# Incentive Competitions as a Policy Tool for Technological Innovation

by

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**Abstract**

Large incentive competitions are becoming increasingly popular amongst policymakers and philanthropists as a mission-orientated tool for inducing innovation, particularly in areas of national priority where market incentives and conventional tools such as patents and procurements tend not to be sufficient. Using inducement mechanisms (motivators) such as a large financial reward, demanding deliverables, and technical support, incentive competitions seek to motivate innovators to exert effort and develop creative solutions to pre-defined problems. According to the literature, these motivators can be powerful mechanisms for influencing effort and creativity but their effectiveness very much depends on the combination of motivators used and conditions under which they are executed. There is a serious lack of empirical evidence on the motivators and conditions of large incentive competitions and their effectiveness to influence behaviour and outcomes. Therefore, we cannot fully appreciate the role of large incentive competitions in the innovation policy tool kit. A small body of empirical data exists on the impact of motivators within small online prizes but these prizes are very different to large incentive competitions in terms of the intended motivators incorporated and the competition-environment.

Through qualitative and quantitative analysis of one large incentive competition- the Progressive Automotive XPRIZE (PIAXP), this thesis aims to explore the motivators incorporated into PIAXP and their ability to orient people towards a specified mission and induce innovative behaviour. In turn, this thesis aims to 1) better understand the role incentive prizes as an innovation tool and 2) identify the motivators and prize design that can be used in incentive competitions to promote desired outcomes. My research identifies two unique features of PIAXP, which can provide insight into large incentive competitions in general. 1) PIAXP effectively attracted and focused a diverse set of solvers on a specific problem, who otherwise would not or could not pursue the prize objective(s). For example, 35% of teams did not exist before. Of those teams that did exist, 30% were informal and 17% were non-vehicle-related, all turning to formal vehicle teams for the PIAXP; 2) PIAXP facilitated the development of participating teams and ideas, and actively induced innovative behaviour during the competition. These findings emphasize the important of motivators and prize design to attract and support the development of solvers and solutions. In terms of competition design, participants and organizations were influenced in different ways. Influential motivators included: recognition (validation, publicity, and personal pride), performance accelerators (business and personal), and intrinsic passion for the cause. Other elements of design that influenced entry levels and behaviour included: structure (length/ barriers to entry), categories (broad, specific or multiple), collaborative events, and support (for the organization and individual). Success within PIAXP was positively correlated with compensation and competition but negatively correlated with recognition. Effort was positively correlated with reputation but negatively correlated with fun.

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# Chapter 1: Introduction

## Innovation Incentives

Policymakers are interested in mission-orientated policy tools that can influence the rate and direction of technological advancement towards areas of national priority. In particular, policymakers are looking for mechanisms that can 1) channel effort towards an objective without specifying the solver or solution i.e. without "picking winners" 2) attract and induce diverse participation in the problem-solving process 3) accelerate the problem-solving process, and 4) promote the development of innovative solutions in a low risk environment.

Conventional mechanisms such as patents and procurement seem to meet a number of these criteria but remain inefficient for meeting others. Through the promise of a temporary monopoly, patents provide a financial incentive to induce the birth and growth of diverse innovations without regard to the solver or solution. The prospect of high future returns induces private companies to invest in basic R&D projects, inventors to commercialize their ideas, and investors to support the development of inventions, despite the large up-front capital and long-lead times. This policy is low risk from the sponsor's perspective because the reward is contingent on market success of the product. Furthermore, this policy can act to accelerate the development of a product, from the idea generation stages through to commercialisation and deployment. However, the patent model presupposes that the importance of specific innovation challenges is closely linked to the potential market opportunity, which is often not the case for areas of social importance because of underdevelopments in their markets. Therefore, patents are effective at promoting general innovations but not as a tool for inducing and directing effort towards a specific cause.

Procurement on the other hand does allow for policymakers to influence the direction of the innovation. Basic R&D grants can provide scientists with the resources necessary to explore and advance our understanding in specific areas of national interest in the hope that new ideas will be generated and picked up by the patent system. Specific procurement (competitive or direct) can focus a solver on a specific problem and deliver a solution in a timely fashion. One problem with this system is that adverse selection occurs as a result asymmetric information that exists between the sponsor and the inventor. For the money to be appropriately allocated, ex ante selection of the best solver and solution must occur (even through a competitive auction process). This is difficult to achieve and thus sub-optimal solutions result. Furthermore, this process is also susceptible to moral hazard. The sponsor pays for research input, rather than output, and thus it is difficult to "prevent researchers from shirking, either by applying little effort or by focusing on areas of pure scientific interest" (Kremer, 1998).

Prizes, or more specifically large incentive competitions, are a possible supplement to conventional innovation incentives, particularly for inducing innovative effort towards specific social challenges where the associated technologies otherwise lack market incentives to be developed. Through inducement mechanisms such as a large financial reward, demanding deliverables, and technical training, incentive competitions seek to motivate innovators to exert effort and develop creative solutions to pre-defined problems. Through these mechanisms, competitions have the potential to attract a diverse set of innovators and innovations ex-ante and reward the prize ex post, which reduces issues of adverse selection and moral hazard. In other words, competitions can provide a mechanism for policymakers to define the criteria upfront and award on delivery of results which allows sponsors to influence the direction of innovation without picking winners. In addition to large incentive competitions acting to "crowdsource" solutions, some modern incentive competitions aim to facilitate the development of innovative solutions during the process through the various inducement mechanisms incorporated and support structures in place (e.g. MIT Clean Energy Prize)[1].

**Historical Successes and Current Initiatives**

Perhaps the most famous example of a successful prize policy was the Longitude Act of 1714. This policy involved a monetary reward of £20,000 (equivalent of $12 million today) set by British Parliament for the development of a method to calculate longitude at sea – a solution to which would save thousands of lives a year and provide the British navy with a considerable competitive advantage at sea. From Galileo to Newton, famous astronomers and scientists from around the world engaged in the quest to solve this problem of accurate navigation through traditional theory but to no avail. The problem was finally solved by an unknown clockmaker from North Yorkshire, John Harrison, through the development of a highly precise chronometer (Sobel, 1995). The prize model as mission-oriented policy is not limited to the United Kingdom. A number of important innovations also emerged from French Prizes during this period. In 1775, the French Academies of Science offered 12,000 francs for the development of artificial alkali, which ultimately lead to the growth of the nineteenth century inorganic chemical industry (Davis, 2004). In 1795, a 12,000 franc purse for a method of food preservation usable

[1] It is important to note that the concept of an incentive prize is different from an award such as the Nobel Prize. Indeed, they differ in terms of both objective and design. Incentive competitions are designed to induce solvers to focus on a specific challenge. The challenge/ objectives are set ex ante and people choose to actively participate in the challenge upfront. Furthermore, incentive competitions incorporate a complex set of motivators and can involve a number of stages and onsite activities. Awards tend to exist to recognize prior achievements rather than induce effort towards a specific goal. Furthermore, people do not actively sign up for an award and their accolades are determined ex poste.

by the French military was offered by the Napoleon's Society for Encouragement of Industry, thus spurring the development of food canning (Wright, 1983, p704). These examples imply the power of prizes to solve problems unable to be solved through traditional means. They also imply the advantages of exposing a problem to a diverse set of participants.

Today, prizes are once again becoming of interest to government agencies as policymakers are forced to confront a growing range of social challenges that lack market incentives to promote technological advancement at a preferable rate. In the United States, this interest has recently transformed from a few isolated experiments to a broader policy initiative. Through a series of regulations and recommendations, the Obama administration has sought to accelerate the adoption of prizes, and emphasizes their role as a major innovation tool, within both the public and private sector. As stated by the National Economic Council, Council of Economic Advisors, and Office of Science, Technology and Policy, "in the months to come, the Obama Administration will work closely with key agencies to leverage the new authority for ambitious prizes in areas of national priority". More specifically, following the release of the President's Strategy for American Innovation in September 2009, the Office of Management and Budget issued guidance in the form of a memorandum for all government agencies to promote and harness innovation through prizes and challenges. With the December 21st passage of the America COMPETES Reauthorisation Act, federal agencies were also given broad prize authority making it much easier for agencies to use prizes and challenges. Not limited to the USA, during a speech given at the Royal Institution (9th July 2010), the UK Science Minister identified public (and publically-inspired) challenges as one of three key UK strategies for promoting technological growth.

**Motivation**

Given the vast history of competition, and the dramatic expansion of interest in incentive prizes, the theoretical and empirical understanding of their role in shaping the rate and direction of innovation activity remains surprisingly limited.

A small body of economic theory discusses prizes as a direct substitute to other incentive mechanisms (see Wright, 1983; Scotchmer, 2001; Kremer & Williams, 2009). However, the appropriateness of prizes as a supplement to other mechanisms or the effectiveness of prizes to induce participation and effort towards mission-orientated objectives is not discussed. Case-based studies of contemporary and historical prizes describe the outcomes of successful competitions and, by using simple ex post statistics, can demonstrate a prize's ability to effectively crowdsource solutions. However, the studies do not discuss how competition act to attract participants, or how competition

influences the behaviour of participants or solutions, if at all (despite the goal of many prizes being to actively influence effort). On the empirical side, the literature is just as sparse, with no evidence to my knowledge in regards to large incentive competitions. The most notable empirical study on competition is the Lakhani study on Innocentive (Lakhani, 2007). Lakhani demonstrates that competitions can successfully crowdsource solutions by showing that a significant portion of his Innocentive problem sample was successfully solved after the problems were exposed to a diverse set of online solvers. His research implies that effort can be induced by competition because the solvers significantly modified their solutions to meet the prize objective. His study also touches on the motivators that drive successful behaviour and shows that the motivators go beyond the prize purse and that both intrinsic and extrinsic motivators influence success. The problem with Lakhani's study, and others like it, is that it is limited in context and detail. Innocentive is an online crowdsourcing platform that aims to induce effort on part of the solver, but provides little incentive beyond the purse (and associated recognition) to induce this behaviour. Large incentive competitions are far more complex in nature in terms of structure and design, especially if they specifically intend to facilitate or accelerate the development of entries.

