

Organizing Highly Creative Research



Insights from US and European Scientific Breakthroughs

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Propositions



1. Creative research is a key-driver for scientific and technological progress, and also a precondition for advances in other societal domains.
 - ❑ US and EU confront global challenges yet limited resources
2. It is important to improve our knowledge and understanding of the *organizational and institutional factors* that support highly creative research
3. These factors may be influenced by research management, funding and policy strategies.
 - ❑ Especially strategies for young researchers in the US & EU, including through transatlantic exchange

Overview



Highly Creative Scientific Research

- Definition of scientific creativity
- Identification of creative scientific research accomplishments
- Key findings from research project
- Implications for research management

Definitions



Creativity is...

- "...the ability to come up with ideas or artifacts that are new, surprising and valuable" (Boden 2004)
- "...the ability to produce work that is both novel (original, unexpected), and appropriate (useful, meets task constraints)" (Sternberg 2003)

Creativity in Science: State of the Art



- Growing interest in creativity – in management, arts, economic development.
- Research on creativity and breakthroughs in science *tends* to focus on *individual* factors (i.e. genius, cf. Sternberg 2003) *rather* than on institutional conditions
 - Recent exceptions: Hemlin, Allwood, Martin (2004); Hage and Meeus (2006); Hollingsworth (2004) on Rockefeller Inst.

Hemlin et al. on creative knowledge environments (CKEs)



CKEs are "those environments, contexts and surroundings the characteristics of which are such that they exert a positive influence on human beings engaged in creative work aiming to produce new knowledge or innovations, whether they work individually or in teams, within a single organization or in collaboration with others."

Project on Creativity Capabilities and the Conduct of Highly Innovative Research in Europe and the United States (CREA)



1. Define and operationalize creative scientific research
2. Identify current scientists and groups with a record of creative work in human genetics and nano S&T
3. Understand current organizational and institutional conditions under which creative research is conducted
4. Review current funding schemes promoting novel and ambitious frontier research
5. Policy recommendations for to foster scientific research creativity

Methods: Bibliometrics, Case Studies, CV Analysis (with controls)

