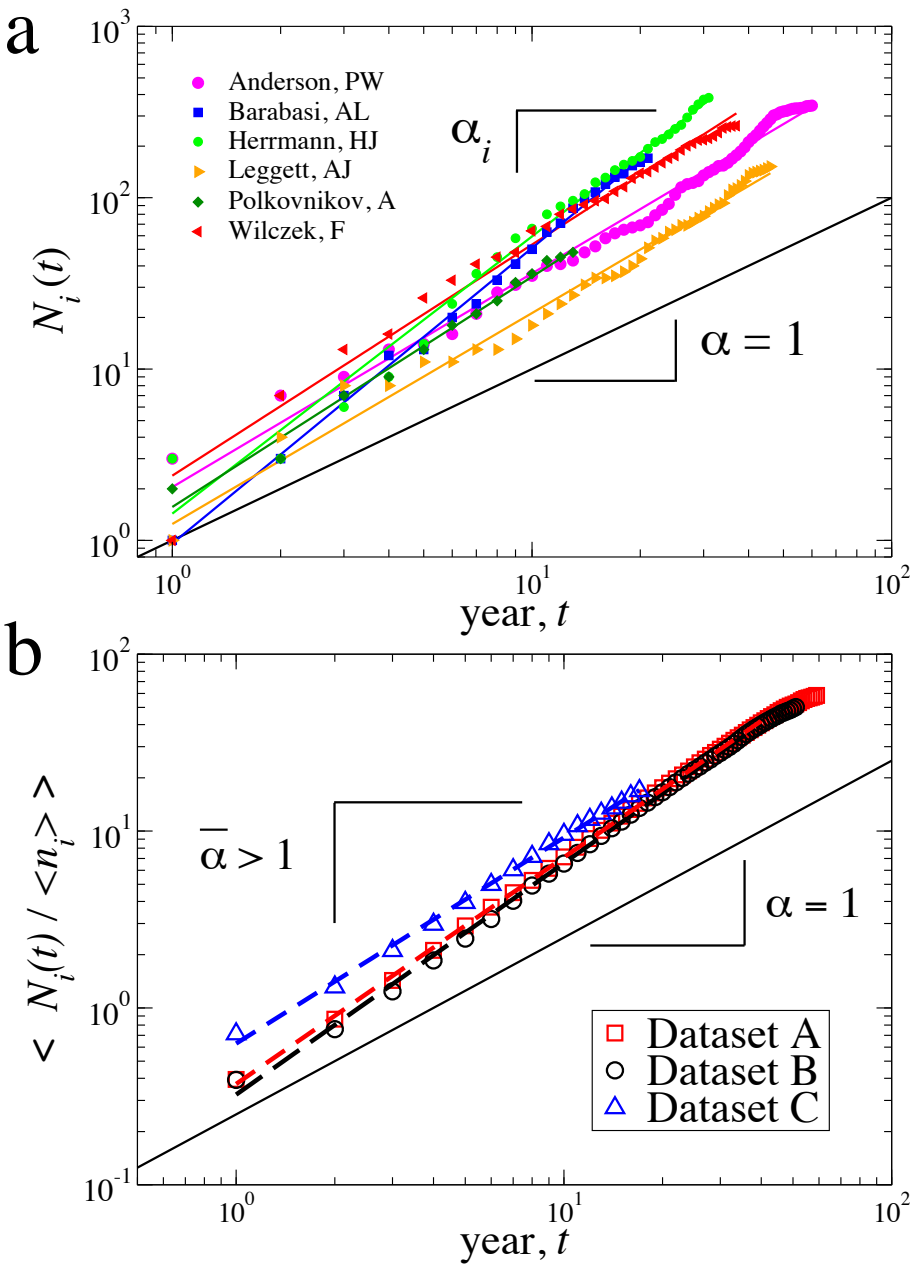
Set B: 100 additional highly-prolific physicists, $\langle h \rangle = 44 \pm 15$

Set C: 100 current assistant professors from 50 US physics depts., $\langle h \rangle = 15 \pm 7$

An analysis of the citation impact of these 300 scientists is available in:

A. M. Petersen, H. E. Stanley, S. Succi. "Statistical regularities in the rank-citation profile of scientists." Scientific Reports 1, 181 (2011).

The career trajectory in science: a tale of knowledge, collaboration, and reputation spillovers



Annual production of individual i

$n_i(t)$ number of publications in year t

Cumulative production, a proxy for career reputation

$$N_i(t) \equiv \sum_{t'=1}^{t} n_i(t')$$

$$\approx A_i t^{\alpha_i}$$ ← for many prolific careers!