Without information on the motivators incorporated into the competition, the environment in which they are executed, and the outcomes that result, it is difficult to understand the effectiveness of competitions to induce innovation. Furthermore, controversy in the literature draws in to question the effectiveness of prize-motivators to induce effort and creative behaviour within a competitive prize environment. However, little empirical evidence exists to provide insight.

**Analysis**

The discrepancies within the motivation literature regarding the effectiveness of competition-motivators to positively affect behaviour, coupled with a serious lack of data-driven empirical analysis on incentives in the context of competitions, are the driving force behind this thesis.

This thesis is focused on one large incentive competition: the Progressive Automotive XPRIZE (PIAXP). Through an in-depth analysis of qualitative interviews with PIAXP participants and quantitative survey data form PIAXP participants, I seek to gain insight in to the mechanisms behind large incentive prizes. More specifically, I endeavour to investigate the reasons why individuals and companies chose to participate in PIAXP, and the effect that competition had on the participants involved, in terms of effort and creativity induced. By understanding the motivators incorporated into PIAXP and their influence on behavioural outcomes such as participation, effort and creativity, we can begin to appreciate whether prizes can be an effective supplementary incentive mechanism for innovation. We

can develop a better understanding of whether competitions can effectively attract and incentive innovation, where traditional mechanisms have previously failed; and whether competitions can induce effort from solvers that wouldn't otherwise participate in the innovation ecosystem. Furthermore, we can identify design traits within large incentive prizes that can be utilized by future prize designers to optimize desired outcomes.

To this end, my thesis proceeds as follows. In chapter 2, I examine the existing evidence on motivation with the intention of understanding the effectiveness of motivators to promote behavioural outcomes. I begin by creating a framework for conceptualizing the literature and my results. Using the developed framework as a guideline, I then assess the different motivators to promote desired behavioural outputs, particularly participation, effort and creativity. Finally, I contrast the insights gathered from the general motivation literature to the motivation literature that is specific to prizes to identify the gaps worth further exploration. In chapter 3, I describe the empirical setting and methods for my thesis. In chapter 4, I describe my qualitative and quantitative results determined from my data on the PIAXP, using the framework laid out in my literature review. This section is broken out in to four parts. First, I examine the motivators that were intentionally incorporated into PIAXP- the "proposed PIAXP inputs"- in the context of the XPRIZE Foundation's expectations and motivation literature. Second, I examine the "observed PIAXP inputs". Third, I examine the "observed PIAXP outputs", paying particular attention to participation of PIAXP, and the level of effort and creativity induced. Finally, I assess whether there exists any relationships between the PIAXP motivator inputs and behavioural outputs. I conclude in chapter 5 by discussing my results (motivator inputs and behavioural outputs) in the context of existing literature, and the extent to which I can use my findings to understand the role of competitions in the innovation policy toolkit and to design future competitions.

## A Framework for Assessing Motivation

Motivation theory can be conceptualised in two steps: motivator inputs and behavioural outputs.

### Motivator Inputs

Motivator inputs relate to the "orientation" or "type" of motivation, and are most often differentiated by the reasons one might engage in an activity (Deci & Ryan, 1985; Amabile, 1983). For example, as explained by Deci & Ryan (1985), a student can be highly motivated to do work out of curiosity and interest or, alternatively, because they want to procure the approval of a Professor. The student might be motivated because they understand their potential utility or value of work or because learning skills will yield a good grade and the privileges a good grade affords.

Motivator inputs range from financial reward, recognition and the desire to learn, to enjoyment and the thrill of a challenge. Nevertheless, according to both theory and empirical research, all motivator inputs can be categorized by two distinct types: intrinsic motivation and extrinsic motivation[2].

Intrinsic motivation arises from the inherent value of the activity, where one is motivated to act for the inherent satisfaction of the fun and challenge entailed. As defined by Amabile (1983), intrinsic motivators are an endogenous part of a person's engagement in the activity; they arise from the person's feelings about the activity, and they are necessarily bound up with the work itself. Individuals are known to be intrinsically motivated when they seek enjoyment, interest, satisfaction of curiosity, self-expression, or personal challenge in the work. Thus, the intrinsic motivators defined in the literature are self-determination, competence, challenge, task involvement, curiosity, enjoyment and interest, and are often clustered on to two scales, Challenge and Enjoyment[3] (Amabile, 1993; Deci & Ryan, 1992).

In contrast, extrinsic motivation pertains whenever an activity is done to attain some separable outcome, and is driven by external prods, pressures or rewards. In other words, individuals are known to be extrinsically motivated when they engage in the work for some instrumental value rather than doing something for the enjoyment of the activity itself. These include anything from an outside source that is intended to control (or can be perceived as controlling) the initiation or performance of the work,

[2] An experiment conducted by Amabile, Hill, Hennessey and Tighe, 1993 directly investigated the possibility of individual differences in intrinsic and extrinsic motivational orientations. They designed a short pencil-paper personality instrument, with items assessing all proposed aspects of intrinsic and extrinsic motivations. After questioning hundreds of working adults in a variety of professions, industries and levels, results found that intrinsic and extrinsic motivators have meaningful trait-like constructs.

such as promised reward, praise, critical feedback, deadlines, surveillance, or specifications on how the work is to be done. Thus, extrinsic motivators, as defined in the literature, include competition, evaluation, recognition, money or other tangible incentives, and constraint imposed by others. Extrinsic motivators are also often clustered on to two scales: Recognition and Compensation (Amabile, 1993; Deci & Ryan, 1992). One is the ability to be socially praised and the other is financial, but both originate externally.

Four sub-definitions of extrinsic motivation also exist to detail the internalization (or increasing personal commitment) of the motivator, because, according to the psychology literature, it is known to affect behaviour (Organismic Integration Theory, sub-theory of Self Determination Theory)[4]. These definitions include external regulation, introjected regulation, identification and integrated regulation, and are differentiated according to their degree of autonomy and the extent to which the motivation for one's behaviour emanates from one's self.

External regulation represents the least autonomous form of extrinsic motivation and is performed to satisfy an external demand or to obtain a predetermined reward. The individual tends to experience a lack of choice and therefore their actions have an, "external perceived locus of causality," or EPLOC (DeCharms, 1968). In other words, the causality of the action comes from somewhere other than oneself. An example of external regulation is an employee who is motivated to work on a task because it is part of the job description, however little he may enjoy the work.

Introjected regulation describes actions that are performed due to external pressure to avoid guilt or anxiety or to attain ego-enhancements or pride i.e. regulation by contingent self-esteem. Although this motivator is internal to the person, it is still classed as extrinsic because the pressure to act is external to oneself. An example of introjection is ego-involvement (Nicholls, 1984; Ryan, 1982) in which a person performs an act to enhance or maintain self-esteem and a feeling of worth such as one participating in a race to gain recognition. This type of motivator also experiences EPLOC as the causality of the action is external i.e. comes from a desire to gain recognition or maintain self-esteem.

Identification is when a person can identify with the personal importance of his or her behaviour. This type of regulation is more autonomous and self-determined as the person tends to

[4] Internalization describes how one's motivation for behaviour can range from amotivation- unwillingness, to passive compliance, to active personal commitment- with increasing sense of personal commitment- internalization- comes a greater persistence, more positive self-perceptions, and better quality of engagement. According the Deci & Ryan (1985), the more one internalizes the reasons for action and assimilates them to the self, the more ones extrinsically motivated actions become self-determined (i.e. more autonomous) but not intrinsic. Intrinsic motivation is a self-determined activity where the benefits are fully internalized such as person completing a task out of pure interest and pleasure.

regulate on his or her own, without inputs from others. An example of regulation through identification is when a student identifies with the value of a learning activity and memorizes spelling lists because they see it as relevant to writing, which is important to him/her.

Integrated regulation occurs when identified regulations have been fully assimilated to the self. This type of motivator is the most similar to intrinsic motivation as it is autonomous and non-conflicting but is still extrinsic because the behaviour is done for its presumed instrumental value with respect to an outcome that is separate from the behaviour, even though it is valued by the self (Deci & Ryan, 1992).

**Behavioural Outputs**

Behavioural outputs are what result from the motivator input(s) having impact on an individual's mindset. The motivator input influences the individual's perception of a task, and can therefore affect the way one behaves towards an activity and determine the outcome. Interestingly, the behavioural outcome is dependent on the motivator input, and, arguably the conditions and combination by which it is executed (Deci & Ryan, 1985). For example, a student might be more inclined to work hard on their homework if incentivized by a carrot, as opposed to a stick (effectiveness of motivators discussed in the next section).