CREA Research Partnership

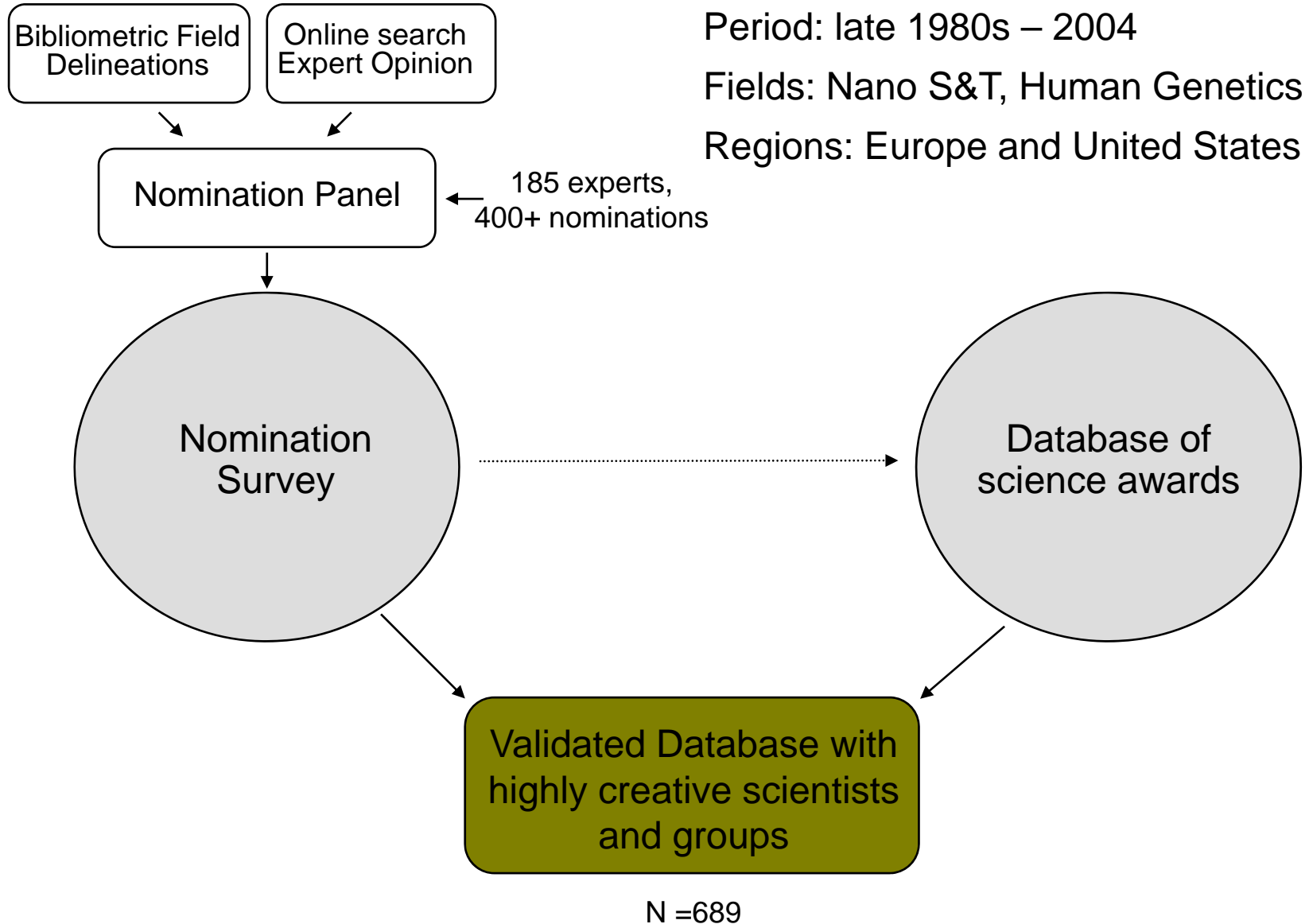


- Project on Creativity Capabilities and the Conduct of Highly Innovative Research in Europe and the United States (CREA)
- Phase I (2003-2006) EU NEST Programme
 - Fraunhofer ISI (DE)/ Twente (NL) (Kuhlmann, Heinze), Georgia Institute of Technology (US) (Shapira), U Sussex (UK) (Senker)
- Phase II (2007-2008) US NSF SciSP
 - Georgia Institute of Technology (Shapira, Youtie, Rogers), University of Bamberg (DE) (Heinze), U Twente (Kuhlmann)
 - <http://www.cherry.gatech.edu/crea/>

Typology of Creative Research Accomplishments

| Type of creative accomplishment | Example |
|---------------------------------|---|
| New theoretical concepts | Theory of Specific Relativity (EINSTEIN, 1905) |
| New empirical discovery | Biodiversity → Theory of Evolution (DARWIN, 1859) |
| New methodology | Factor Analysis → Theory of Mental Abilities (SPEARMAN 1904a, 1904b, 1927) |
| New instruments | Raster Scanning Microscopy → Nanotechnology (BINNIG & ROHRER, 1982) |
| New synthesis | General Systems Theory BERTALANFFY (1949), ASHBY (1956), LUHMANN (1984) |

Identification of creative scientists/groups



Examples of laudations



NANOTECHNOLOGY

- Advanced the basic theory and electrical transport phenomena for carbon nanotubes
- Simple, flexible methods for creating micro- and nano-structured materials.
- First demonstration of directed adsorption of thiol to gold surfaces. Became basis of self-assembly.

HUMAN GENETICS

- Discovered genetic mechanisms underlying Fragile X syndrome (mutated X chromosomes)
- Developed high quality DNA sequence of the human genome

Types of creative accomplishments (%)

| Type of creative accomplishment | Nano S&T | Human genetics |
|---------------------------------|----------|----------------|
| New theoretical concepts | 22 | 29 |
| New empirical discovery | 18 | 21 |
| New methodology | 22 | 19 |
| New instruments | 16 | 15 |
| New synthesis | 17 | 13 |
| Other (open category) | 5 | 4 |
| Total | 100 | 100 |

Source: CREA Survey 2005, N = 689

Sample of creative scientists/groups

| | Nano S&T | | Human genetics | |
|---|-----------|-----------|----------------|-----------|
| | Europe | US | Europe | US |
| Multiple prize winners | 9 | 5 | 10 | 1 |
| Multiple nominations | 7 | 21 | 0 | 3 |
| Prize winner and nomination | 16 | 17 | 5 | 9 |
| Multiple prize winners and multiple nominations | 3 | 4 | 0 | 0 |
| Total highly creative scientists | 22 | 29 | 14 | 11 |
| Total scientists in database | 224 | 204 | 150 | 111 |

Source: CREA Survey 2005. N = 689

Analysis methods



Phase I:

- Bibliometric analysis
- Case studies (triangulated)

Phase II:

- Matched control group (c. 700 US, EU scientists)
 - Field, start year (first article), journals
- CV analysis (in progress)

| Case | 2 | 5 | 6 | 8 | 18 | 20 |
|---|-----------------|-----------|-------------------|-------------|------------------|-----------|
| Type of multiple expert and prize nominations | MultNom | MultNom | MultPrizNom | MultPrizNom | PrizNom | PrizNom |
| Type(s) of CE | 2,3 | 3,5 | 3,5 | 2,3 | 3 | 1,2 |
| Multiple CEs | Yes | | Yes | Yes | | Yes |
| CE preparation phase | 1985-1992 | 1993-1996 | 1997-1998 | 1993-1997 | 1975-1990 | 1985-1992 |
| CE accomplishment phase | 1995-2000 | 1997-2002 | 1998-2000 | 1997-1998 | 1990-2000 | 1993-2002 |
| Career stage | Early | Early | Early | Mid | Mid | Early |
| Field | Nano | Nano | Nano | Nano | HG | HG |
| CE accomplishment institution | Basic Ind. Lab. | Univ. | Univ. / Gov. Lab. | Univ. | Hosp./ Gov. Lab. | Univ. |
| CE accomplishment country | US | US | DE, FR | NL | FR | US |
| Current institution | Univ. | Univ. | Univ./ Gov. Lab. | Univ. | Hosp./ Gov. Lab. | Univ. |
| Current country | S | D | S | S | S | S |

Findings from cases




Key organizational and institutional factors

underlying highly creative scientific breakthroughs

- Small group size – large context
- Multidisciplinary contacts
- Flexible research funding
- Independence for junior scientists

Small group - large context



Creative research is most likely to be accomplished by small research groups that are embedded and interact with other scientists in a large and complex organizational environment.