[A] 100 "top" physicists ($\bar{\alpha} = 1.28 \pm 0.01$)

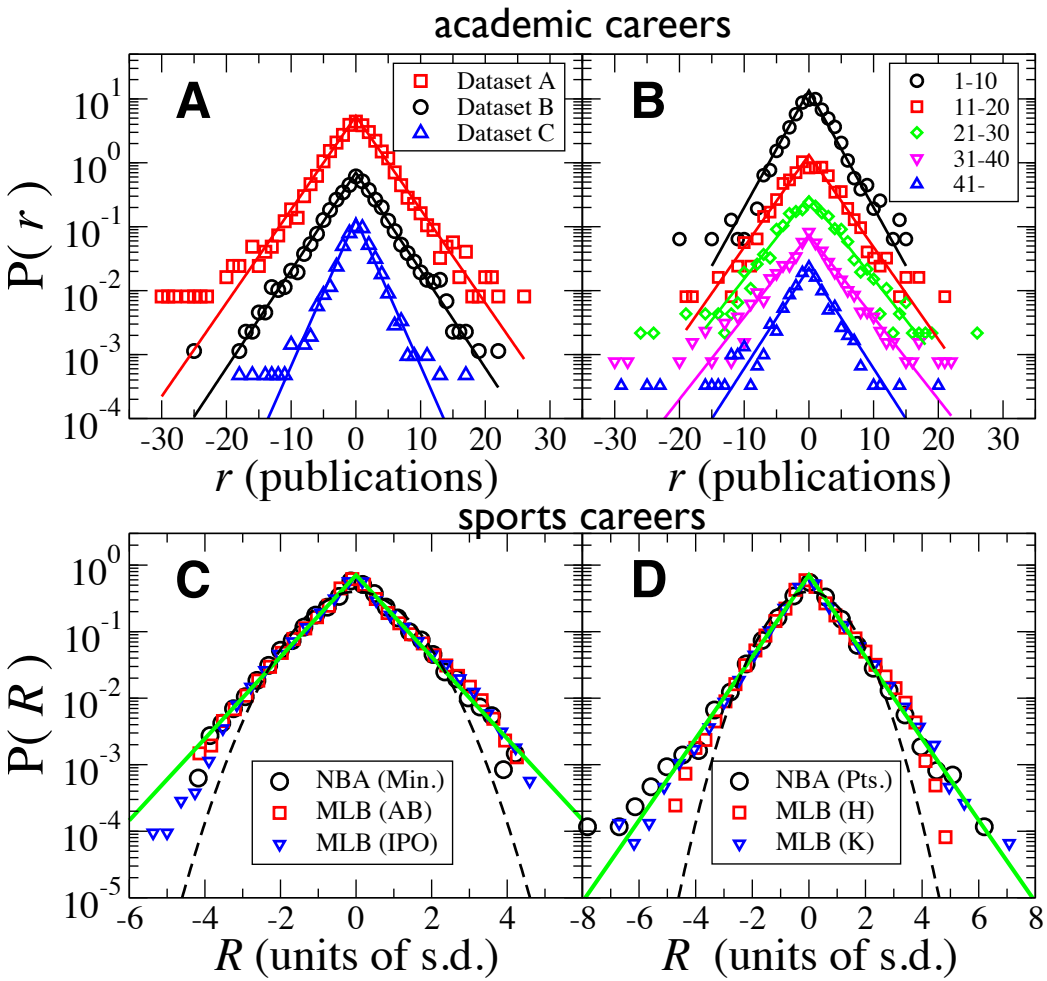
[B] 100 (prolific) control physicists ($\bar{\alpha} = 1.31 \pm 0.01$)

[C] 100 asst. professors (physics) ($\bar{\alpha} = 1.15 \pm 0.02$)

knowledge, reputation, and collaboration spillovers contribute to the increasing returns across the academic career

Cumulative advantage: Successful leaders become "attractors" of new opportunities

