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The Impact of Innovation Inducement Prizes

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Abstract

This paper is part of the Compendium of Evidence on the Effectiveness of Innovation Policy Intervention. This report brings together the existing evidence on the effects of innovation inducement prizes by drawing on a number of ex-ante and ex-post evaluations as well as limited academic literature. Innovation inducement prizes have a wide range of rationales and there is no agreed on dominant rationale in the literature. It is evident from the literature we analysed that the evidence on the impact of innovation inducement prizes is scarce. There are only a few evaluations or academic works that deal with the creation of innovation output and even those which deal with the innovation output only rarely deals with the additionality. Only a very limited number of studies looked at if innovation inducement prizes led to more innovation itself or innovation outputs. There is also a consensus that innovation inducement prizes are not a substitute for other innovation policy measures but are complementary under certain conditions. Prizes can be effective in creating innovation through more intense competition, engagement of wide variety of actors, distributing risks to many participants and by exploiting more flexible solutions through a less prescriptive nature of the definition of the problem in prizes. They can overcome some of the inherent barriers to other instruments, but if prizes are poorly designed, managed and awarded, they may be ineffective or even harmful.

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The Compendium of Evidence on the Effectiveness of Innovation Policy Intervention Project is led by the Manchester Institute of Innovation Research (MIoIR), University of Manchester, and funded by Nesta, an independent charity with the mission to make the UK more innovative. The compendium is organised around 20 innovation policy topics categorised primarily according to their policy objectives. Currently, some of these reports are available. All reports are available at http://www.innovation-policy.org.uk. Also at this location is an online strategic intelligence tool with an extensive list of references that present evidence for the effectiveness of each particular innovation policy objective. Summaries and download links are provided for key references. These can also be reached by clicking in the references in this document. Corresponding Author: Abdullah Gök; Harold Hankins Building, MIoIR, University of Manchester, Oxford Road, Manchester M13 9PL United Kingdom; abdullah.gok@mbs.ac.uk.

This report is part of the Compendium of Evidence on the Effectiveness of Innovation Policy Intervention Project led by the Manchester Institute of Innovation Research (MIoIR), University of Manchester. The project is funded by the National Endowment for Science, Technology and the Arts (NESTA) - an independent body with the mission to make the UK more innovative.

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All reports are available at http://www.innovation-policy.org.uk. Also at this location is an online strategic intelligence tool with an extensive list of references that present evidence for the effectiveness of each particular innovation policy objective. Summaries and download links are provided for key references. These can also be reached by clicking in the references in this document.

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Executive Summary

Innovation inducement prizes are one of the oldest types of innovation policy measure. The popularity of innovation inducement prizes has gradually decreased during the early 20th century. However, innovation inducement prizes have regained some of their popularity since the 1990s with new prizes awarded by the US X Prize Foundation and with the current USA Administration's efforts to use them in various government departments as an innovation policy instrument. Innovation Prizes are also becoming an important innovation policy instrument in the UK. A recent report by McKinsey & Company (2009) estimates the value of prizes awarded to be between £600 million and £1.2million. Despite the growing popularity of innovation inducement prizes, the impact of this innovation policy measure is still not understood. This report brings together the existing evidence on the effects of innovation inducement prizes by drawing on a number of ex-ante and ex-post evaluations as well as limited academic literature. This report focuses on ex-ante innovation inducement prizes where the aim is to induce investment or attention to a specific goal or technology. This report does not discuss the impact of ex-post recognition prizes where the prize is given as a recognition after the intended outcome happens (e.g. Nobel Prize).

Innovation inducement prizes have a wide range of rationales and there is no agreed on dominant rationale in the literature. Traditionally, prizes have been seen as an innovation policy instrument that can overcome market failure by creating an incentive for the development of a particular technology or technology application. A second rationale is that the implementation demonstration projects in which not only creation of a specific technology is intended but also demonstration of the feasible application of this technology is targeted. A third rationale is related to the creation of a technology that will later be put in the public domain to attract subsequent research. Prizes are also increasingly organised for community and leadership building. As prizes probably allow more flexibility than most of the other innovation policy instruments, there is a large number of different prize characteristics and thus a vast number of prize typologies based on these characteristics.

Evidence on the effectiveness of prizes is scarce. There are only a few evaluations or academic works that deal with the creation of innovation output and even those which deal with the innovation output only rarely deals with the additionality. Only a very limited number of studies looked at if innovation inducement prizes led to more innovation itself or innovation outputs. As well as developing the particular technology that the innovation inducement prizes produce, they create prestige for both the prize sponsor and entrants. Prizes might also increase the public and sectoral awareness on specific technology issues. A related issue to the prestige gained from the prizes is the motivations of participants as a conditioning factor for innovation performance. Design issues are the main concern of the prizes literature. This reflects the importance of a careful design for the achievement of desired effects (and the limitation of undesired effects). There are a relatively large number of studies that investigated the influence of the design of prize objective on the innovation performance. A number of studies points out that sometimes prizes should be accompanied with or followed by other demand side initiatives to fulfil their objectives, mostly on the basis of ex-ante evaluations. Finally, prizes are also seen as a valuable opportunity for experimentation in innovation policy.

