A quantitative model to investigate and inform the design of innovation prizes based on systems and complexity theory approaches

Luciano Kay[1]

Inducement prizes–where cash rewards are given to motivate the attainment of targets—have been long used to stimulate individuals and groups to accomplish diverse goals. Recently, their popularity has grown, including in science, technology and innovation domains. Yet, our understanding of prizes and their potential to, for example, induce innovation is still not up to the increasing interest and actual prize use by governments, companies, and others.

This research is set out to develop a quantitative model of technological innovation in prizes that builds upon existing theoretical models, new modeling approaches for technological innovation, and empirical verification. The development of this kind of model can significantly increase our understanding of the phenomenon and inform the design, implementation, and evaluation of prizes. This research is particularly interested in "innovation prizes," which are generally organized as competitions to achieve pre-specified technological challenges or targets before a deadline. These challenges originate with the prize sponsor, who generally offers an ex-ante, fixed monetary reward to the first prize entrant to accomplish a certain feat.

A great deal of the work to model incentive mechanisms in general and prizes in particular has been developed on theoretical grounds and serves as the basis for further investigation. The work by Wright (1983), for example, which explores the optimal allocation of alternative incentives to induce innovative activity, is among the earliest applications of formal modeling techniques to compare incentive mechanisms, including prizes. Several others have built upon Wright's research to compare the effectiveness of incentive schemes, including de Laat (1997), Shavell & Ypersele (1999), and Newell & Wilson (2005). Formal economic modeling has been also applied to the examination of optimal prize designs (see, for example, Taylor, 1995, and Moldovanu & Sela, 2001).

An alternative perspective to the study of technological innovation—with potential to investigate prizes—draws on systems and complexity theories. This research thrust has contributed a number of core complex models to, for example, analyze emerging properties in technological design processes and the structure of interactions in processes of collective invention (see, for example, Frenken & Nuvolari, 2004; McCarthy, 2004; Silverberg & Verspagen, 2005). An interesting feature of these approaches is their ability to explain complex phenomena using fewer parameters and, therefore, to offer more encompassing explanations of the phenomena with parsimony and without the sacrifice of analytical rigor (Frenken, 2006). This feature also suggests an opportunity to model prizes as unit of analysis and consider both prize entrant- and context-level factors that might influence the ultimate prize outcome.

Recently, the researcher investigated cases of modern innovation prizes with support from the U.S. National Science Foundation and The IBM Center for the Business of Government (Kay, 2011b, 2011a, 2011c). That research contributed a qualitative model based on theoretical insights and empirical testing to investigate aerospace prizes such as the Ansari X Prize, the Northrop Grumman Lunar Lander Challenge, the Google Lunar X Prize, and the DARPA Challenges. Although the model demonstrated to be effective to develop explanations of diverse aspects of the prize phenomenon, its operationalization still implies a challenging task for data gathering and analysis. A logical next step would be to develop a quantitative prize model with increasing accuracy and predictive power based on that qualitative modeling experience. Empirical findings from case studies can contribute valuable insights to develop, test, and calibrate a new model and assess its robustness and predictive power.

[1] Georgia Tech Program in Science, Technology and Innovation Policy and School of Public Policy, Georgia Institute of Technology, Atlanta, GA 30332-0345 (E-mail: luciano.kay@gatech.edu).

Certainly, no single model will be able to capture all of the dimensions of the prize phenomenon. Yet, we can think of an ideal model (IM) that deals with the following stylized facts, some of which are not fully developed in our prior conceptual approaches to this topic:

- Prize competitions are sophisticated collective innovation processes in which existing and new R&D threads converge. The IM shall consider prizes as a system with endogenous complexity that evolves over time and encompasses: a) a number of agents that include entrants and other participants; b) a technological target that is a system in itself; and, c) a given technological field and broader context that evolve over time as well.
- Prizes generally target the development of technological systems/platforms and not single, discrete innovations. The IM shall consider prize targets as systems of certain architecture and complexity, or even as platforms that enable the development of complementary technologies, in the context of a technological landscape that offers knowledge and technological options of varying maturity.
- Prize monetary rewards are not necessarily the most important motivation of prize entrants. Little research has modeled prizes and considered the effect of non-monetary incentives (e.g. Brunt et al., 2008). The IM shall consider alternative motivations when modeling the search behavior of entrants to reflect goals that exceed technological fitness (Kauffman, 1993). For example, entrants may seek to: a) minimize time or costs of accomplishment to win the competition; b) maximize profits to create a new business; or c) minimize/maximize other measures to accomplish other non-prize goals.
- Prize entrants are very heterogeneous in composition and roles and not always single, profit-maximizing entities of uniform characteristics. Entrants even include "unconventional entrants" that are generally not familiar with the prize technologies and may contribute fresh, creative ideas for problem-solving. The IM shall model prize entrants as agents embedded in multiple institutional settings through diverse membership and networks that connect entrants with partners and volunteers with diverse personal and organizational goals.
- Prize R&D activities not only reflect the search for a winning innovation but also the pursuit of other goals. Moreover, entrants contribute ongoing projects and their point of entry in the prize process varies widely. The IM shall model R&D as the search for solutions in a design space that is defined by the prize target but also depends on the entrant's entry point in time and technological approach, and is local v. global depending on entrants' embeddedness in broader networks.
- The context of prize implementation affects significantly the development and outcomes of prizes. The IM shall model the prize context as a technological landscape with certain institutional settings (i.e. industry structure) and as a source of more pervasive incentives (e.g. market demand) and key resources (e.g. knowledge, funding.)

The researcher proposes to develop a quantitative model of innovation in prizes that combines core approaches that draw on systems and complexity theories and deals with those stylized facts. The researcher proposes to: 1) review and build upon prior literature's contributions, 2) compile empirical evidence from his case studies, 3) develop the model conceptually and practically, 4) calibrate and verify the model empirically, and 5) simulate different theoretical implementations of innovation prizes to assess the model's robustness and predictive power. This work will also discuss R&D program and policy implications for the design, implementation, and evaluation of innovation prizes.

The time span for development of this project is the academic year 2012-2013 in agreement with NBER. The researcher will use the project funding as a research stipend and support for conference travel and acquisition of software and scholarly literature if necessary.

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