Productivity Growth Dynamics



Output change ("growth fluctuation"),

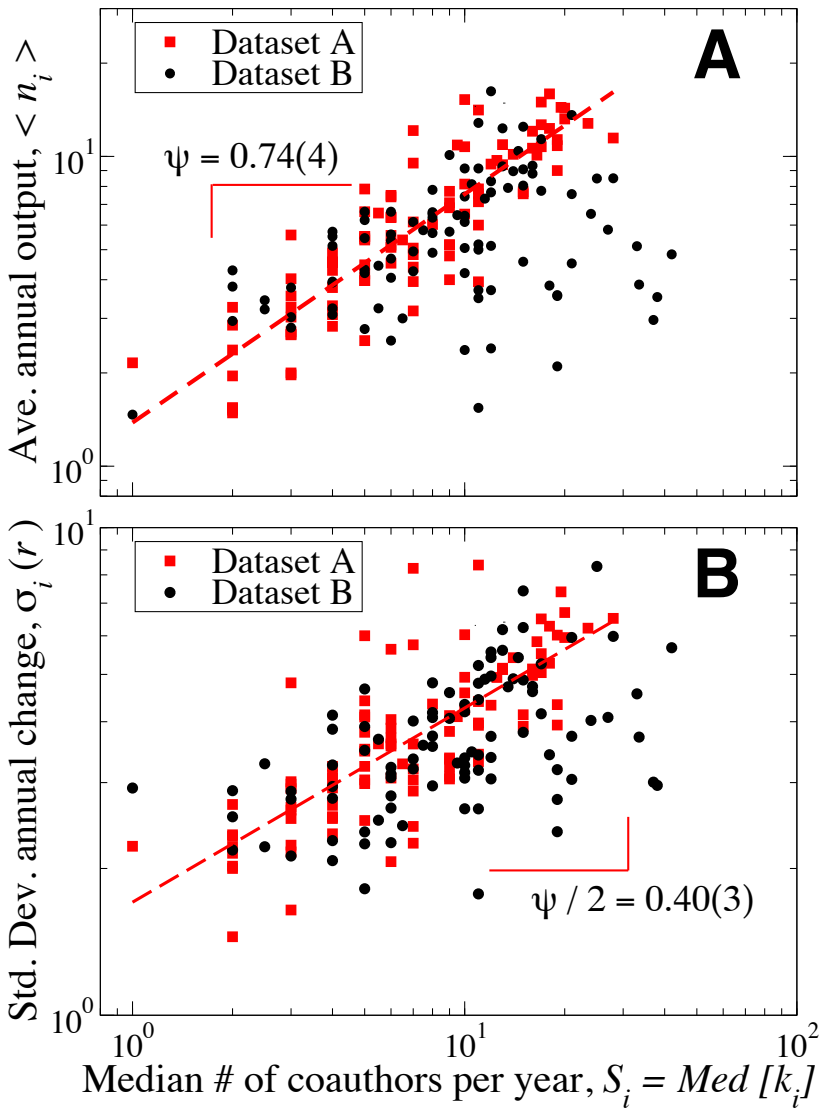
$$r_i(t) \equiv n_i(t) - n_i(t - \Delta t)$$

A proxy for career "uncertainty" ("risk" or "volatility"),

std. dev. $\sigma_i(r)$

The "tent-shaped" double-exponential distribution *P(r)* is leptokurtic, similar to what is observed for the growth patterns of diverse economic systems (country GDP, company market capitalization, etc.)

Collaboration Radius and team efficiency



Towards a micro-level production function:

$$\langle n_i \rangle \sim S_i^{\psi}$$

average number of publications per year

S_i is median number of coauthors per year

$$\sigma_i(r) \sim S_i^{\psi/2}$$

std. deviation of publication change

team efficiency parameter ψ

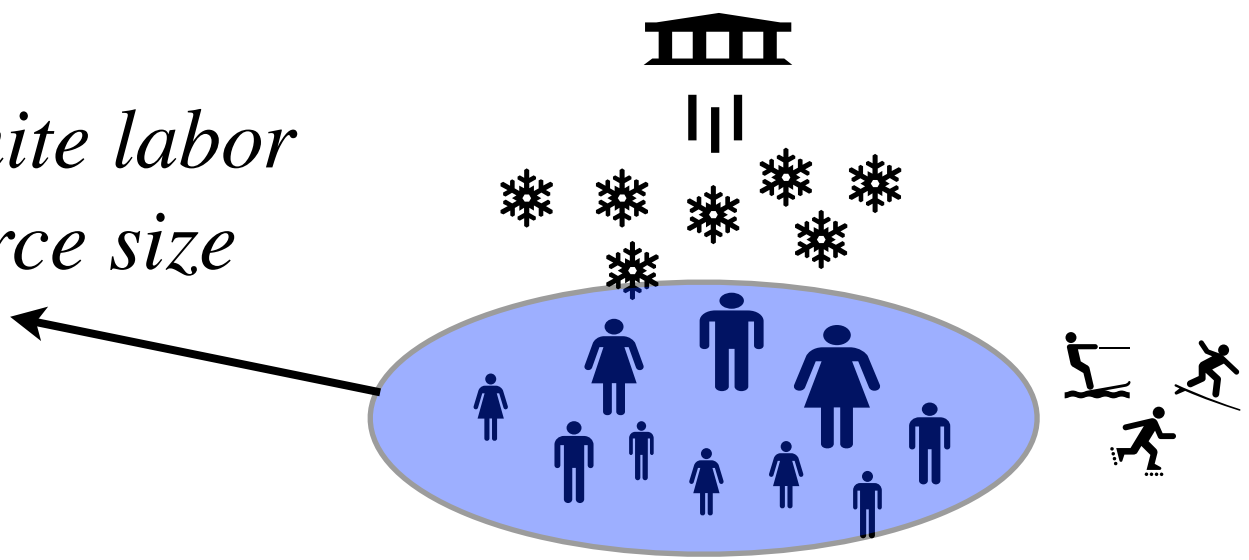
$$r_i(t) \equiv n_i(t) - n_i(t - \Delta t)$$