It is evident from the literature we analysed that the evidence on the impact of innovation inducement prizes is scarce. There is also a consensus that innovation inducement prizes are

not a substitute for other innovation policy measures but are complementary under certain conditions. Prizes can be effective in creating innovation through more intense competition, engagement of wide variety of actors, distributing risks to many participants and by exploiting more flexible solutions through a less prescriptive nature of the definition of the problem in prizes. They can overcome some of the inherent barriers to other instruments, but if prizes are poorly designed, managed and awarded, they may be ineffective or even harmful.

1 Introduction

Innovation inducement prizes are one of the oldest types of innovation policy measures. The well-known example of the Longitude Prize offered by an Act of Parliament in 1714 led to important advances in naval navigation and was claimed by a series of inventors. Other well-known historical examples include a French food preservation prize during Napoleonic Wars, the Orteig prize for a non-stop flight between London and New York and a series of prizes by the Montyon Fund (for a comprehensive list of historical examples see Knowledge Ecology International (KEI) (2008), Masters and Delbecq (2008) and McKinsey & Company (2009)).

The popularity of innovation inducement prizes have gradually decreased during the early 20th century. Royal Academy of Science in Paris used prizes as their main instrument in 1800s but transitioned to grants afterwards. Their Montyon Fund, whose winners included Louis Pasteur, spurred a political controversy as to how to design a prize and decide on the winner. Other prizes also gradually vanished with the belief that the patent system that became more institutionalised by that time is more efficient system of inducing innovation (Wei, 2007).

Innovation inducement prizes gained back popularity after 1990s with a number of prizes offered by the US X Prize Foundation and also with the current USA Administration's efforts to use them in various government departments as an innovation policy instrument. Innovation Prizes are also becoming an important innovation policy instrument in the UK. The National Endowment for Science, Technology and Arts (NESTA) ran the Big Green Challenge in 2008 and established The Centre for Challenge Prizes and is currently running a number of prizes together with various partners including Department for Business Innovation and Skills, UNDP and European Commission. Similarly, the NHS in England recently started an Innovation Challenge Prizes programme.

A recent report by McKinsey & Company (2009) estimates the value of prizes awarded to be between £600 million and £1.2million. Kay (2011c) reports that there were 55 prizes ranging between $200 to $15 Million announced in Challenge.gov as of January 2011. This figure is about 234 as of December 2012.

Despite the growing popularity of innovation inducement prizes, the impact of this innovation policy measure is still not understood. McKinsey & Company (2009) reports that more than 40% of prizes were not evaluated for their impact and those that were evaluated only evaluated ad hoc. Therefore, the literature on the impact of innovation inducement prizes is slender.

This report brings together the existing evidence on the effects of innovation inducement prizes by drawing on a number of ex-ante and ex-post evaluations as well as limited academic literature. Section 2 discusses the rationale for innovation inducement prizes. Section 3 outlines the scope of this report. Section 4 reports the existing evidence base while finally Section 5 concludes. As it will be discussed later in this report, there are many different types of innovation prizes.

This report focuses on ex-ante innovation inducement prizes where the aim is to induce investment or attention to a specific goal or technology. This report does not discuss the impact of ex-post recognition prizes where the prize is given as a recognition after the intended outcome happens (e.g. Nobel Prize).

2 Rationale for Innovation Inducement Prizes

Innovation inducement prizes have a wide range of rationales and there is no agreed on dominant rationale in the literature. Traditionally, prizes have been seen as an innovation policy instrument that can overcome market failure by creating incentive for the development of a particular technology or technology application. Williams (2012) outlines four issues regarding to this rationale. First, the size of the prize should be set carefully. Conventional measures such as grants or tax credits are based on actual cost of research while for prize estimating the cost ex-ante is very difficult. If the prize is too low, it will not attract enough attention from potential entrants. History shows that there are a substantial number of unclaimed prizes (Knowledge Ecology International (KEI) (2008), Masters and Delbecq (2008) and McKinsey & Company (2009)). However, if the prize amount is set too high, there may be inefficiencies both in terms of the money spent by the prize organiser and also above optimal amount of research conducted by participants who are attracted by high prize. Secondly, unlike the patent system, the target technology might not be as socially desirable as the prize organiser hopes. For instance, Whirlpool's product which won the Super Efficient Refrigerator Program (SERP) prize did not subsequently attract consumer attention. Third, choosing and refining prize targets is very difficult as not all technology areas are suitable for a prize instrument as the progress in some technology areas cannot be easily determined a priori and thus clear, achievable and measurable technology goals are not easy to set. Extensive consultation with experts, affected parties, and categories of potential participants are needed (National Research Council, 2007). Fourth, defining the desired product in advance in prizes often proves a challenge compared to grants for instance. Basic research cannot be supported by prizes as it does not allow room for serendipitous scientific discoveries since the prize technology should be well defined (Kalil, 2006; National Research Council, 2007). As prizes give the reward ex-post (i.e. after the target outcome is reached), prizes might not give sufficient inducement to any those parties who cannot afford to develop the technology in the first instance. Furthermore, implications for the disclosure of the intention to develop a specific technology and the results might be different for prizes than the patent system or alternative instruments (National Research Council, 2007). Fifth, from an economic point of view, prizes can also lead to monopoly deadweight if the winner retains full IPR (which is the case in some prizes but not in others).