When discussing the effectiveness of motivator inputs to achieve desired outcomes, theorists tend to make three distinctions. The first obvious yet important distinction to make is between motivation and amotivation. To be motivated is to be moved or driven to do something. A person who feels no impetus or inspiration to act is thus considered as unmotivated, whereas a person who is energized or activated toward an end is characterised as motivated (Deci & Ryan, 1999).

A second distinction, as an extension of the first, relates to the "level" or "amount" of motivation one has for an activity. Behaviour is not binary; rather one can feel "very motivated", "not very motivated" or somewhere in between, depending on the motivator input. For example, when one is working towards an impending deadline, a thesis deadline perhaps, one might be more inclined to dedicate more time and effort than usual, to ensure requirements are met in the specified timeframe. This is a useful distinction to make as most everyone who engages in work or play faces questions of "how much" motivation oneself, or another, has for an activity, and how to foster more motivation (Deci & Ryan 2000).

A third distinction, and perhaps the most useful, relates to the "type" of behavioural output. The three "types" often discussed in the literature include: participation, effort, and creativity. Understanding the motivator inputs in the context of these "types" can have considerable practical utility, especially in the context of a competition. If one understands the reasons why one engages in an

activity such a competition, why people exert effort, and how to promote creativity, one can design activities, or adjust their interactions with those who they are trying to motivate, to promote desired behavioural outcomes.

## Effectiveness of Motivator Inputs on Behavioural Outputs

Now that we have a framework to work within, we can begin to investigate the effectiveness of the different motivator inputs to promote desired behavioural outcomes; participation, effort and creativity. One might think this is an easy task, by simply measuring and recording the behavioural traits associated with the different motivators. However, interestingly, the effects of the different motivators are more controversial than one might think.

It is generally accepted in the literature that extrinsic and intrinsic motivators can control behaviour (e.g. Skinner 1953, Deci & Ryan 1971, Amabile 1983, Camerer & Hoigart 1999, Lazer 2000, Sherer 2004, Dickinson 1999, Villarroel & Tucci 2009, Lakhani 2008, and Lerner & Tirole 2002), and that motivators can have stable trait forms (e.g. Amabile study, 1983). However established this may be, there are significant disagreements in the literature regarding the ability for the different motivators to promote effort and creativity. This disagreement is especially strong along the boundary between economics and psychology. Furthermore, there seems to be different views regarding the synergistic affects of motivators and their effectiveness within certain environments.

This section aims to address these discrepancies by assessing the established views surrounding each type of motivator, in terms of their effectiveness. It is also of interest to establish the known cooperative or disruptive effects these motivators may have when used in concert, and how these combinations can create different patterns of behaviour output.

**Extrinsic Motivation: Compensation**

Rewards are the most common type of extrinsic motivators for controlling and promoting behavioural outcomes. By the 1970's, many studies had established that rewards increased the likelihood of repetitively eliciting behaviours.. Behaviour was shown to continue as long as the reward remained standing. When the reward was removed, performance of the task reverted to baselines established before its introduction (Skinner, 1953). These studies significantly influenced the minds of policymakers and industry leaders throughout the country and, before long, extrinsic reward schemes were commonplace in both domains.

Economists, in particular, are strong advocates for the use of financial reward schemes. Indeed, many believe that extrinsic rewards are not just useful but necessary to invoke participation in an

activity. They argue that an agent will only participate in an activity if they derive net extrinsic benefit from engaging in that activity, where the net benefit is equal to the immediate payoff. This is defined as current benefits minus current cost, plus the delayed benefit minus delayed cost (Lerner & Tirole, 2002).

Economists also argue that specially designed extrinsic rewards such as "pay-for performance" and "lump-sum" schemes can promote the participant to exert more effort on a task, and therefore enhance productivity, in addition to promoting participation. In other words, economists presume that people do not work for free, and work harder, more persistently, and more effectively, if money is offered for better performance.

Ample empirical evidence exists in the economic literature to support this viewpoint. The effectiveness of "pay-for-performance" schemes are demonstrated through studies such as the work on windshield installers in Safelite Glass Corporation (Lazear, 2000) and a randomized field experiment with Canadian tree-planters (Sherer, 2004), where productivity increases were observed when worker's compensation changed from fixed-wages to piece-rate (i.e. performance-based) pay. Productivity increases were also observed from experiments involving letter-typing (Dickinson, 1999), walnut cracking (Fahr & Irlenbusch, 2000), solving two-variable optimization problems (Van Dijk, Sonnemans & van Winden, 2001), and stuffing letters in to envelopes (Falk & Ichino, 2006). These studies found that subjects output (e.g. number of letters, walnuts cracked, solved problems) increased when their compensation was more sensitive to performance*5*.

"Lump-sum" goal orientated reward schemes have been found to be particularly effective motivators for sales people (Hull, 1932, 1938; Mace, 1985; Latham & Locke 1991). It is also argued that bonuses encourage people to reach sales targets that they otherwise would not obtain (Darmon, 1997). Moreover, some evidence suggests that lump-sum payments are more effective than pay-for-performance incentive structures. Through a study based on monthly observations of revenue production of 2,570 individual salespeople over the period of two years, it shows that lump-sum bonuses motivate salespeople to work harder, and to not play timing games. Bonuses cause those who are unlikely to make quotas reduce effort, but this effect is more than compensated for by productive increases in output by other salespeople within the same organization (Steenburgh, 2008)*6*.

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*5* Examples as presented in Manso's paper "Is Pay-for-Performance Detrimental to Innovation?"

*6* This study counteracted previous literature on lump-sum bonuses, which points out two arguments for why lump-sums are not effective. First, as described by Steenburgh, Holmstrom and Milgrom (1987) and Lal and Srinivasan (1993) state that the motivational effects of lump-sum bonuses disappear once sales quotas have been met and incentives have been earned: "It is not uncommon to hear of salespeople spending time playing golf or indulging in other leisurely activities if their past efforts have been unusually successful." A flat commission rate, on the other hand, should not induce such fluctuations in behaviour since the incentive to work is constant over time and independent of how well or poorly an individual has performed in the

Steenburgh states the rationale for such behaviour is " simple and well-known: quotas are set so as to provide salespeople with objectives that are challenging and worth being achieved. In order to enhance salespeople's performance, management grants them some reward when they reach a pre-specified performance level (the quota) which is higher than the level they would have achieved otherwise".

The economic literature surrounding open source projects also provides insight into the effectiveness of compensation as a motivator. Extrinsic reward such as pay, even in small amounts, was found to be the most statistically reliable predictor of participation and contribution on a firm-sponsored project website, Amazon Mechanical Turk (AMT). AMT is an online marketplace which enables "requesters" to submit simple tasks that an informal community of globally distributed contributors can solve. Contributors are anonymous to sponsors but can be contacted*7* . 40% of participants were from India, of which 30% said the money made was their primary source of income and just under 40% said it was their secondary source of income. 50% of participants were from the USA, 17% of which said it was their primary source of income and 60% said it was their secondary source of income. Compensation did not motivate everyone but seemed to be the dominant driver. Effort was demonstrated through the fact that 25% of these workers were contributing 4-8 hrs a week and 10% were contributing 20-40 hrs a week (Ipeirotis, 2010; Villarroel & Tucci, 2007). Interestingly, those who valued free time were negatively affected by rewards. This result implies that those positively affected by payments do not consider their time spent as free time. In other words, they receive some type extrinsic benefit from participation, although this benefit may not necessary be compensation.

In contrast to the economic literature, there exists an extensive body of empirical evidence to suggest that extrinsic rewards are not effective motivators for promoting participation or effort and, in some cases, can actually undermine performance. Furthermore, it has been shown that the behaviour of extrinsic rewards is not consistent over time, conditions, or between participants.

Much of the social psychological literature (esp. Lepper & Green, 1978) demonstrates that extrinsic constraints undermine intrinsic motivation. Since intrinsic motivation positively affects effort, these constraints are assumed to hinder performance as well.. A few examples of these constraints are

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past. Second, Oyer (1998) and Jensen (2003) state that lump-sum bonuses tempt salespeople to manipulate the timing of orders to meet sales quotas without having to expend additional effort.

*7* The statistical analysis of 391 complete responses to an online survey of contributors to Amazon Mechanical Turk showed that non-volunteerism factors (i.e. compensation) were reliable determinants of performance in the firm- sponsored online community (in addition to fun- a typically motivation found in online communities.

the promise of tangible rewards under controlling conditions such as deadlines (Amabile et al. 1967), evaluations (W.E. Smith 1975) and imposed goals (Mossho Ider, 1980).

An economics study comes to the same conclusion that extrinsic motivators can hinder effort, via different logic. The study shows that a small compensation per unit output may insult subjects leading them to exert less effort than if they were paid a fixed wage (Gneezy & Rustichini, 2000). Also, the introduction of explicit incentives can reduce the performance of workers in a firm- worker relationship because reciprocity was compromised[8].

Many psychologists do accept the ability for extrinsic rewards, such a piece-rate pay, to induce effort. However, they emphasise that the effectiveness will depend on the execution, specifically the degree of autonomy and level of personal endorsement involved (Deci & Ryan, 1985; Amabile, 1983). The more freedom one has to make a decision on whether to participate in an activity and the more they care about the experience and the outcome, the more internal is the drive to do well, and thus the more effort one is willing to put in to an activity, whether or not a reward is offered.