Not surprisingly, there is a decreasing marginal returns with increasing collaboration radius, likely attributable to team management inefficiencies

2. Preferential Capture Model

Stochastic competition model for the limited output / production opportunities

I = *finite labor force size*



Preferential Capture Model

1) For a given allocation period t, choose random individual to capture an output opportunity, so that

$$n_i(t) \rightarrow n_i(t)+1$$

the individual i is chosen with probability $\mathcal{P}_i(t)$ proportional to the quantity $w_i(t)$

$$\mathcal{P}_i(t) = \frac{w_i(t)}{\sum_{i=1}^{I} w_i(t)}$$

2) In each period, the capture rate of a given individual i is calculated by an appraisal of the achievement history

$$w_i(t) \equiv \sum_{\Delta t=1}^{t-1} n_i(t-\Delta t)e^{-c\Delta t}$$

3) The cohort of I competing individuals compete for a fixed number of opportunities $\propto I$ in each period over a lifespan spanning $t = 1 \ldots T$ periods.

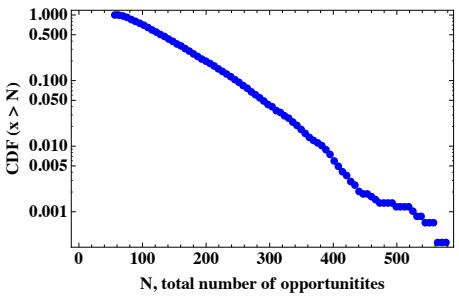
$c \rightarrow 0$: appraisal over all lifetime achievements (~ tenure system)

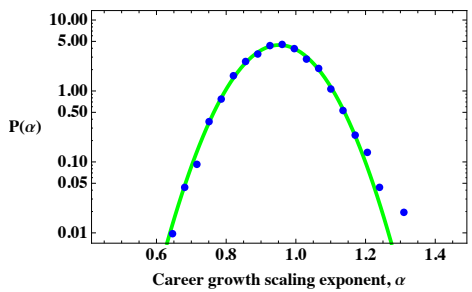
$c > 1$: appraisal over only recent achievements (short-term contract system)

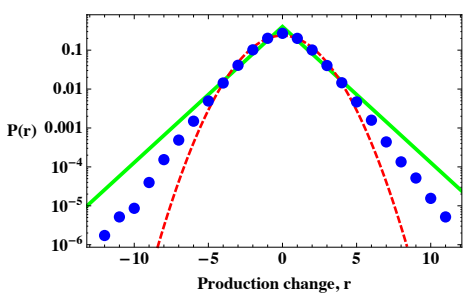
Results for the linear preferential capture model

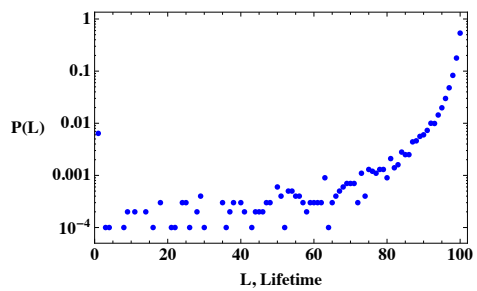
Distributions of 4 career measures:

c = 0 (long) *N(total)* α *Production change, r* *Longevity, L*

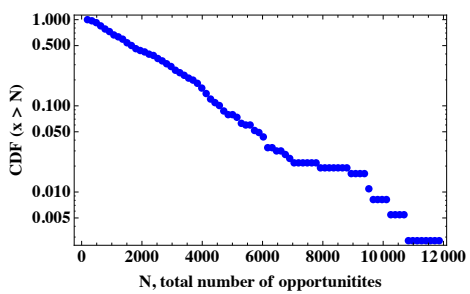


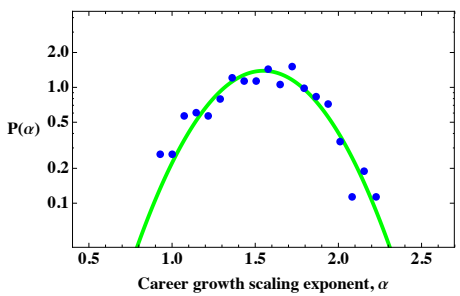


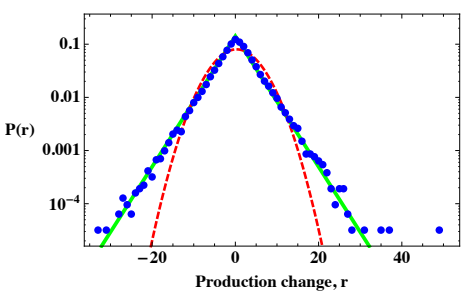


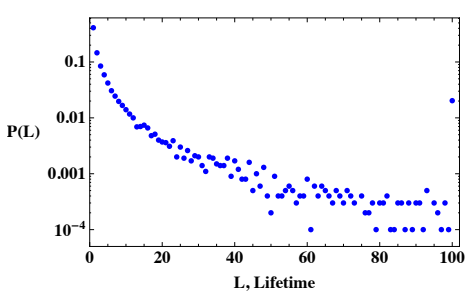


c = 10 (short)









appraisal system: $$w_i(t) \equiv \sum_{\Delta t=1}^{t-1} n_i(t-\Delta t)e^{-c\Delta t}$$

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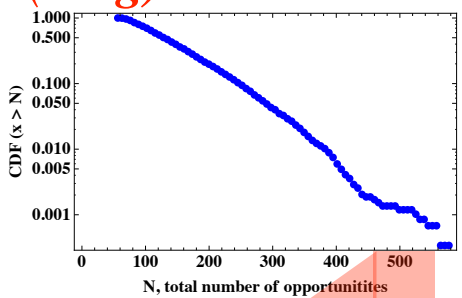
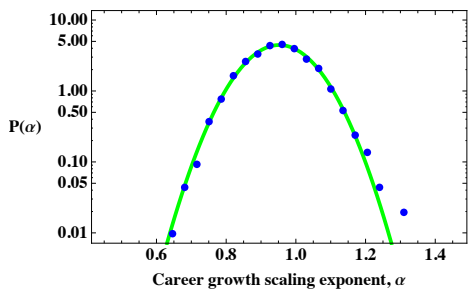
"Sudden death" careers and "kingpins"

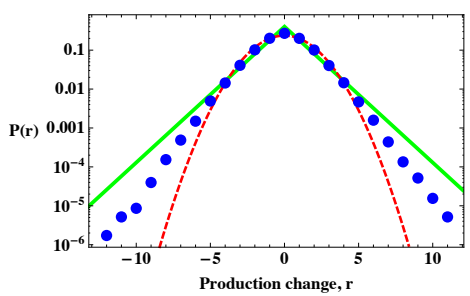
Distributions of 4 career measures:

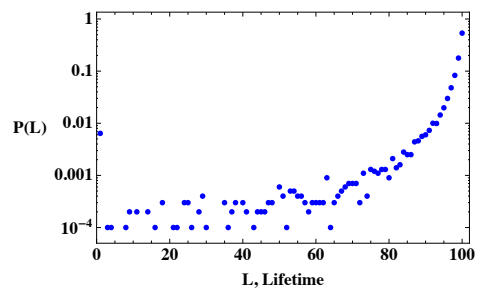
N(total) | α | *Production change, r* | *Longevity, L*

c = 0 (long)