There are two further rationales according to Williams (2012). First one is the implementation demonstration projects in which not only the creation of a specific technology is intended but also the demonstration of the feasible application of this technology is targeted. Examples include the 1992 SERP sponsored by a set of US utility companies aimed to develop and sell 250,000 units of fridges efficient to a given set of criteria. Another example is an advanced market commitment which involves the development and supply of a large quantity of vaccine for pneumococcal disease organised by a number of low income countries together with Bill & Melinda Gates Foundation. The second one is the creation of a technology that will later be put in the public domain to attract subsequent research. An example for this is the patent buyout for Daguerreotype photography studied in detail by Kremer (1998).

The National Academy of Engineering (1999) outlines the rationale for prizes as the following:

- "Identify and engage non-traditional participants and unorthodox approaches to challenges
- Educate and inspire the public

- Stimulate nascent or "stalled" technologies
- "Stretch" existing technologies by demonstrating their usefulness
- Foster technology diffusion
- Address neglected or seemingly intractable societal problems
- Build "social capital""

Prizes are also increasingly organised for community and leadership building. The best-known example for this rationale is NESTA's Big Green Challenge, which is a social prize in which participants do not compete for a particular technology or a product but for a relative goal of achieving carbon emissions reduction. The other criteria used by the judges are innovation, community engagement, longevity and scalability/replicability (Brook Lyndhurst, 2010). Another example for community and leadership building and science awareness type of prizes is FIRST Robotics where high school students develop robots.

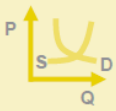
There is a long list of theoretical literature that discusses the efficiency of a prize mechanism compared with other innovation policy instruments. The well-cited choice theory modelling by Wright (1983) shows that the prizes and contracts as instruments of innovation policy might only be superior to patents in terms of their cost efficiency to the policy-maker (or prize organiser) if the information on the costs and benefits of a research "grant approach" is not asymmetric between researcher and government. Otherwise, the monopoly deadweight arising from intellectual property rights is outweighed by the higher relative cost of information asymmetry. This theoretical discussion has generally been helpful in understanding the efficiency of prizes, although it relies on many assumptions and frames prizes in a very simplistic sense. However, as noted by Kremer and Williams (2009) and Williams (2012), the recent policy and academic debate is not on whether to select prizes over patents but on the effective design and implementation of a prize structure.

Unlike other innovation policy instruments, prizes are frequently given by non-governmental actors. According to the McKinsey & Company (2009) survey, more than half of prizes are given by charitable organisation, more than a quarter by for profit organisation and only 17% by governments. However, there is a small difference in terms of administration and design in the prizes given by these different sponsors.

Prizes work best when there is an achievable and measurable goal, so they are potentially most appropriate for applied research, prototyping, and stretch innovation goals, but not for basic research where the goal is not always set from the beginning.

As prizes probably allows more flexibility than most of the other innovation policy instruments, there are a large number of different prize characteristics and thus a vast number of prize typologies based on these characteristics. Classification of prizes by the timing of the prize produces two main categories, *ex-post recognition prizes* (e.g. Nobel) and *ex-ante inducement prizes* (e.g. Longitude Prize). There are prizes that has one winner (i.e. *one-winner-takes-all*) or *multiple winners*. Reward can be given to final product (i.e. *final product prizes*) or for milestones (i.e. *milestone prizes*). Prize targets can be specific (i.e. *targeted prizes*) or general (i.e. *blue sky prizes*). Figure 1 shows a comprehensive typology by McKinsey & Company (2009) which is also very similar to the typology by Zients (2010).

Figure 1: Prize Typology by McKinsey & Company (2009: 48)

	Archetype	Goal of prize	Primary change levers
	**Exemplar**	· Focus attention on, set standards in, and/or influence perception of a particular field or issue	· Identifying excellence · Influencing perception
	**Exposition**	· Highlight a range of best practices, ideas, or opportunities within a field	· Identifying excellence · Mobilizing capital
	**Network**	· Celebrate and strengthen a particular community	· Identifying excellence · Strengthening community · Mobilizing capital
	**Participation**	· Educate and change behavior of participants through the prize process	· Strengthening community · Educating/improving skills
	**Market stimulation**	· Emulate market incentives, driving costs down through competition and exposing latent demand	· Identifying excellence · Mobilizing talent, capital · Focusing a community · Influencing perception
	**Point solution**	· Solve a challenging, well-defined problem requiring innovation	· Focusing a community · Mobilizing talent

3 Scope and Methodology

This report synthesises the existing evidence on the effects of innovation inducement prizes. It relies on the existing evidence and does not conduct any primary research. This report builds on two key sources: a) a number of influential scholarly works on innovation inducement prizes that were identified from a series of keyword searches of the SCOPUS database and b) other forms of independent assessments of prize systems and individual evaluations of prizes.

As discussed at the previous section, prizes span a wide variety of domains. This report focuses only on ex-ante innovation inducement prize. Therefore it excludes ex-post recognition prizes (e.g. Nobel Prize and Queen's Award for Enterprise) as well as prizes not focusing on innovation.

This section summarises the main results of the (limited) evaluations and academic contributions as to the effects of prices. The number of ex post contributions, assessing the effects after the prize competition has finished is very limited. There is also a broad number of ex ante evaluations that look at the viability of a particular prize design in general or in a specific context before it is put in practice. This report includes both ex-post and ex-ante evaluations of innovation inducement prizes.