To emphasize the power of autonomy to impact behaviour, I will revert back to the thesis example. One the one hand, one might be motivated to write a thesis because the learning experience is valuable for their chosen career. On the other hand, the individual might be motivated to do it because a fear of department sanctions and a risk of not graduating. Both the desire to learn and fear of sanctions are extrinsic as they are pursued to attain a separable outcome. The difference between the two motivators is that the former case entails personal endorsement and a feeling of choice, where as the latter case involves mere compliance with external control. It is more than likely that the motivator input would influence the quality of the thesis (intrinsic motivators are also relevant here, but discussed in the following section).

Although psychologists accept the case for reward schemes in certain scenarios, they emphasize that they are only effective for influencing participation and effort. Amabile argues that "pay-for-performance compensation might induce effort or improve sheer technical quality by promoting repetition of previous successes (at the expense of the exploration of untested approaches), but does not promote creativity or innovative behaviour."

It is also important to note that the economic evidence given previously focuses on the principal-agent problem of how to induce the agent to exert more effort for a routine task, not necessarily innovative or creative behaviour. These studies are limited to judgement tasks such as

[8] Note: rewards discussed here are all pure piece rate i.e. they look in to effectiveness of rewards based on relative performance: the student with the highest score gets an A, the salesman who sells the most gets a large bonus, firm with largest market share becomes the leader, or best manager gets promoted to company vice-president.

memory or recall (where paying attention helps), probability matching (where predications are improved through memory of pasts trials), and clerical tasks (e.g. coding or building things).

For tasks that require exploration, creativity and innovation, many studies conclude that monetary incentives to motivate agents should not be used (McGraw 1978, McCullers 1978, Kohn 1993, and Amabile 1996). Experimental work by Amabile also supports this conclusion. She constantly shows that salient extrinsic motivators can lead to lower levels of creativity, and that certain factors can synergistically hinder the behavioural outcome of extrinsic reward. For example, Amabile found that commissioned art work was significantly less creative than non-commissioned art work, but only when commissions were accompanied by some constraints on exactly how the work was being done (Amabile, Philips & Collins 1993). Within R&D labs, she shows that extrinsic motivators that have a negative impact on creativity include: win-lose competitions, expected negative evaluation of one's ideas, a concern with rewards, and a constraint on how work is being done. Amabile justifies this behaviour by stating that "non-synergistic rewards undermine self-determination without adding feelings of competence such as stringent controls that lead people to feel controlled by others". In other words, reward might not itself undermine intrinsic motivation and creativity but reward that signifies or is accompanied by constraint can have serious detrimental effects.

Amabile also argues that it is possible to actively improve the effectiveness of extrinsic rewards. She provided evidence to show that high levels of extrinsic motivation can be made to temporarily coexist, through training and experimentally-induced situational factors, with very positive effects on creativity (Hennessey, Amabile, & Martinage 1989; Hennessey & Zbikowski 1993).[9] In other words, training or encouraging people to focus on intrinsic benefits of the process, in addition to a reward can actually bolster creativity rather than detract from it.

So, although Amabile argues that extrinsic rewards cannot promote creativity by itself, and in some cases it can undermine it, by supplementing the reward with intrinsic motivators or internalized extrinsic motivators, one can actually promote creativity. Supplementary behaviour or the coexistence of intrinsic and extrinsic motivators can be extremely effective. Factors that have been shown to bolster

[9] In Amabile's study, small groups of children went through brief training sessions to encourage them to focus on intrinsic benefits of the task (i.e. learning benefits), and strategies for keeping extrinsic factors in perspective. The control group went through similar training on a different topic. The children were then asked to complete a creative task. Half the children were offered a reward, half the children were not.
The untrained children who were offered the reward produced less creative work than children who were not offered the reward. By contrast, the trained students who were offered the reward produced more creative work than the trained students not offered the reward.

creativity when supplementing reward include: reward or recognition for creative ideas, clearly defined project goals, and frequent feedback.

Manso supports the use of financial reward schemes to motivate an agent to be productive and innovative. Through both controlled laboratory experiments and observational studies, and in academic and business settings, Manso and co-authors show that performance-based financial incentives can promote innovation (more so than fixed-wages), but the incentive scheme must be structured differently from standard pay-for-performance schemes. The reward scheme must allow for a tolerance (or even reward) for early failure, and reward for long-term success. Moreover, Manso et al. emphasises that a commitment from management to a long-term compensation plan, job security, and timely feedback on performance are required to motivate innovation effectively. Such an incentive scheme should promote exploration (as opposed to exploitation), and the subjects are therefore more likely to discover a novel strategy than subjects under fixed wages or stand pay-for-performance incentive schemes (Manso et al. 2009)[10]. Manso's study also finds evidence to suggest that the threat of termination can undermine incentives for innovation, while "golden parachutes" can alleviate these innovation-reducing effects[11].

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[10] Two of the best studies to emphasize the effectiveness of "early-tolerance and long-term reward" are a controlled experiment on lemonade stands (Ederer & Manso 2009), and an observational study that compared the funding mechanisms of Howard Hughes Medical Institution and grantees from the National Institute of Health (Azoulay, Zivin & Manso). Ederer & Manso conducted a controlled experiment where 3 subject groups, each with a different compensation structure, control the operations of a lemonade stand for 20 periods. Subjects were able to make decisions on how to run their lemonade stand by choosing between fine-tuning product decisions given to them by the previous manager ("exploitation") or choosing a different location and radically altering the product mix to discover a better strategy ("exploration"). The only difference between the 3 subject groups was the compensation offered: group 1 was compensated through fixed-wages, group 2 was compensated through a standard pay-for-performance (i.e. receiving 50% of profits for 20 periods), and group 3 was compensated through contract tailored to motivate exploration (i.e. receiving 50% of profits produced during the last 10 periods, allowing the subjects to explore during the first 10 periods). The results showed that subjects under the exploration contract were more likely to find an optimal business strategy (choosing better locations and obtaining higher profits) than the subjects under fixed-wage and standard pay-for-performance. As described by Ederer & Manso, the two features of the exploration contract that encouraged subjects to explore were 1) tolerance for early failure permitted subjects to fail at no cost during the first 10 periods while they explored different strategies, and 2) the perspective of being paid for performance later on encourages subjects to learn better ways to perform the task.

Azoulay, Zivin & Manso assess an observational study on key differences across funding streams within the academic life sciences to estimate the impact of incentives on the rate and direction of scientific exploration. More specifically, they compare the success of investigators of the Howard Hughes Medical Institute (HHMI) (which tolerate early failure, rewards long-term success, and gives its appointees great freedom to experiment and provides rich feedback to its appointees), to grantees from the National Institute of Health (which are subject to short review cycles, pre-defined deliverables, and renewal polices unforgiving of failure). They find that selection in to the HHMI investigator program leads to higher levels of breakthrough innovation, compared with NIH funding.

*11*Ederer & Manso also explore the effects of termination on innovation and performance by introducing 2 additional treatment groups: a termination treatment group and a termination with golden parachute treatment group. Subjects in both groups receive the exploration contract and are also told that the experiment will end early if their profits in the first 10 periods are lower than a certain threshold. Subjects in the termination with golden parachute treatment group are told that they will receive a reparation payment if the experiment ends after 10 periods. Subjects in the golden parachute group were more likely to find the optimal location than the other subjects. This implies that a guarantee of at least some profits or benefits, will lead to more creative effort being put in (as it lowers the risk of exploration).

Benefits of long-term reward structures, which allow for exploration, are emphasised by a study on corporate R&D labs (Lerner & Wulf 2007). Here it is shown that higher levels of deferred compensation are associated with the production of more heavily cited patents, while short-term incentives bare no relationship to firm innovative performance.

**Extrinsic Motivator: Recognition**

The literature regarding recognition is rather similar to that of compensation as a type of motivator, which makes sense considering that some see recognition as a delayed (or indirect) extrinsic reward. This literature addresses the potential for recognition to promote participation and induce effort, however does not mention much about its impact on creativity. It also focuses very much on the individual's reasons for participation as opposed to a company or team.

Recognition, or "the signalling effect", is found to be a powerful extrinsic motivator for promoting participation and performance. The open source literature demonstrates that people can be strongly motivated with or without a financial reward. Indeed, empirical evidence suggests that recognition can induce effort for self-organized e-collective work such Wikipedia, Linux, and Facebook. [12] (Lerner & Tirole 2009), collaborative open source projects, firm-sponsored work (Villarroel & Tucci, 2007), and competitive environments such as Netflix, Topcoder, and Innocentive prizes (Bennett &Lanning 2006; Boudreau et al., 2008; Lakhani, 2010).

Millions of people participate in open source problems, both firm-sponsored and self-organized. As a result, this has lead to a rapid diffusion in open source software, with significant capital investments in to open source projects by the likes of Hewlett Packard, IBM, and Sun. At first glance, open-source behaviour can appear baffling to an economist. First, the solver has a high opportunity cost of time, where they give up monetary compensation that would be received if they worked directly for a university or commercial firm. Second, the solver is not focusing on their primary career. Third, others

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What does? Shows Subjects under "early-tolerance long-term success reward" incentive schemes explore more and are thus more likely to discover a novel business strategy than subjects under fixed-wage and standard pay-for-performance incentive schemes. (Ederer & Manso 2009).