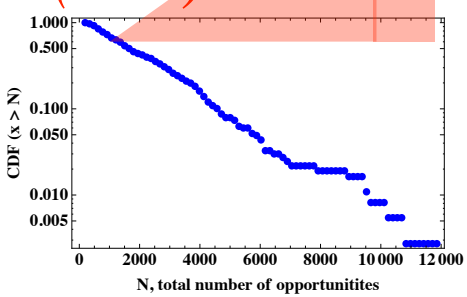


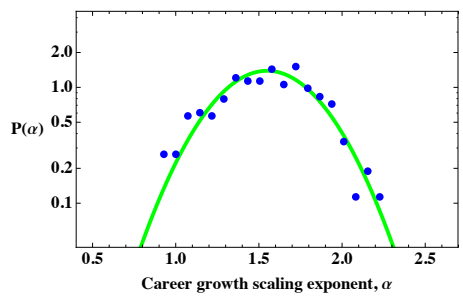


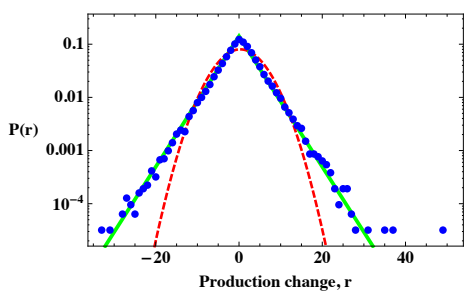


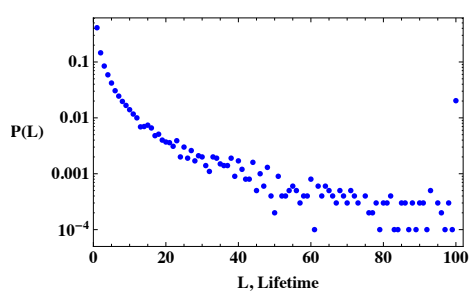
"heavy tails" emerge

c = 10 (short)









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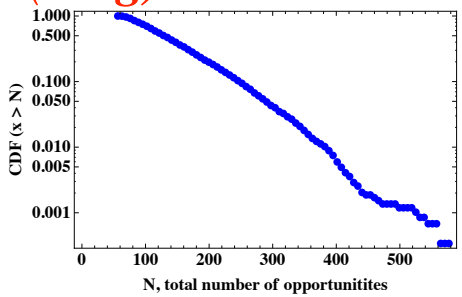
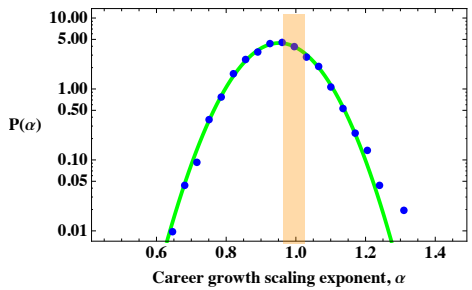
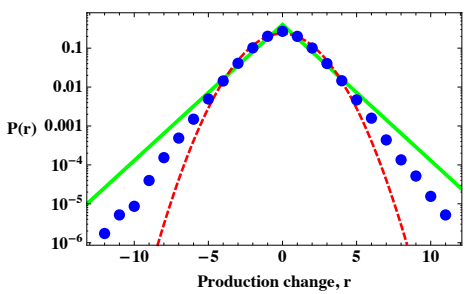


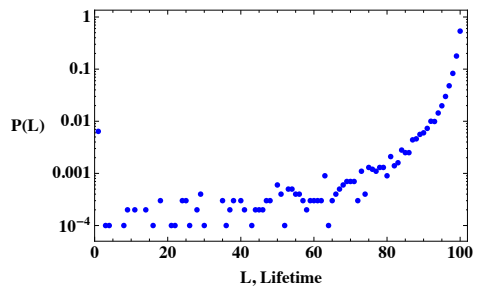
α



Production change, r

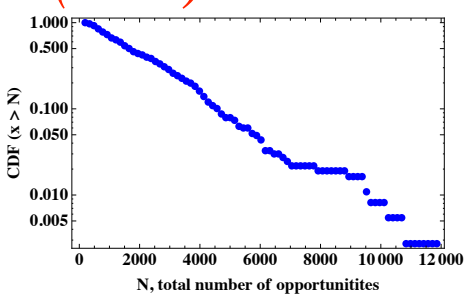


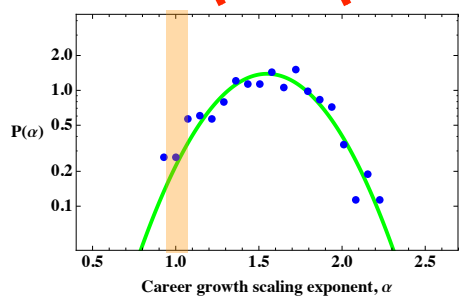
Longevity, L

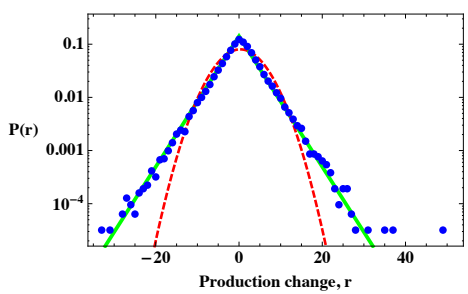


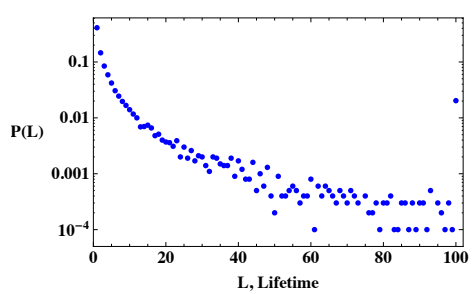
emergence of increasing returns / cumulative adv.

c = 10 (short)