4 Effects

Evidence on the effectiveness of prizes is scarce. There are only a few evaluations or academic works that deal with the creation of innovation output and even those which deal with the innovation output only rarely deal with additionality, i.e. whether these effects would have happened anyway or with an alternative prize design or another innovation policy measure (Kay, 2012; Murray et al., 2012; Williams, 2012). This section of the report summarises the

evidence first starting with the limited number of studies dealing with innovation output (Section 4.1). It also includes evidence on the effect of innovation inducement prizes on raising awareness and prestige, experimentation and data creation (Section 4.2). Furthermore, it briefly discusses the design related issues that might influence the innovation performance such as motivations of participants, number of participants, prize objectives, selection of the winner and finally prize conditions related to demand for innovation (Section 4.3 and 4.4). Finally it discusses prizes in interaction with other demand side measures (Section 4.5) and the importance of experimentation and data creation (Section 4.6). The studies that have been found and used which present ex-post evidence or ex-ante conceptual consideration and effect expectations are summarised in Table 1 at the end of this section.

4.1 Innovation Performance

Only a very limited number of studies looked at if innovation inducement prizes led to more innovation itself or innovation outputs. One of the very few of clearly focused studies analysing the relationship between innovation inducement prizes and innovation performance is by Brunt et al. (2011). This econometric study looks at the role of the Royal Agricultural Society of England (RASE) annual competitions between 1839 and 1939 in the patent output of the participants and it finds that i) RASE competitions, especially larger and more prestigious ones, created competitive entry, ii) RASE spurred patents (both monetary prizes and medals have a positive relationship with the number of extended patents) and iii) RASE medals were more important than monetary rewards in increasing patent numbers.

Kay (2011a) looks at the Ansari X Prize (AXP) which awarded $10 Million winner-takes-all final prize offered to the winner of a competition to build and launch a spacecraft capable of carrying three people to 100 kilometres above the earth's surface, twice within two weeks in 2004. He estimates that $10 Million prize created over $100 million investment. Similarly, he investigates the Northrop Grumman Lunar Lander Challenge (NGLLC) also organised by X Prize Foundation in association with NASA and aimed at creating vertical take-off and landing technologies multi-layered multi-winner design. According to Kay (2011a) this $2 million prize spurred $20 million total investment. While it is not exactly clear how these values are calculated, he (2011a: 370, 373) also argues that the AXP "accelerated on-going R&D activity, attracted new innovative players, and induced conceptual and operational innovations as well" and the "triggered new R&D activity in a narrowly defined technology sector with no active developments". While assessing additionality is very difficult, Kay (2011a) concludes that additional and accelerated innovation can be created in the presence of open-ended rules, technology gaps to win the competition, and significant technology incentives.

Final evaluation that assesses the innovation performance implications of innovation inducement prizes is by Davis and Davis (2004). After the analysis of a number of historic prizes they argue that prizes might lead to less duplication compared to patents as the collaboration in prizes is more common and prizes can be more effectively designed to minimise duplication. However, they also warn that the prizes that do not allow patenting of the innovation might limit the further development of innovation by decreasing subsequent incentives.

4.2 Prestige and Raising Awareness

As well as developing the particular technology that the innovation inducement prizes produce, prizes create prestige for both the prize sponsor and entrants. In their evaluation of the Progressive Automotive Insurance X PRIZE (PIAXP), Murray et al. (2012) looked at the a prize that awarded $10 million to three teams that built cars which achieved 100 MPGe in real world conditions. This prize was supported by the insurance industry and also the US Department of Energy and it was delivered by the X Prize Foundation in collaboration with consultancy companies that specialise measuring energy efficiency. In their evaluation of the PIAXP Murray et al. (2012: 1791) establishe that as well as the solution to the defined problem, prizes are designed with "myriad of complex goals, including attention, education, awareness, credibility and demonstrating the viability of alternatives." Therefore, reaching to a winner and the solution does not necessarily define the success of the prize on its own. Rewards such as "publicity, attention, credibility, access to funds and testing facilities, community building" can be reached by non-winning participants as well and they justify the resources they invest. Davis and Davis (2004) also conclude similarly by arguing that prizes might spur spill-overs and they are effective sources of reputation for sponsors and entrants. This is also corroborated by Kay (2012) who argues that prizes create communities and networks which operate beyond a particular prize. Influencing public perception, focusing communities on specific problems and educating individuals are three of the seven areas identified where prizes influenced change by McKinsey & Company (2009) (others are identifying excellence, mobilizing new talent, strengthening problem-solving communities and mobilizing capital).

Prizes might also increase the public and sectoral awareness on specific technology issues. Anastas and Zimmerman (2007) discuss raising awareness opportunity as one of the foremost benefits of the prize on Green Nanotechnology they proposed. The National Research Council (2007) recommends that NSF should design a series of prizes in which raising public awareness should be an important aim.

One example of a concrete reputation and awareness effect is presented in a report by the US Defense Advanced Research Projects Agency DARPA Prize Authority. A DARPA report concludec that the media coverage of the 2004 and 2005 DARPA Grand Challenge prizes attracted innovators who have not previously worked with DARPA (DARPA Prize Authority, 2006).