[12] A good example to demonstrate the effectiveness of open source "e-collective" work is the development of "Facebook Translations" – an initiative to incentivisethe facebook community to translate Facebook in to every language. The imitative was supported by a simple online application which allowed fb users to translate words and phrases from the fb platform and other users could vote to judge accuracy. Within 4 weeks, 15000 Spanish speakers had translated fb completely. Within a year, the community had translated fb platform in to 100 different languages and dialect, without requiring formal contractual ties or pecuniary compensation. (Example from Villarroel & Tucci paper).. Other successful e-collective endeavors include: Linux and Wikipedia- who had similar success to FB.

directly profit from your work, where many of the beneficiaries are well-to-do individuals or Fortune 500 companies[13].

The question is "why do thousands of top-notch programmers contribute freely to the provision of free good?" According to a study of four of open-source mini-cases, Apache, Linux, Perl and Sendmail, existing economic theory can help explain active and productive open source participation (Lerner & Tirole 2009). The answer is based around the fact that recognition leads to tangible yet delayed benefits. Peer recognition, higher status in exchange community, and improvement of skills through practise and interaction with community, can lead to future job offers or shares in commercial open source projects (Raymond 1999b Lerner & Tirole, 2002). In other words, as argued in the compensation section, a programmer will only participate in an activity if they derive a net benefit from participation (broadly defined as an immediate plus delayed pay-off.

Open-source projects actively try to lever the power of recognition. For example, Apache makes a point to recognize all contributors on their website, and highlights its most committed members. Interestingly, the open source community is rather elitist, where important contributors are few and assigned to core group status- the ultimate recognition by peers and co-workers (Villarroel & Tucci, 2007). This elitist community is demonstrated in a study assessing 25 million lines of open source code. Out of the 13,000 contributors to the 3149 distinct projects, more than three-quarters of the teams only contributed once whereas the top decile of contributors accounted for 72% of the code in open source projects (Ghosh & Prakash, 2000). The same was true for Apache, where the top 15 developers contributed 81% to 91% of changes (Mockus et al., 1999).

Economists (e.g. Holmstrom, 1999) also describe conditions that can make the "signalling effect" even stronger. First, one can increase visibility of performance to the relevant audience, such as the solver's peers, labour market, or the venture capital community. Second, one can increase the impact of effort on performance by allowing one to take full responsibility for the project. Third, one can ensure to highlight talent. In fact, it is seen as one of the ultimate crimes, not to give credit to someone for their contributions (Open Source Initiative, Raymond, 1999b).

These economic arguments provide insight into who is more likely to contribute (i.e. those who derive direct benefits or who want to use open source software as a port of entry), and what tasks are more suited to open source projects (i.e. task with strong incentives and tasks that demonstrate capabilities).

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[13] especially in the case of commercially sponsored work, e.g. Amazon Mechanical Turk- where not just the users but private companies are benefiting/ FB- YouTube (Villarroel & Tucci, 2009).

Although psychologists do not support the economists' viewpoint that motivators have to result in tangible reward (even if delayed), they do advocate for the use of recognition as a motivator under certain circumstances. They believe recognition can work synergistically with other motivators, as long as competence and autonomy are promoted in parallel (e.g. Deci & Ryan 1986, Amabile, 1996).

**Intrinsic Motivation**

Despite the economic literature implying that extrinsic motivators are required to induce effort, psychologists have ample evidence to show that intrinsic motivators can be strong and effective on their own (Deci & Ryan 1983; Amabile 1996). The concept of intrinsic motivation is reasonably new. It was first introduced in 1949 by Harry Harlow, Professor of psychology at the University of Wisconsin, following a discovery he made during a series of experiments on primate learning behaviour. After exposing a group of monkeys to a simple mechanical puzzle, Harlow and his team observed that the monkeys almost immediately began playing with the contraptions, and in a short time had figured out how they worked, without any additional encouragement of food, affection or applause. "The solution did not lead to food, water, or sex gratification... [and] significant learning was attained and effective performance maintained". This result was surprising as the motivator in play was distinct from the accepted behavioural drivers of the time. The monkeys' did not act through biological drivers- the desire for humans and animals to eat to sate their hunger, drink to quench their thirst and copulate to satisfy carnal urges, or through external drivers- rewards and punishments delivered by the environment for behaving in a certain way (Harlow, 1949, Pink 2000). Rather, the motivator driving the monkeys to complete the task was inherent to the activity, or, to put it another way, as described by Harlow, "the performance of the task provided intrinsic reward".

This phenomenon of exploratory, playful, and curiosity-driven behaviours in the absence of reinforcement or reward was acknowledged by White (1959) and later supported though evidence provided by Deci (1979), Ryan (1985), and Amabile (1983). Research by Deci, Ryan, and Amabile not only enforced the existence of "intrinsic motivation" but also emphasized its capacity to improve specific outcomes, and suggested factors through which one could facilitate or undermine its effectiveness.

According to Amabile (1983), two common methods of measurement exist for characterizing intrinsic motivation. The first method involves basic experimental research and rests primarily on a behavioural measure known as "free choice". In this type of experiment, participants are exposed to a task under varying conditions (e.g. reward, no reward). Following this period, the experimenter informs the participant that they will not be asked to work on with the target task any further, and are left alone in the room with the task experiment and other distracting activities. This provides the participant with

a period of "free choice" to return to the activity without external prodding or pressure. Assuming no extrinsic reason for doing the task, the more time that is spend on the task during this period, the more intrinsically motivated they are. The second method involves collecting self-reports of interest and enjoyment of an activity. The "free choice" method often relies on task-specific measures (Ryan 1982; Harackiewicz) whereas the "self-report" measure uses more general "domain" focused measures, such as one's intrinsic motivation for school (e.g. Harter, 1981).

Intrinsic motivators are known to be particularly effective at incentivizing creativity. For example, using the self report method, Amabile showed that professional artists who score higher on intrinsic motivation tend to spend more time in their art studios working on their art (Amabile 1983, 1989). McGraw (1978) justifies this behaviour by explaining that cognitive flexibility and complexity is at its highest under strong intrinsic motivation, and thus creativity must depend to some extent on the individual's level of intrinsic motivation.

Furthermore, informational events such as the provision of choice (Zuckerman et al. 1978) and the acknowledgment of feelings (Koestner et al. 1984) have been found to enhance intrinsic motivation and therefore performance and creativity. According to Amabile, other intrinsic factors to support creativity include some degree of autonomy in the work, work that perceives as positively challenging and important, and a sense of interest and excitement in the work itself (Amabile, Conti, Coon, Lazenby & Herron 1992; Amabile & S Gryskiewicz 1987, Amabile & N. Gryskiewicz 1989).

As discussed previously, extrinsic motivators that appear controlling or undermining can hinder intrinsic performance and thus creativity. When someone is deeply inspired by their work, because they appreciate the inherent value in the fun and challenge, the person may be impervious to the undermining effects of extrinsic motivation. In other words, initial levels of intrinsic motivation are important.

These conclusions are supported by certain studies on open-source projects. A Wikipedia study involving a survey to understand the motivations behind ordinary people participating in voluntarily activity highlights the importance of fun as a strong determinant for contribution (measured in hrs per week). A study of the effort and motivations of individuals that contributed to the creation of Free/Open Source (F/OSS) software, based on a web survey administered to 684 software developers in 287 F/OSS projects, shows that enjoyment-based intrinsic motivation, namely how creative a person feels when working on the project, is a stronger and more pervasive driver than extrinsic motivation. They also find that user need, intellectual stimulation derived from writing code, and improving programming skills are top motivators for project participation (Lakhani & Wolf 2005). ). In a study of

open source software, solver success was found to be based on familiarity with project and fun associated with the challenge[14]. For example, the initial set of contributors for Apache, was almost entirely made up of systems administrators who were struggling with the same types of problems in work, but the open-source projects were more fun to solve (Lerner & Tirole, 2002)[15].

**Summary**

In summary, there seems to be ample empirical evidence to show that both extrinsic and intrinsic motivators can promote participation and effort separate from other inputs, despite economic theory that implies extrinsic motivators are necessary, and psychology data that illustrates motivator ineffectiveness. For example, economists show that pay-for-performance and lump-sum can encourage people to exert more effort in routine tasks (e.g. see Sherer or Steenburgh). Open source literature shows that people participate in online projects in the absence of financial rewards, for recognition purposes that can boost their ego and lead to delayed benefits such as skill improvement or future job offers. Psychologists and the open source literature show that intrinsic motivation can be strong and effective for promoting effort, and even more so for promoting creativity.

However, the effectiveness of these motivator inputs to exert effort does seem to be very much dependent on the situation and the conditions under which they are executed. Psychologists argue that in order for extrinsic motivators to induce effort, they must be accompanied by autonomy and a sense of competence; the more internal the drive to perform, the better the outcome. Extrinsic motivators under controlling constraints like deadlines, evaluations and imposed goals arguably hinder effort. Furthermore, the amount of compensation per unit needs to be carefully determined because, if it is too low, it can insult the subject and therefore also induce less effort.

In terms of creativity, extrinsic motivators are arguably not effective (Lepper & Green) and, in controlling environments, can undermine it (Amabile, 1996). There are three notable exceptions. First, if high levels of intrinsic behaviour existed before; extrinsic motivators have been shown to boost performance. Second, by training people to focus on intrinsic benefits, intrinsic and extrinsic motivators have been shown to temporarily co-exist, and thus use extrinsic motivators to boost creativity. Third, reward structures have been shown to work if they are long-term to allow for exploration, and have a

[14] Lots of solvers to motivate- According to US DEPT OF Labor, the IT community (computer systems, administrators, database administrators, computer programmers, and other comp sci and engineers) represent 2.1 million jobs in the US (in 1998) – large % are self-employed or retain project to project basis by employers.