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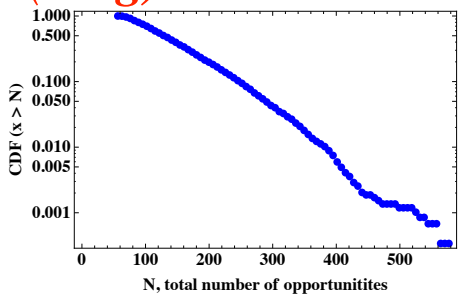
N(total)



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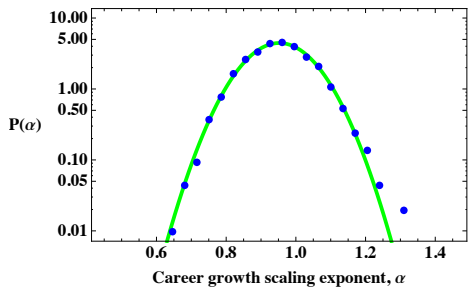
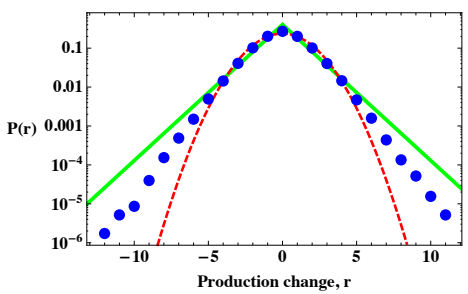
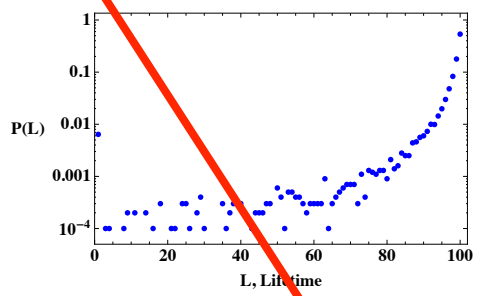


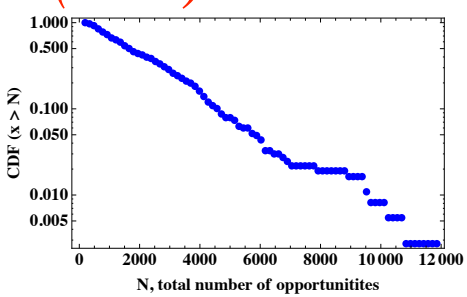
Production change, r

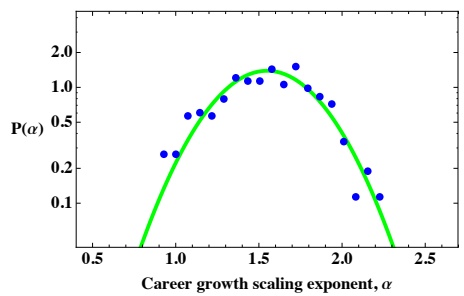


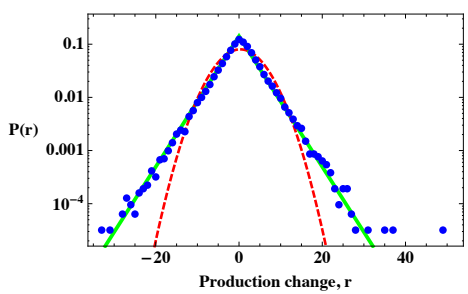
Longevity, L

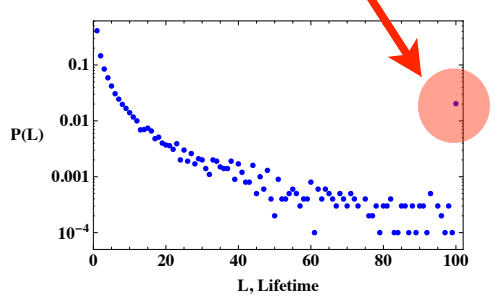


c = 10 (short)









$c \to 0$: appraisal over the lifetime of achievements (~ tenure system): career is better protected from intrinsic negative production shocks (periods of lull) and as a result, most careers sustain production throughout the career, reaching the maximum career lifespan T.

$c > 1$: appraisal over only recent achievements (short-term contract system): most individuals experience "sudden death" termination relatively early in the career. Meanwhile, a small number of "kings" survive the initial selection process, which is governed primarily by random chance, and dominate the system.