4.3 Motivations

A related issue to the prestige gained from the prizes is the motivations of participants as a conditioning factor for innovation performance. Kay (2011a) argues on the basis of empirical evidence that, in the context of AXP and NGLLC, reputation and learning and value of technology is the most important motivation for "unconventional prize participants" that do not have prior activity in the technology area of the prize while for "conventional prize participants" that have some prior experience, reputation is also important but they are less interested in with the overall value of the technology. In another study concerning Google Lunar X Prize, Ansari X Prize, Northrop Grumman Lunar Lander Challenge, Kay (2012) argues on the basis of qualitative evidence that non-monetary incentives and potential market value of technologies are more important incentive than the monetary prize. In their field experiment analysed econometrically, Boudreau and Lakhani (2011) show that cash incentives increased the effort and performance of especially higher skilled participants. Lakhani et al. (2011) also

econometrically analysed the data from the InnoCentive.com where over 80,000 independent scientists (solver) try to solve problems posted by individual firms or research establishments in return of a prize or recognition. They established that i) the more different the solvers expertise than the problem, the more likely that they produce a winning solution due to the fact that being "outsider" increase the chance of a fresh look and innovative solution, ii) teams with more diverse expertise are more likely to come up with a solution with teams with more expertise but only on the topic of the problem and iii) career and social motivations are more important than cash prizes. Similarly, evaluation of NESTA's Big Green Challenge found that the enhanced credibility from being part of the prize enabled Finalists to attract partners and leverage funding (Brook Lyndhurst, 2010).

4.4 Design Issues

Design issues are the main concern of the prizes literature. This reflects the importance of a careful design for the achievement of desired effects (and the limitation of undesired effects). Kay (2012) argues that unsuccessfully designed prizes might do more harm than good by depreciating the trust of stakeholders, displacing efforts and spending too much resource on administering the prize process.

There are a relatively large number of studies that investigated the influence of the design of prize objective on the innovation performance. Brook Lyndhurst (2010) argued in their evaluation of the NESTA's Big Green Challenge that the specific design features of a prize model can exert a strong influence on the effectiveness of community innovations - it is not enough to have a single outcome measure (such as CO2 reduction). Kay (2011a) argues that only open ended prize rules and objectives can attract diverse participants and "unconventional participants", who in turn are more likely to pursue novel approaches. He also underlines the importance of flexibility in the design by pointing out that R&D approaches and technologies that entrants would choose might not be successfully anticipated/planned by the sponsor ex-ante (Kay, 2012). In another study, Kay (2011c) lists the required design features for innovation performance as

- Defining an exciting prize challenge
- Setting a prize reward that considers commercial opportunities and other non-monetary benefits of participation for prize entrants
- Crafting simple and transparent prize rules
- Defining a scheme to finance the program that considers alternative funding sources

Reinforcingly, Murray et al. (2012) conclude that the objective of a prize is not always very easily definable due to technological nature of the objective. Similarly, badly designed criteria bias the competition and limit the innovation effect. Prize governance and management matters greatly and flexible approaches are needed. However, this might be the major source of cost for the prize.

DARPA Prize Authority (2006) evaluation of DARPA's 2004 and 2005 DARPA Grand Challenge shows that persistence in prize objective might pay off. The aim of both prizes were to finish a challenging desert course by an unmanned car. The 2004 Prize had offered $1 million but no vehicle could complete the 132 mile test route during the given time (the best was 7 miles). In 2005, with the same objective and rules, 5 participants finished the route and 21 participants

progressed more than 7 miles. Therefore, continuation of the Prize in 2005 in spite of the failure in 2004, led to major technological progress.

Teamwork is one of the design issues whose implications for the innovation performance is discussed in the literature. Boudreau and Lakhani (2011) conducted a 10 day field experiment of a contest where 500 software developers tried to solve a particular problem. They divided the sample into two groups: a sorted group of individuals assigned groups or individual working based on their preference and an unsorted group consisting of people randomly allocated to teams or individual working. They econometrically showed that sorting almost doubled problem solving performance. This is widely cited in the prizes literature to show that while teamwork is an important facilitating factor for innovation performance, this should be voluntary and natural and those prizes whose rules are too strict to force teamwork might decrease the innovative performance. In another study, Boudreau et al. (2011) analysed the TopCoder competition that is aimed to attract coders to develop solutions for certain problems, which in turn generate profit for the organiser. They asked the question whether adding more competitors increases or decreases the efficiency of a prize competition and try to find out an optimal number of participants. Their results show 3 different effects of participant numbers on the outcome:

- Negative incentive effect: the higher the number of the participants, the lower the expected incentives for participants, the less likely the outcome (i.e. solution)
- Positive parallel paths effect: the higher the number of participants, the more variation in exploration pathways, the more likely the outcome (especially by the top performers)
- Moderating uncertainty effect: the more multidisciplinary is needed to solve the problem, the more uncertain the solution, the more likely the positive parallel paths effects and the less likely the negative incentive effects

Boudreau et al. (2011) study implies that generalised free entry decreases the success and should only be used where there is high degree of uncertainty to be able to benefit a situation where positive parallel paths effect outweighs negative incentive effects. In contrast, Davis and Davis (2004) argued that more inclusive criteria for eligibility tends to create more innovation.

Finally, Kalil (2006: 6) argued that "prizes are especially suitable when the goal can be defined in concrete terms but the means of achieving that goal are too speculative to be reasonable for a traditional research program or procurement".