[15] In addition to status, reputation and affiliation (Hertel et al 2003; Raymond 1999, V&T and Lerner & Tirole 2002, Lakhani), other motivators suggested to contribute to open software community participation includes: ideology (Hars & Ou 2002; Stallman 2007; Stewart & Godsin 2006; career (Roberts et al 2006; Lerner * Tirole 2002), learning (Lakhani & von Hippel, 2003), social ties (Hertel, Niedner, and Hermann 2003), and fun and enjoyment (Lakhani & Wolf 2005; Torvalds 1998).

high tolerance for failure, so people are willing to take risks. In this scenario, there is also a need for positive feedback and job security.

These conclusions seem particularly relevant to large incentive competitions. Large incentive competitions are based around the premise that financial reward can effectively induce participants to exert effort towards a specific goal. However, the psychologists argue that it can hinder effort, particularly in constraining environments, which incentive prizes arguably are, considering they are competitive and structured in nature. On the other hand, psychologists argue that under certain conditions and synergies, extrinsic reward can be supplemented to boost performance. Given the huge discrepancies in the literature, it is difficult to extrapolate the conclusions to large incentive competitions, and thus calls for an in-depth search of the prize literature to determine the evidence that exists to support or hinder the motivation literature already discussed.

## Motivation and Prizes

This section looks at the motivator inputs that have been incorporated in the previous competitions, and how they have been assessed in terms of effectiveness to promote certain behavioural outcomes.

### Competition-Motivator Inputs

*"I think the XPRIZE changes the paradigm, and changes the way people think about a problem. By putting a large cash prize on a grand challenge, we're not saying can it be done? We're saying it can be done, and we will pay the first guy to do it"*

Peter Diamandis, M.D., XPRIZE Foundation, Founder and Chairman

### Extrinsic Reward

Competitions can incorporate multiple motivator inputs but the one emphasized most by economic theory, historical and contemporary case studies, and empirical data is the prize purse (e.g. Wright 1985; Scotchmer 2007; Stanford Business School 2006; Morgan 2008; Lakhani 2007). As described by Morgan, "throughout history, bold announcements of large cash purses have remained the driving force [for prizes]". This general perception comes as no surprise considering that large cash prizes have been used by sponsors for centuries to motivate people to solve problems, with little emphasize on additional incentives. Examples of large impact prizes include the £20,000 Longitude Prize, the $25,000 Orteig Prize, and more recently the $10 million Ansari XPRIZE.

Other forms of "cash rewards" that fall under the prize model include Advanced Market Commitments (AMCs), such as the Gates Foundation $1.5 billion pilot AMC for pneumococcus vaccine

suitable for children in the developing world, where the prize is associated with a sales contract as opposed to a lump-sum award.

**Extrinsic Recognition**

With similar logic to open-source literature, recent studies on web-crowdsourcing prizes such as Netflix, TopCoder and Innocentive show that recognition can play a dominant role in competition. Solvers supposedly appreciate being recognized and improving their status within, or simple affiliation with, the community for future career benefits and personal pride (Tirole and Lerner 2002; Lakhani and Wolf 2005).

A study on the eighteenth century British Royal Agricultural Society Prizes also implies prize designers have an appreciation for recognition as RASE organizers incorporated non-pecuniary prizes such as medals, in replacement for certain monetary prizes (Lerner 2006).

**Intrinsic Fun and Challenge**

Although not emphasized in cases studies on prizes, recent empirical work show that intrinsic motivators are important. Lakhani's study on Innocentive shows that enjoying problem-solving and cracking tough problems is important to participants. The TopCoder study found that extreme competition and rivalry (in a behavioural or game-playing sense, rather than an economic sense) was important. According to a qualitative study on Threadless, the on-line T-Shirt design competition, their prize attracts people with the opportunity to develop creative skills, and interact with the Threadless community. They also discuss "addiction", which was apparently used by participants to describe their activity on the site, giving greater weight to the love of community as a motivator, which cannot be removed.

**Other Motivators**

Other potential prize-motivators appreciated in the open source literature, but not so much in the prize literature, include the ability for competitors to learn and develop skills during the prize for extrinsic or intrinsic benefit, the potential for competitors to accelerate their own ideas or personal intellects in return for future career benefits. These motivators can be supported through judging feedback, mentorship, on-site collaborative events, on-line interaction, or the prize structure such as milestones, deadlines, and competition pressure, all of which can be incorporated into prize design.

**Effectiveness of Competition-Motivators**

Now that we have a better idea of which motivators can be incorporated into competition, we can move on to discuss the effectiveness of these motivators to promote innovation within the context of a competitive environment. An incentive prize aims to attract a diverse set of participants, and motivate participants to exert effort towards a specific goal. However, as discussed above, some contradictory theories exist within the literature regarding the motivators incorporated into prizes and the conditions under which they are executed to attract participation, induce effort and creative behaviour.

There is ample evidence to show that prizes and competitions have been successful previously attract people to participate and engage in an activity. This can be shown through simple ex-post statistics of how many people were attracted and stimulated by a prize, and how many solutions were successfully solved. For example, the $25,000 Orteig Prize is known to have stimulated $400,000 of combined investment in the industry, and resulted in the successful Lindbergh crossing of the Atlantic with Spirit of St. Louis. The Ansari X PRIZE incentivized twenty-six teams from across seven nations to collectively invest $100 million, resulting in SpaceShip One: the first commercial spacecraft.

Despite the ability for these studies to show how prizes can successfully solve problems, they have little practical utility. First, the accuracy of their statistics is dubious and second, they provide no insight in to how competition-motivators influence the participant, and thus the outcomes. First, we need to understand whether prizes actually induce effect towards a specific goal or just act to crowdsource successful solutions. If the prize just acted to crowdsource ideas, it would imply that prizes do not in fact induce effort or innovation, rather some other incentive mechanism is more effective. Second, if effort is induced by prize incentives, then how do they behave together within the competition environment, particularly for promoting the development of creative solutions?

Recent empirical work on competitions provides insight into the mechanisms behind competition, and how prize-motivator result in the development of successful solutions. Most notably is a study on Innocentive (Lakhani, 2007). Innocentive is a crowdsourcing platform that has posted thousands of challenges and exposes them to over 80,000 solvers world-wide. His study highlights three important findings. First, he provides empirical evidence to show that exposing a problem to a diverse set of solvers can effectively solve a problem. Out of the 166 sample prizes studied, he showed over a third of them were successfully solved. These problems were unable to be solved through traditional means, which implies a place for prizes in the innovation toolkit. Second, He implies that effort is induced as a result of a prize. The prize did not just crowdsource existing solutions. The majority of

solutions were known to exist previously (72.5%) but were modified significantly in order to fit the problem criteria (55%). Third, Lakhani's study discusses the motivators incorporated in the Innocentive prize and discusses their relationship with successful solvers.

In terms of the motivator inputs or the reasons why these solvers chose to focus their ideas on the broadcasted problem, Lakhani provides two key insights: reasons why people chose to participate and how the motivator inputs influenced success. Reasons to participate are shown in table x and range from intrinsic to extrinsic motivators. The probability of success was significantly and positively correlated with both extrinsic motivators (i.e. a desire to win the award money) and intrinsic motivations (i.e. problem solving, cracking a tough problem). However, the effect of intrinsic motivation was stronger and more significant, despite the substantial monetary prize for creating the best solution. He also reported that having free time to actually participate significantly and positively correlates with being a winning solver yet participating due to career and social motivations or to beat others to solve the problem was negatively correlated with winning (table 1).

A study on the Topcoder competition contradicts this viewpoint by recognizing that the on-line platform for incentivizing solvers to generate complex algorithms harnesses the value created by a wide variety of motivations that are typical of coder communities, the most dominant of which being recognition within the community, future career benefits and personal pride (Boudreau & Hagiu 2008; Tirole and Lerner 2002; Lakhani and Wolf 2005). A study on the eighteenth century British Royal Agricultural Prizes highlighted the power of recognition and showed that this can be more influential than the financial reward for promoting entry. Medals were used as substitutes for the RASE prizes. The study found a large entrant effect of medals in comparison to cash prizes i.e. more people entered when the prize was a "gold medal" (Lerner, 2007).