- Seed bed that nurtures serendipitous findings
- Fruitful mentor-student relationships
- Flexibility to address new problems or ideas as they arise

Multidisciplinary contacts



Research environments that provide easy interaction across disciplinary or thematic boundaries promote creativity. This is achieved in the following settings:

- Blend between thematic proximity on the one hand, and variety of themes and skills on the other hand
- Arrangements that support unplanned multidisciplinary contact
 - Spatial: laboratory facilities, staircases, coffee rooms
 - Social: lunchtime pattern

Flexible research funding



Flexibility in the use of research funds gives scientists degrees of freedom in exploring their research ideas. It allows them to address intrinsically risky research problems or to change field.

- Core institutional research funding
- Well-endowed individual research grants
- Abundance of external funding sources

Independence for junior scientists



Research creativity *potential* resides in junior scientists – but institutional conditions can influence how, where, and whether it is unleashed

Non-hierarchical research environments with open dialogue between all researchers and financial independence from senior research management provide the best setting to foster creativity.

- Effective mentor-student relationships
- Mobilization of external knowledge and expertise
- Articulation and discussion of novel ideas

Mobility

Mixed findings on mobility

- Several cases, scientists move prior to making creative breakthroughs
 - USSR → EU → US; EU → US; EU → US; 3rd county → US; EU → EU
- In other cases, creative scientists build their career at one institution (large R&D labs; also univ, gov labs)

Observations

- Creative scientists *seek* creative knowledge environments – and will stay when they find one
- Institutional factor: scientific creativity may be linked through mobility via increased knowledge source variety but institutional factors which emphasize knowledge variety and flexibility may be more important

Insights




- Organization and management of R&D groups
 - Group size, membership
- Management of R&D institutions
 - Leadership and vision
- R&D funding programs
 - Types of funding programs, flexibility
- Framework conditions for R&D
 - Career development patterns, labor mobility

Institutional factors & creative breakthroughs in: Large industrial R&D labs



1. Mission oriented research program
2. Access to a large diversity of skills and multidisciplinary knowledge
3. Excellent instrumentation and experimental capabilities
4. Significant job stability for staff researchers
5. Base level of funding
6. No other organizational obligations or demands

Institutional factors & creative breakthroughs in: Universities



1. Many indications that university researchers made efforts to create a setting as close to the one described for industrial R&D labs, while preserving the broader mission of academic work:
2. Important role of post-docs to focus the work on the important problems and allow rapid research progress
3. General lack of core funding to protect against interruptions of the work
4. Considerable efforts necessary to gain access to needed equipment and compensate for the time demanded by graduate students
5. Burden of non-research obligations such as committee work and other university services

R&D funding programs



Review of EU innovative national & US funding schemes (parallel project by Thomas Heinze)

1. Only few funding agencies set aside sizeable budgets to support creative and innovative research
2. Funding needs to be accompanied by complementary institutional conditions in order to encourage creative, high-risk research

Schemes examined by Heinze: Investigator Program (Hughes Medical Institute, US); Förderpreis für junge Hochschullehrer (Krupp Stiftung, DE); 21st Century Science Initiative (McDonnell Foundation, US); Europ. Young Invest. Award (European Science Foundation); Showcase Award (Wellcome Trust, UK); Off the beaten track (Volkswagen Stiftung, DE); Ideas Factory (Eng. & Phys. Sciences Research Council, UK); Focal Research Initiatives in S&T (Israel Science Foundation)



PROGRAM STRENGTHS

- Self-nomination procedures instead of nomination by institution
- Multidisciplinarity as important selection criterion
- Efforts to balance problems inherent in peer review mechanism

PROGRAM WEAKNESSES

- Arbitrary funding thresholds, no matching with de facto talent pool
- Administrative burden of programs above-average
- Matthew effect not taken into consideration (well-endowed receive even more endowments)

Conclusions:

Opportunities and Challenges



- Small group size is relevant as research sponsors increasingly emphasize large centers of excellence.
- Enhancing flexibility and independence at early-stage career development may require institutional changes and the expansion of early career research awards.
- Knowledge source variety can be enhanced through mobility, but also necessitates institutional changes
 - Support for US-EU collaborations can be helpful, but expect increased mobility to the most creative sites as a result
- R&D awards which seek innovativeness and provide flexibility – a case for (careful) expansion
- R&D awards might give more consideration to institutional conditions
 - improving as well as considering institutional conditions