4.5 Prizes and Other Demand Side Measures

A number of studies points out that sometimes prizes should be accompanied with or followed by other demand side initiatives to fulfil their objectives mostly on the basis of ex-ante evaluations. Williams (2012) argued that advanced market commitments and product sales conditional prizes are effective ways of ensuring that the technology developed through the prize process is socially desirable. In these prize designs pricing of the final product to be developed is an important element so that the prospective developers has sufficient incentives. Wilson and Palriwala (2011) look at this issue in in their assessment of the two different prize proposals to develop a TB diagnostic product by X-Prize Foundation and Bangladesh, Barbados, Bolivia, and Suriname (BBBS), where the objectives are very similar but the proposed mechanisms are different. They conclude that some sort of market condition (e.g. price ceiling for the final product) is required for these prize proposals to accomplish the aim. With a similar

argument, Masters and Delbecq (2008) argued that a proportional prize where the prize is awarded according to the impact created in the African Agriculture sector might provide a leverage effect. However, in contrast to Williams (2012), Masters and Delbecq (2008) and Wilson and Palriwala (2011), Davis and Davis (2004) argue that historical prize examples show that ensuring buyer commitment is not necessarily a problem.

In her ex-ante assessment of the Medical Innovation Prize Act of 2005 in the USA, Wei (2007) argues that this proposed prize which aims to fill a gap to induce innovation in non-blockbuster drugs that the patent system are not able to close, will potentially suffer from the issues such as i) problems of deciding on the prize value due to information asymmetries and difficulty of assessing the social value of medical innovations, ii) duplication of resources, iii) ineffective creation of marketing opportunities and finally iv) potentially high administrative costs. She proposes that the proposed structure given in the Medical Innovation Prize Act of 2005 might be useful if it is operated as optional not compulsory (see Masters (2003); Shavell and Van Ypersele (2001) for more discussion) and only focusing on specific technologies that the current patents system is ineffective in dealing with.

4.6 Experimentation and Data Creation

Prizes are also seen as a valuable opportunity for experimentation in innovation policy. Anastas and Zimmerman (2007: 7) asserted that the Green Nano Prize they proposed can provide a very good of source of data "on industrial processes that improve human health and the environment that are currently very difficult to obtain". National Academy of Engineering (1999) recommended experiments in the US Departments into the effectiveness of prizes in creating a complementary mechanism, where these prizes should be designed flexibly. They also recommended that these experiments should be closely evaluated. More specifically, National Research Council (2007) suggested that NSF should experiment with prizes, in variety of designs and these experiments should start in small scales where the prize is designed by NSF and continue with larger scales where there is a process of translating grand challenges to prize objectives. Kalil (2006) argued that the transition from the experimentation phase to institutionalisation can be accomplished if support agencies have dedicated resources for collaborative generation of prize ideas and legislative infrastructure for organising prizes, especially with private partnership and internationally should be in place.

5 Conclusion

This report aimed to synthesis the literature on the evidence of the effectiveness of innovation prizes. To do this, a brief discussion of prize rationales and typologies is followed by a discussion of effects grouped around issues such as innovation performance, prestige and raising awareness, participant and sponsor motivations, various design issues, other demand side measures and finally experimentation and data creation.

It is evident from the literature we analysed that the evidence on the impact of innovation inducement prizes is scarce for two main reasons. First, although prizes have a relatively long history, it is only recently they are being rediscovered in innovation policy in some countries while they are non-existent in the innovation policy-mix of majority of countries. Therefore, the number of studies that look at impact is relatively low. Second, there are additional evaluation challenges for prizes. Measuring impact is very difficult and costly in prize competitions and

when additionality is relatively more difficult to assess. This is due to the fact that the fundamental additionality question (i.e. treatment and non-treatment outcomes are not observable at the same time, therefore what would have happened in the absence of a prize is very difficult to assess) is more prevalent in a prize setting. And third, it seems that non-monetary incentives and gains are more important to prizes than they are to other policy measures (Kay, 2012; Murray et al., 2012; Williams, 2012).

There is also a consensus that innovation inducement prizes are not a substitute to other innovation policy measures but they are complementary under certain conditions. For instance, Kay (2012) argues that prizes can only be effective if the technology areas that i) the prize targets are specific, ii) potential solution would be easy to verify and understand iii) and also core technologies required for the solution are easily available to all participants. Similarly, Wilson and Palriwala (2011) suggests that prizes are more appropriate only if there is a clear path to a solution and also there are many potential solvers who has reasonable access to other funding. Prizes might also be ineffective in economic slowdown periods (Kay, 2011a) as they require ex-ante investment by the prize participants who might already be constrained by financing problems.

Prizes can be effective in creating innovation through more intense competition, engagement of wide variety of actors, distributing risks to many participants and by exploiting more flexible solutions through a less prescriptive nature of the definition of the problem. They can overcome some of the inherent barriers to other instruments, but if prizes are poorly designed, managed and awarded, they may be ineffective or even harmful (Kay, 2012; Murray et al., 2012; Williams, 2012).