| | Non-winning Solvers | | Winning Solvers | | |
|---|---|---|---|---|---|
| | Mean | S.D | Mean | S.D | Significance |
| To learn about these types of Challenges | 4.31 | 2.21 | 3.85 | 2.08 | - |
| Because I enjoy solving these types of Challenges | 5.84 | 1.49 | 6.45 | 1.01 | * |
| For the intellectual challenge of solving this Challenge | 5.09 | 1.99 | 6.03 | 1.62 | ** |
| To enhance my skills | 4.78 | 2.06 | 5.20 | 1.98 | - |
| To gain scientific recognition | 3.41 | 2.28 | 3.21 | 2.12 | - |
| Because someone suggested I participate in solving this Challenge | 1.50 | 1.21 | 1.20 | 0.79 | - |
| To enhance my career prospects | 3.36 | 2.32 | 3.03 | 2.16 | - |
| Because others I know have participated before | 1.61 | 1.39 | 1.43 | 1.26 | - |
| Because my boss asked me to work on it | 1.13 | 0.60 | 1.05 | 0.22 | - |
| To impress my colleagues | 2.18 | 1.81 | 2.10 | 1.89 | - |
| Because I had free time available | 3.26 | 1.92 | 3.98 | 2.41 | * |
| Because I already knew how to get the solution | 3.75 | 2.05 | 3.70 | 2.15 | - |
| Because InnoCentive told me about this Challenge | 3.80 | 2.34 | 2.80 | 2.33 | * |
| Because my work/job at the time was not satisfying | 2.19 | 1.79 | 2.13 | 1.96 | - |
| To try to beat other InnoCentive solvers | 3.15 | 2.21 | 2.58 | 2.17 | - |
| To win the award money | 5.44 | 1.83 | 5.73 | 1.38 | - |
| Eigenvalue | | | | | |
| Percentage of variance explained (two factor solution) | | | | | |
| Cronbach Alpha | | | | | |
| Factor analysis. Varimax Rotation. Horst Correction. Loadings <= 0.4 not retained. Stata version 8 | | | | | |
| * p <0.05. ** p <0.01 | | | | | |

**Figure 1: Motivators of non-winning solvers and winning solvers of Innocentive challenges**

**Table 3 - Logit Analyses Predicting Which Solver Submits A Winning Solution (N=295 Respondents)**

| | Coefficient | Robust Standard Error | P-value |
|---|---|---|---|
| **Expertise** | | | |
| Interest count (at registration) | -0.315 | 0.172 | 0.068 |
| Problem distance from field of expertise | 0.398 | 0.197 | 0.044 |
| **Motivations** | | | |
| Win award money | 0.503 | 0.214 | 0.019 |
| Social and work related motivations | -0.398 | 0.221 | 0.072 |
| Intrinsic motivations | 0.668 | 0.220 | 0.002 |
| Beating other solvers | -0.400 | 0.234 | 0.088 |
| Unsatisfactory job | -0.126 | 0.265 | 0.635 |
| Had free time | 0.559 | 0.234 | 0.017 |
| **Control Variables** | | | |
| RTP Problem Type | 0.330 | 0.448 | 0.460 |
| Time to develop solution | 0.004 | 0.002 | 0.012 |
| Log Pseudolikelihood | -85.62 | | |
| Wald's Chi Square | 32.14 | | |
| Df | 10 | | |
| Pseudo R Square | 0.15 | | |

**Figure 2: Logit analysis of Innocentive solvers to determine relationship between motivator inputs and success**

In summary, the prize-motivation literature has conflicting views and evidence about the influence of motivators on behavioural outputs; they conflict with the current motivation literature and they conflict with each other. Furthermore, they are limited in context, and tell us little about the influence of motivators on participation, effort, and success.

In terms of participation, the Innocentive and TopCoder studies show that both extrinsic and intrinsic rewards are effective at attracting people but do not differentiate between motivators in terms of which type is more influential. The RASE study shows that recognition is more influential than reward.

In terms of effort and creativity, the Innocentive study and TopCoder study provide the most insight into the effectiveness of motivators to influence behaviour. These studies do not directly measure effort or creativity; rather, they measure the motivators that influence those who successful solve the problem. Success can be associated with effort and creativity because in order to create a successful solution one would probably need to exert effort and be creative, even for solutions that

existed before (and as shown by Lakhani, the majority of the solutions that existed before were significantly modified for the competition anyway, which further emphasises the ability for the competition to induce effort). The Lakhani's study shows that prizes can be effective at motivating people to solve problems that established R&D firms had previously failed to solve, and that the driving motivator behind successful solvers was intrinsic rather than extrinsic. Furthermore, Lakhani shows that social and work related motivations (including recognition) are negatively correlated with success (although "winning the award money" can also be associated with recognition and that was positively correlated to success). The Topcoder study shows the opposite behaviours: that the most dominant motivators are recognition within the community for future career benefits and personal pride. Interestingly Lakahni's findings support the psychology literature and the Topcoder study supports the economic literature and the majority of the open source literature. Deci & Ryan, and Amabile provide ample evidence to show that intrinsic rewards are effective at inducing effort but the economists and open-source literature emphasize the importance of financial reward and recognition. A study on Apache implies that recognition for career benefits is the dominant driver for participation, as opposed to intrinsic motivators (Lerner & Tirole 2009). The study on Amazon Mechanical Turk contradicts Lakhani's by showing that money is the primarily motivator for participating and exerting effort with entertainment and learning showing an effect but not a dominant one (Ipeirotis 2010; Villaroel & Tucci 2008). Lakhani's Innocentive study is supported his own work on open source software- that enjoyment-based intrinsic motivation, namely how creative a person feels when working on the project, is a stronger and more pervasive driver than extrinsic motivation (Lakhani & Wolfe 2005).

The biggest problem here is that there is simply not enough empirical data on competitions to determine who is right. Motivators are complex in nature and influence behaviours in different ways depending on the conditions under which they are executed. There exists controversy in the literature to whether extrinsic or intrinsic motivators are more effective at influencing success therefore prize designers do not know what to emphasize in future competitions. Furthermore, there is very little empirical evidence that shows that competitions can influence effort or creativity therefore policymakers cannot fully appreciate the potential for prizes. Lakhani implies that prizes can "crowdsource" successful solutions, but no one really understands the full impact that a prize can have on a solution. The existing evidence focuses on online competitions that offer little beyond the prize purse. Large incentive competitions have much more potential than competitions previously assessed as they can incorporate multiple milestones, onsite collaborative events, a very large prize purse and recognition.

## Research Questions

My study focuses one large incentive competition, the Progressive Automotive XPRIZE. I therefore try to address the controversies and gaps highlighted in the literature through the context of PIAXP.

My broad objectives for this study include:

- Understanding the role of large incentive prizes in society amongst the other conventional policy mechanisms such as patents and procurement

- Understanding the motivators and prize environment that can promote participation, and induce effort and creativity so that they can be utilized by future policymakers and prize designers.

More specifically, I ask:

- What motivator inputs are incorporated into the PIAXP?

- What behavioural outcomes result from the PIAXP?

- What is the relationship between the motivator inputs and behavioural outputs of PIAXP?

- Are the motivator inputs and complimentary prize design sufficient for attracting a diverse set of solvers, inducing effort towards a specific goal, and inducing the development of innovative solutions to defined problems?

## Chapter 3: Empirical Setting & Methods

## Empirical Setting: The Progressive Automotive XPRIZE

### X PRIZE Foundation

Inspired by the success of the US$25,000 Orteig prize, MIT alumnus, space enthusiast and entrepreneur, Peter Diamandis founded the X PRIZE Foundation in 1986. His mission was to *"bring about radical breakthroughs for the benefit of humanity by creating and managing prizes that drive innovators to solve some of the greatest challenges facing the world today"*. Through the use of large prize purses, of around US$10M per prize, the X PRIZE Foundation is achieving just what Peter intended. The X PRIZE vision was first explored in 1996 with the ANSARI X PRIZE; a US$10 million incentive prize, sponsored by the Ansari family, for the first privately funded team to produce and launch a reusable manned spacecraft into space with the capability of reaching an altitude of 100km. The vehicle was also expected to carry a payload equivalent to the weight of three passengers, and replicate the feat twice within two weeks. This competition was a great success. It attracted 26 competitors from seven countries, who collectively invested more than $100 million in to private space flight. In 2004, Spaceship One (designed by Burt Rutan, and financed by Microsoft cofounder, Paul Allan) won the Ansari XPRIZE, and earned its spot next to the Spirit of St. Louis in Washington DC's Air and Space Museum as the first commercially funded spacecraft to fly in space (Stanford Business School, 2006). As quoted on the X PRIZE website: the Spaceship One victory "opened up a new era where space is no longer the exclusive domain of massive government space programs and ordinary people can now realistically dream of one day reaching the stars." What began as a $10 million prize that inspired 26 teams, has gone on to inspire a brand new industry. Indeed over US$1.2 billion has been invested in space flight since the competition began; Sir Richard Branson and Rutan have formed Virgin Galactic- the first commercial space venture. Similar subsequent X PRIZES have been announced- including Archon XPRIZE in 2006 and the Google Lunar XPRIZE in 2007.