Take home messages

- Knowledge, reputation, and collaboration spillovers are major factors behind the increasing returns that are possible within the scientific career trajectory
- An institutional setting that neglects specific features of academic career trajectories (increasing returns from knowledge spillovers and cumulative advantage, collaboration factors, career uncertainty) may inadvertently expose temporarily "cold" careers, leaving them out to freeze.
- nano-sociology : A quantitative picture of Science at the level of single individuals can improve academic policies aimed at increasing career sustainability
- There are many analogies between the superstars in science and the superstars in professional sports, possibly arising from the generic aspects of competition. However, the contract length, compensation, and appraisal timescale in these two professions are VERY different. Is Science becoming more like professional sports?

i) A. M. Petersen, Woo-Sung Jung, Jae-Suk Yang, and H. E. Stanley. "Quantitative and empirical demonstration of the Matthew effect in a study of career longevity." PNAS 108, 18-23 (2011).

ii) A. M. Petersen, H. E. Stanley, and S. Succi. "Statistical regularities in the rank-citation profile of scientists." Scientific Reports 1, 181 (2011).

iii) A. M. Petersen, M. Riccaboni, H. E. Stanley, and F. Pammolli. "'Persistence and Uncertainty in the Academic Career." Forthcoming, PNAS.

Persistency and Uncertainty Across the Academic Career

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Abstract

Recent shifts in the business structure of universities and a bottleneck in the supply of tenure track positions are two issues that threaten to change the longstanding patronage system in academia and affect the overall potential of science. The shift away from long term towards short term contracts necessitates that the employment review process account for coauthorship factors and the coexistence of cumulative advantage and uncertainty in the annual production $n_i(t)$ of a given scientist i. Here we analyze the longitudinal publication rate $n_i(t)$ on the 1-year time scale for 300 physicists $i = 1...300$ and show that the productivity of many physicists accelerates, $N_i(t) \approx A_i t^{\alpha_i}$, with $\alpha_i > 1$, reflecting the benefits of learning and collaboration spillovers which constitute a cumulative advantage. We find that the variance in production scales with "collaboration radius" size S_i as $\sigma_i^2 \sim S_i^{\psi}$ with $0.4 < \psi < 0.8$. To compare intellectual labor with manual labor, we analyze in parallel two comprehensive sports leagues comprising 21,156 careers. We use a preferential growth model to gain insight into the relation between career persistency and career uncertainty. This model shows that excessive emphasis on nonstop production, a consequence of short-term contract systems, results in a significant number of "sudden death" careers that terminate due to unavoidable negative production shocks. Altogether, our results indicate that short-term contracts may increase the strength of "rich-get-richer" mechanisms in competitive professions and hinder the upward mobility of young scientists.

Preferential Capture with Appraisal

1) In each Monte Carlo step we allocate one opportunity to a randomly chosen individual i so that $n_i(t) \rightarrow n_i(t)+1$

2) The individual i is chosen with probability $\mathcal{P}_i(t)$ proportional to $[w_i(t)]^\pi$

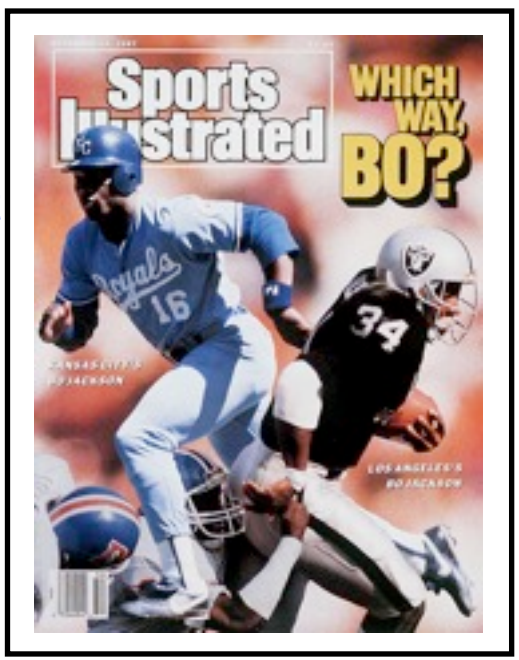
$$\mathcal{P}_i(t) = \frac{w_i(t)^\pi}{\sum_{i=1}^{I} w_i(t)^\pi}$$

where the value $w_i(t)$ is given by an exponentially weighted sum over the entire achievement history

$$w_i(t) \equiv \sum_{\Delta t=1}^{t-1} n_i(t-\Delta t) e^{-c\Delta t} \ .$$

The details of the appraisal determines how much the past record of accomplishment determines the ability to capture new opportunities

Reputation and knowledge spillovers are cumulative $\longrightarrow$ history dependent

Numerous Nobel Prizes awarded for work primarily done during the PhD

If the appraisal timescale is too short, then a Nobel worthy phd thesis loses it's weight overnight ! In sports this is exemplified by the "sudden death" careers which occur in sports so frequently!