Annex

Table 1: Summary of the Evidence on the Effectiveness of Innovation Inducement Prizes Based on Empirical and Conceptual Literature

Reference	Prize	Method/Data Source/Timing	Findings
(Anastas and Zimmerman, 2007)	A Proposed Green Nano Award	Ex-ante assessment	• This kind of award can provide a very good of source of data "on industrial processes that improve human health and the environment that are currently very difficult to obtain." P7 • It might provide a raising awareness opportunity
(Boudreau and Lakhani, 2011)	Custom designed software development contest	Field experiment analysed econometrically	10 day field experiment in a contest where 500 software developers tried to solve a particular problem. They divided the sample into two groups: a sorted group of individuals assigned groups or individual working based on their preference and an unsorted group consisting of people randomly allocated to teams or individual working. Results: • Sorting almost doubled problem solving performance • Cash incentives increased the effort and performance in both groups and more greatly of higher skilled participants.
(Boudreau et al., 2011)	TopCoder Software Contest	Econometric analysis	This study tries to find out if adding more competitors increase or decrease the efficiency of a prize competition and tries to find our an optimal number of participants. Their results show 3 different effects of participants numbers on the outcome: • Negative incentive effect: the more the number of the participants, the less expected incentives for participants, the less likely the outcome • Positive parallel paths effect: the more the number of participants, the more variation in exploration pathways, the more likely the outcome especially by the top performers • Moderating uncertainty effect: the more multidisciplinary the problem, the more uncertain the solution, the more likely the positive parallel paths effects and the less likely the negative incentive effects Implication for prize design: • Generalised free entry decreases the success and should only be used where there is high degree of uncertainty to be able to benefit a situation where positive parallel paths effect outweighs negative incentive effects.
(Brook Lyndhurst, 2010)	Big Green Challenge	Mixed Method	This is an accompanying evaluation of NESTA's Big Green Challenge which aimed "community led responses to climate change" • "An outcome based prize can provide the right incentives to stimulate results-focused community led innovation. • The specific design features of a prize model can exert a strong influence on the effectiveness of community innovations - it is not enough to have a single outcome measure (such as CO2 reduction). • Enhanced credibility from being part of the Big Green Challenge enabled Finalists to attract partners and leverage funding. • An outcome prize reduces risks for funders but increases them for communities. • A prize is not a substitute for grant funding."

Reference	Prize	Method/Data Source/Timing	Findings
(Brunt et al., 2011)	Royal Agricultural Society of England (RASE) annual competitions between 1839 and 1939	Econometric Analysis	This study looks at the impact of RASE prizes on innovation performance as measured by patents. Results: • Prizes especially larger and more prestigious ones created competitive entry • Prizes spurred patents. Both monetary prizes and medals have a positive relationship with the number of extended patents. • Medals were more important than monetary rewards in increasing patent numbers
(DARPA Prize Authority, 2006)	DARPA Grand Challenge	Ex-post Internal Assessment	• Ex-post internal assessment of DARPA's $2 million prize for the fastest unmanned vehicle in 2005. 2004 Prize had offered $1 million for the same goal but no vehicle could complete the 132 mile test route during the given time (the best was 7 miles). In 2005, 5 participants finished the route and 21 participants progressed more than 7 miles. • The media coverage of this event attracted innovators who have not previously worked with DARPA. • Continuation of the Prize in 2005 in spite of the failure in 2004, led to major technological progress.
(Davis and Davis, 2004)	Role of prizes in three 20th century innovations	Historical accounts	The paper looks at the historical accounts of the motorized flight, human-powered flight, and energy efficient refrigerators and tries to assess the impact of prizes on them. Results: • Welfare effects of prizes: o Prize values are often arbitrary and does not reflect the social value of the innovations induced o Prizes might lead to less duplication compared to patents as they collaboration in prizes is more common and prizes can be more effectively designed to minimise duplication o Prizes might spur spill-overs and they are a more effective source of reputation for sponsors and entrants o Prizes that do not allow patenting of the innovation might limit the further development of innovation by decreasing subsequent incentive • Design Issues: o Ensuring buyer commitment is not necessarily a problem o More inclusive criteria for eligibility tends to create more innovation
(Kalil, 2006)	A set of proposed prizes	Ex-ante assessment of proposed prizes	• "Prizes are especially suitable when the goal can be defined in concrete terms but the means of achieving that goal are too speculative to be reasonable for a traditional research program or procurement." P6 • The less prescriptive nature of prizes in terms of how to reach a certain goal might make it more conducive for exploration in innovation. • Prizes can overcome some of the inherent problems of other instruments • To be able to institutionalise prizes as an innovation policy, support agencies should have dedicated resources for collaborative generation of prize ideas and legislative infrastructure for organising prizes, especially with private partnership and internationally should be in place. • Prize victory conditions should be too easy nor too

