

Understanding the Reward System of Science

An Economic Approach

Kevin J.S. Zollman ¹ P. Kyle Stanford ²

¹Carnegie Mellon University

²University of California, Irvine

Historical eras

AMATEUR ERA

- Individual scientists pursuing their own curiosity
- No central authority for the provision of credit
- No central funding or approval process

PROFESSIONAL ERA

- Central authority who provides credit for success
- No central funding or approval process

MODERN ERA

- Central authorities for credit, funding, and approval

Historical eras

AMATEUR ERA

- Individual scientists pursuing their own curiosity
- No central authority for the provision of credit
- No central funding or approval process

PROFESSIONAL ERA

- Central authority who provides credit for success
- No central funding or approval process

MODERN ERA

- Central authorities for credit, funding, and approval

Historical eras

AMATEUR ERA

- Individual scientists pursuing their own curiosity
- No central authority for the provision of credit
- No central funding or approval process

PROFESSIONAL ERA

- Central authority who provides credit for success
- No central funding or approval process

MODERN ERA

- Central authorities for credit, funding, and approval

Scientist's concerns

[T]oday's free intellectuals ... find themselves tethered to national goals for health, defense, economic competitiveness, and the like.

Colleges, universities, and research institutes have come to depend on federal research support, a dependence that is transmitted (and perhaps amplified along the way) to the scientists and scholars they employ, further limiting intellectual "free play." New ideas must pass through the filter of peer review, which stimulates opposition and encourages applicants to be cautious, if not conservative, in their proposals. (Chubin and Hackett 1990, p. 10)

Scientist's concerns

If you look at most cancer research journals you will see that our focus remains on finding smaller cancers, doing less surgery and radiation and developing new drugs to add to the old ones in an attempt to treat the cancers we detect. This approach ... hasn't changed since I was a resident in training 30 years ago. ... There is little chance, much less financing, for the wild idea that might prove revolutionary. ...

[Our peer review system for financing research] works well at eliminating poor investments, but it squelches innovation and fosters the old boy network. ... And our academic and research institutions reward projects with clearly defined objectives that have a good chance of quickly leading to publications and tenure. (Love 2007)

Two concerns

SCIENTIFIC FREEDOM

To what extent are scientists free to choose their own projects?

SCIENTIFIC DIVERSITY

How many different projects are pursued by a community of scientists?

Central research questions

To what extent are scientific diversity and scientific freedom assisted or hampered by the three different eras of scientific incentives?

Our model

Set of hypotheses (H)
Set of experiments (E)
Set of experimental outcomes (O)
Probability distribution over $H \times E \times O$
Utility function over O



Our model

Experiment A
is better than
Experiment B
is as good as
Experiment C



Our model



Experiment A
is better than
Experiment B
is as good as
Experiment C



Experiment B
is better than
Experiment C
is as good as
Experiment A



Experiment A
is as good as
Experiment B
is better than
Experiment C



Experiment C
is better than
Experiment A
Is better than
Experiment B



Experiment A
is as good as
Experiment B
is as good as
Experiment C

Different eras

AMATEUR ERA

Each scientist chooses to maximize her own probability/utility functions – she has only herself to answer to

PROFESSIONAL ERA

Each scientist utilizes her own probability function and a common utility function – everyone gets credit from the same institution

MODERN ERA

Each scientist utilizes her a common probability and utility function – each person must get pre-approval from the same organization

Different eras

AMATEUR ERA

Each scientist chooses to maximize her own probability/utility functions – she has only herself to answer to

PROFESSIONAL ERA

Each scientist utilizes her own probability function and a common utility function – everyone gets credit from the same institution

MODERN ERA

Each scientist utilizes her a common probability and utility function – each person must get pre-approval from the same organization

Different eras

AMATEUR ERA

Each scientist chooses to maximize her own probability/utility functions – she has only herself to answer to

PROFESSIONAL ERA

Each scientist utilizes her own probability function and a common utility function – everyone gets credit from the same institution

MODERN ERA

Each scientist utilizes her a common probability and utility function – each person must get pre-approval from the same organization

Freedom

Definition

One era exhibits more freedom than another, if it allows for *strictly* more community profiles than another

Theorem

The amateur era exhibits more freedom than the professional era which exhibits more freedom than the modern era.

Freedom

Definition

One era exhibits more freedom than another, if it allows for *strictly* more community profiles than another

Theorem

The amateur era exhibits more freedom than the professional era which exhibits more freedom than the modern era.

General diversity

Definition

One era exhibits more **general-diversity** if it allows *strictly* more “diverse” community profiles than another

Theorem

The amateur era exhibits more general-diversity than does the professional era which exhibits more general-diversity than the modern era

General diversity

Definition

One era exhibits more **general-diversity** if it allows *strictly* more “diverse” community profiles than another

Theorem

The amateur era exhibits more general-diversity than does the professional era which exhibits more general-diversity than the modern era

Common scientists diversity

Definition

One era exhibits more diversity *for a particular set of scientists* if those scientists would pursue diverse projects under one and not another

Theorem

For an arbitrary set of scientists, there is no diversity ordering between the amateur and professional era.

Common scientists diversity

Definition

One era exhibits more diversity *for a particular set of scientists* if those scientists would pursue diverse projects under one and not another

Theorem

For an arbitrary set of scientists, there is no diversity ordering between the amateur and professional era.