Reference	Prize	Method/Data Source/Timing	Findings
			hard, nor too ambiguous nor too precise.
(Kay, 2011a)	Ansari X Prize and the Northrop Grumman Lunar Lander Challenge	Case study analysis of primary and secondary written material	• **Leverage of Prize:** o AXP: $10 Million winner-takes-all final product prize created over $100 Million investment o NGLLC: $2 Million multi-layered multi-winner prize created $20 investment • **Innovation Effects:** o AXP: "accelerated ongoing R&D activity, attracted new innovative players, and induced conceptual and operational innovations as well" p370 o NGLLC: "triggered new R&D activity in a narrowly defined technology sector with no active developments." p373
(Kay, 2011c)	Ansari X Prize, Northrop Grumman Lunar Lander Challenge, Grand and Urban Challenges of DARPA	Case Studies	• Required design features: o Defining an exciting prize challenge o Setting a prize reward that considers commercial opportunities and other non-monetary benefits of participation for prize entrants o Crafting simple and transparent prize rules o Defining a scheme to finance the program that considers alternative funding sources
(Kay, 2012)	Google Lunar X Prize, Ansari X Prize, Northrop Grumman Lunar Lander Challenge	Review of existing evidence	This is a review of evidence provided by (Kay, 2011a, b) and other sources. Findings: • Non-monetary incentives and potential market value of technologies are more important incentive than the monetary prize • R&D approaches and technologies that entrants would choose might not be successfully anticipated/planned by the sponsor ex-ante. • Non-winning participants also successfully create intermediate innovations. This effect is greater when rewards are larger, challenge is open ended, and there are large technology gaps to reach the goal. • Conditions for more effective prizes: o Technology areas that the prizes target should be specific and potential solution would be easy to verify and understand o Core technologies required for the solution should be easily available to all participants o There are monetary and non-monetary rewards that are attractive for all the participants • Prizes create communities and networks which operates beyond a particular prize • Unsuccessfully designed prizes might do more harm than good by depreciating the trust of stakeholders, displacing efforts and spending too much resource on administering the prize process.
(Lakhani et al., 2011)	InnoCentive.com	Econometric analysis, simulations and mathematical modelling	They analyse the data from the InnoCentive.com where over 80,000 independent scientists (solver) try to solve problems posted by individual firms or research establishments in return of a prize or recognition. • The more different the solvers expertise than the problem, the more likely that they produce a winning solution due to the fact that being "outsider" increase the chance of a fresh look and innovative solution • Teams with more diverse expertise are more likely to come up with a solution with teams with more

Reference	Prize	Method/Data Source/Timing	Findings
			expertise but only on the topic of the problem • Career and social motivations are more important than cash prizes
(Masters and Delbecq, 2008)	Proposed Prize for an African Agriculture Prize	Ex-ante assessment of proposed prizes	• Features of successful prizes: o achievable but difficult goal aimed at a good timing o clear winning criteria o credible and transparent judging process • A proportional prize where the prize is awarded according to the impact created in the African Agriculture sector might provide a leverage effect.
(McKinsey & Company, 2009)	12 Prizes	Case study of 12 Prizes and a survey of a number of other prizes	• This study, among other things, analyses 12 prizes through case studies. All of these prizes organised by non-governmental sponsors and some of them are out of this study (recognition prizes etc.) • Charitable prizes are growing much faster than the charitable activity in the US (18% versus 2.5%). • Prize organisation and management becoming institutionalised with the emergence of organisations that provide this service for other entities (e.g. X-Prize Foundation, InnoCentive, Idea Crossing, etc.) • Growing number of prizes posit a duplication risk and the sophistication of mechanisms are not growing as fast as prize numbers and amounts. • 7 areas identified where prizes influenced change: o Identifying excellence o Influencing public perception o Focusing communities on specific problems o Mobilizing new talent o Strengthening problem-solving communities o Educating individuals o Mobilizing capital
(Murray et al., 2012)	Progressive Automotive Insurance X PRIZE (PIAXP)	Case Study	This is a real-time evaluation of PIAXP offered in 2006 by the X Prize Foundation for the development of an efficient car. Findings: • As well as the solution to the defined problem, prizes are designed with "myriad of complex goals, including attention, education, awareness, credibility and demonstrating the viability of alternatives." (p.1791) Therefore, reaching to a winner and the solution does not necessarily define the success of the prize on its own. • Not always the objective of a prize is very easily definable due to technological nature of the objective. Badly designed criteria bias the competition and limit the innovation effect. • Rewards such as "publicity, attention, credibility, access to funds and testing facilities and community building" can be reached by non-winning participants as well and they justify the resources they invest. • Prize governance and management matters greatly, and flexible approaches are needed. This might be the major source of cost for the prize.
(National Academy of Engineering, 1999)	Use of Federal Prizes in the US	Ex-ante assessment by an expert panel reinforced by a background report	• There should be experiments into the effectiveness of prizes in creating a complementary mechanism • Prizes should be designed flexibly • The experimentations recommended should be closely evaluated
(National Research	Use of Prizes in NSF	Ex-ante assessment of	• NSF should experiment with prizes, using a variety of designs.

Reference	Prize	Method/Data Source/Timing	Findings
Council, 2007)		the use of prizes in NSF	• These experiments should start in small scales where the prize is designed by NSF and continue with larger scales where there is a process of translating grand challenges to prize objectives. • Raising public awareness should be an important aim of NSF prizes.
(Williams, 2012)	America COMPETES Reauthorization Act	Ex-ante analysis	• Advanced market commitments and product sales conditional prizes are effective ways of ensuring that the technology developed through the prize process is socially desirable. In these prize designs pricing of the final product is an important element.
(Wilson and Palriwala)	Two proposals for Tuberculosis Diagnostic	Ex-ante assessment through case study	• This study assesses the two prize proposals to develop a TB diagnostic product by X-Prize Foundation and Bangladesh, Barbados, Bolivia, and Suriname (BBBS), where the objectives are very similar but the proposed mechanisms are different • Milestone prize rather than end-product prize is more suitable for this objective as o There is a substantial demand and expertise to develop the product at the final phase o Current main barrier is technological which might be overcome by a milestone prize that is attractive to new and small players • Some sort of market condition (e.g. price ceiling for the final product) is required for the prize to accomplish the aim • In general, prizes are more useful compared to other measures if o There is a clear part to a solution o There are many potential solvers who has reasonable access to other funding
Wei (2007)	Medical Innovation Prize Act of 2005	Ex-ante analysis	This proposal can only be useful if it is operated as optional and not only focusing on specific technologies that the current patents system is ineffective in dealing.

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