Example

	1	2
Critical experiment	Theory A accepted	Theory B accepted
Incremental project	Incremental progress	

- *Scientist One:* Critical experiment > Incremental project
 - Accepting A > Incremental progress > Accepting B
 - State 1 is more likely than state 2
- *Scientist Two:* Critical experiment > Incremental project
 - Accepting B > Incremental progress > Accepting A
 - State 2 is more likely than state 1

Example

	1	2
Critical experiment	Theory A accepted	Theory B accepted
Incremental project	Incremental progress	

- *Scientist One:* Critical experiment \succ Incremental project
 - Accepting A \succ Incremental progress \succ Accepting B
 - State 1 is more likely than state 2
- *Scientist Two:* Incremental project \succ Critical experiment
 - Accepting B \succ Incremental progress \succ Accepting A
 - State 2 is more likely than state 1

Example

	1	2
Critical experiment	Theory A accepted	Theory B accepted
Incremental project	Incremental progress	

- *Scientist One*: Critical experiment \succ Incremental project
 - Accepting A \succ Incremental progress \succ Accepting B
 - State 1 is more likely than state 2
- *Scientist Two*: Critical experiment \succ Incremental project
 - Accepting B \succ Incremental progress \succ Accepting A
 - State 2 is more likely than state 1

Example

	1	2
Critical experiment	Theory A accepted	Theory B accepted
Incremental project	Incremental progress	

- *Scientist One*: Critical experiment \succ Incremental project
 - Accepting A \succ Incremental progress \succ Accepting B
 - State 1 is more likely than state 2
- *Scientist Two*: Critical experiment \succ Incremental project
 - Accepting B \succ Incremental progress \succ Accepting A
 - State 2 is more likely than state 1

Example

	1	2
Critical experiment	Theory A accepted	Theory B accepted
Incremental project	Incremental progress	

- *Scientist One*: Critical experiment \succ Incremental project
 - Accepting A \succ Incremental progress \succ Accepting B
 - State 1 is more likely than state 2
- *Scientist Two*: Critical experiment \succ Incremental project
 - Accepting B \succ Incremental progress \succ Accepting A
 - State 2 is more likely than state 1

Common scientists diversity

Definition

One era exhibits more diversity *for a particular set of scientists* if those scientists would pursue diverse projects under one and not another

Theorem

For an arbitrary set of scientists, there is no diversity ordering between the amateur and professional era.

Theorem

There are some groups of scientists where both the amateur and professional era exhibit more diversity than the modern era and no group where the modern era exhibits more diversity than the amateur or professional era.

Common scientists diversity

Definition

One era exhibits more diversity *for a particular set of scientists* if those scientists would pursue diverse projects under one and not another

Theorem

For an arbitrary set of scientists, there is no diversity ordering between the amateur and professional era.

Theorem

There are some groups of scientists where both the amateur and professional era exhibit more diversity than the modern era and no group where the modern era exhibits more diversity than the amateur or professional era.

Strategic interaction

- In this model, scientists are choosing for themselves
- Strategic interaction can lead to a reduction of diversity, even in the amateur era
- Future work will include this possibility

Strategic interaction

- In this model, scientists are choosing for themselves
- Strategic interaction can lead to a reduction of diversity, even in the amateur era
- Future work will include this possibility

Strategic interaction

- In this model, scientists are choosing for themselves
- Strategic interaction can lead to a reduction of diversity, even in the amateur era
- Future work will include this possibility

Conclusions

- The modern era exhibits less diversity and freedom than does the earlier eras
- Prizes exhibit more freedom and diversity than does the peer-reviewed grant system
- Should we switch?
 - Are diversity and freedom desirable?
 - Disallowing them comes at a cultural worth paying (e.g., violations of public trust)
- Much future work to do...

Conclusions

- The modern era exhibits less diversity and freedom than does the earlier eras
- Prizes exhibit more freedom and diversity than does the peer-reviewed grant system
- Should we switch?
 - Are diversity and freedom desirable?
 - Do we have them? (e.g., culture, world, young, etc.)
 - How do we measure them?
 - How do we promote them?
- Much future work to do...

Conclusions

- The modern era exhibits less diversity and freedom than does the earlier eras
- Prizes exhibit more freedom and diversity than does the peer-reviewed grant system
- Should we switch?
 - Are diversity and freedom desirable?
 - Does allowing them come at a cost not worth paying (e.g. violations of public trust)?
- Much future work to do...

Conclusions

- The modern era exhibits less diversity and freedom than does the earlier eras
- Prizes exhibit more freedom and diversity than does the peer-reviewed grant system
- Should we switch?
 - Are diversity and freedom desirable?
 - Does allowing them come at a cost not worth paying (e.g. violations of public trust)?
- Much future work to do...

Conclusions

- The modern era exhibits less diversity and freedom than does the earlier eras
- Prizes exhibit more freedom and diversity than does the peer-reviewed grant system
- Should we switch?
 - Are diversity and freedom desirable?
 - Does allowing them come at a cost not worth paying (e.g. violations of public trust)?
- Much future work to do...

Conclusions

- The modern era exhibits less diversity and freedom than does the earlier eras
- Prizes exhibit more freedom and diversity than does the peer-reviewed grant system
- Should we switch?
 - Are diversity and freedom desirable?
 - Does allowing them come at a cost not worth paying (e.g. violations of public trust)?
- Much future work to do...