### The Progressive Automotive XPRIZE (PIAXP)

In 2006, the Progressive Insurance Automotive X PRIZE became the fourth innovation prize launched by the X PRIZE Foundation. With a prize award of US$10 million, the competition was designed to incentivize "teams from around the world to focus on a single goal [of building] viable, super fuel-efficient vehicles that give people more car choices and make a difference in their lives".[16] In March 2008, at the New York International Auto Show, the X PRIZE Foundation announced that Progressive

*16* Accessed from http://www.progressive.com/progressive-insurance/autoxprize.aspx on 5/9/2011

Insurance would come on as title sponsor to fund the $10 million prize purse, and that the U.S Department of Energy would fund a $3.5 million national education program. The goal of the corporation in providing such significant sponsorship was described as being "because it's about innovative solutions and coming together in a way that can make a real difference in people's lives. We believe the Progressive Automotive X PRIZE will change the face of the automotive industry — just like we changed the face of car insurance. A car insurance company looking to make things better — now that's Progressive."[17] More broadly, the Prize was designed not only to provide for innovative solutions but also to increase global awareness of more fuel-efficient vehicle options, with a belief that this would enable their development and stimulate marketplace demand. To accomplish this paradigm shift, it was important to demonstrate not just one or two designs that can accomplish this goal, but a new generation of vehicles that consumers will want to drive and that can be manufactured in volume.[18]

**Competition Structure**

The PIAXP was structured around a set of competition guidelines that outlined the requirements of potentially winning vehicles, with guiding principles laid out in the Competitive Guidelines document (see Table 2).

| Competition Guidelines Version 1.3<br>Guiding Principles (pp. 5-6) |
|---|
| Throughout the prize development process we have been guided by the principles that the Progressive Insurance Automotive X PRIZE should:<br>• Achieve our main goals - inspire a new generation of super-efficient vehicles that help break our addiction to oil and stem the effects of climate change<br>• Stimulate the development of many new options for consumers<br>• Be simple to understand and easy to communicate<br>• Remain independent, non-partisan, and technology-neutral – treating competitors with equality and fairness<br>• Result in production-capable new vehicles and existing-vehicle modifications, not concept cars<br>• Provide clear technical boundaries (i.e., for fuel economy, emissions, safety, performance, cost, features, feasibility, etc.)<br>• Attract both existing automobile manufacturers and newcomers |

*17* Accessed from http://www.progressive.com/progressive-insurance/autoxprize.aspx on 5/9/2011.
*18* REF

| |
|---|
| • Attract competitors from around the world<br>• Attract a balanced set of donors, sponsors, and partners to help competitors succeed<br>• Provide many opportunities for recognition so that it's worthwhile to compete, and not just for first place<br>• Make heroes out of the competitors and winner(s) through widespread exposure, media coverage and a significant cash award<br>• Educate the public on key issues related to the energy costs and environmental impact of transportation, and on the benefits of different vehicles and technologies represented in the competition |

**Table 2: PIAXP Guiding Principles (excerpted from Competition Guidelines Version 1.3)**

In order to be eligible for a place in the final rounds of the competition, a vehicle had to meet four criteria: i) exceed 100MPGe, ii) produce <200g/mi CO2 equivalent, iii) meet US vehicle emissions standards and iv) be production capable[19]. The definition of Miles per Gallon equivalent (MPGe) required new and creative work on the part of the X-Prize Foundation in the design of the prize. At the time of the prize inception, no such metric was available. MPGe was a new way to directly compare the efficiency of gasoline to electric and other alternative fuelled vehicles. It was defined as "a pump-to-wheels energy efficiency measure that expresses fuel economy ...based on the energy equivalence of all fuel(s) consumed" according to the following formula:

***MPGe = (miles driven) / [(total energy of all fuels consumed)/(energy of one gallon of gasoline)]***

Beyond these requirements, the PIAXP was organized into two separate classes of vehicles depending on the architecture of the vehicle design. Half of the $10 million purse was awarded to the fastest Mainstream Class vehicle. The remaining $5 million split between the two winners of the Alternative Class – the fastest vehicle with side-by-side seating, and the fastest-vehicle with tandem seating. The specifications for the Mainstream class were derived from typical existing small, 5-passenger economy mixed-use vehicles. The Alternative Class was described as an outlet for innovation, with fewer performance & design restrictions. The Demonstration Division which was added later in the

*19* Defined as being plausibly produced in volumes of at least 10,000/year by 2014, being desirable to consumers, and with a credible business plan (as defined in the Competition Guidelines accessed on 5/9/2011 from http://www.progressiveautoxprize.org/files/downloads/auto/PIAXP_Guidelines_V_1.3.pdf

prize but removed because of lack of interest, was available for manufacturers of high-efficiency vehicles that are currently in production or are committed to production in the very near future.

The original competition design entailed a rigorous cross-country stage race that combined speed, distance, urban driving and overall performance; the winning vehicle would have been the one that could exceed 100 MPGe, meet strict emissions standards and finish in the fastest time. However, this did not work out due to the complex nature of a multi-city race, and significant resistance from competitors. Instead, the XPRIZE Foundation team designed a multi-stage knockout competition that began with paper submissions on their vehicle's features, production capability, safety and business plans in the summer of 2009, and ended in a series of onsite testing phases at the Michigan International Speedway and national testing labs in the summer of 2010. The details of the stages are complex and described in Table 3 and Figure 2 (using information taken from the PIAXP competition guidelines document).

**Registration/Acceptance:**
Teams will be accepted for the Progressive Insurance Automotive X PRIZE competition based on preliminary information about their entry.

**Design Judging**
Accepted teams will then provide evidence that their vehicle or vehicle modification designs are production-capable, in the form of detailed Data Submissions that will be judged on a pass/fail basis.... Those that pass will be invited to bring their vehicle(s) to the competition events. An initial series of technical reports, technical inspections, and active safety performance tests will eliminate unsafe vehicles. (Undertaken in three rounds)

**Shake-Down**
The Stage Race is a high-mileage race comprising stages with courses that will reflect known consumer driving patterns, incorporating a variety of realistic and performance-illustrating driving conditions, terrains, and trip profiles. Vehicles will race over closed track facilities. Vehicles must obey all simulated traffic regulations, including speed limits. The Stage Race will enable fair, technology-neutral comparisons of vehicles while maximizing public impact. Following a 2-3 week hiatus after the initial race stages that will serve as a shake-down period, a "knockout" qualifying event will be held to admit vehicles to the final race stages.

**Knock-Out**
To advance, vehicles must pass a full set of active safety performance tests, demonstrate Tier 2, Bin 10 criteria emissions, and demonstrate at least 67 MPGe (i.e., two-thirds of the 100 MPGe target) over a road course based on a composite of the Urban Dynamometer Drive Schedule (UDDS) and the Highway Fuel Economy Driving Schedule (HWFET) test cycles. The knockout event will be conducted at a suitable test track or proving ground, and may be open to the public and the media at selected periods.

**Finals**
After the "knockout" event, there will be at least a 2-week hiatus to allow the surviving teams to apply what they have learned during the shake-down stages and knockout event before the final stage. To complete the Progressive Insurance Automotive X PRIZE Stage Race successfully, vehicles must maintain a minimum average speed (maximum allowable time) while meeting Progressive Insurance Automotive X PRIZE requirements for fuel economy and emissions – determined by averaging the dynamometer test results with the overall scoring-stage averages.

**Validation**
At the end of the final stage, there will then be a coast-down stage followed by the chassis dynamometer stage that will conclude the competition events. For those vehicles that successfully complete all of the Stage Race requirements, placement (ranking) will be based on the total of the stage completion times. Time penalties will be applied for infractions and equipment failures.

**Winners**
Final ranking will be determined by the adjusted total time – i.e., the fastest vehicles are the winners.

**Table 2: Stages of the PIAXP Competition (based on Competition Guidelines Version 1.3)**

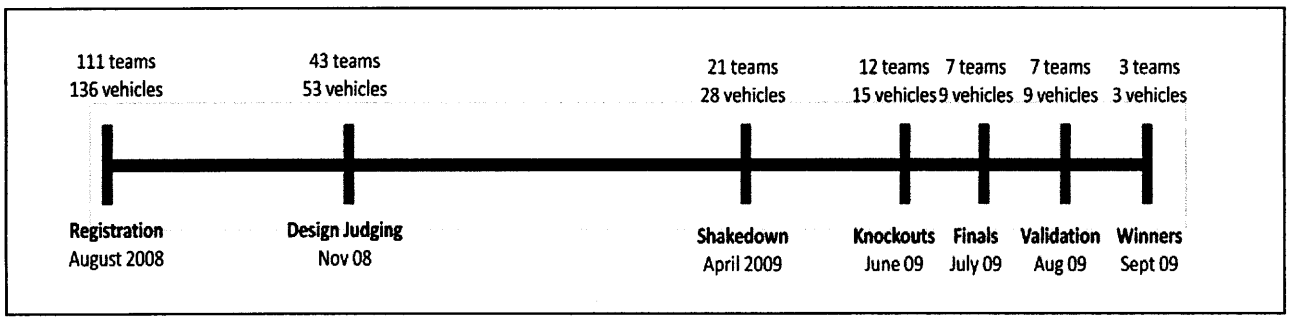



**Figure 3: Stages of the PIAXP Competition with Number of Teams & Vehicles**

In brief, teams initially registered for the PIAXP with a letter of intent. **Registration** for the Prize opened as early as March 2006 but closed in August 2008. After this Registration phase, teams were asked to provide a variety of information for the **Design Judging Stage**. During this stage (which took place over a period of time), teams provided information that their vehicles were production capable with a variety of detailed data submissions. Just prior to an event in Las Vegas in November 2009 where PIAXP provided detailed information as well as technical inspections and active safety performance tests, unsafe vehicles were eliminated. Following the paper submissions, qualified teams went to Michigan in April 2010 for the start of the on-track performance events. These were organized by PIAXP in cooperation with the Michigan Economic Development Corporation (MEDC) and the Michigan International Speedway (MIS). The competition at this point was organized into a series of competition

stages aimed at evaluating the efficiency, safety and performance of each competition vehicle under real world conditions. During the **Shake-down Stage**, the purpose was to conduct safety inspections and on-track dynamic safety evaluations of competition vehicles. Teams submitted their cars to on-the-ground challenges for the purpose of shaking out problem areas and preparing their vehicles for the Knockout Qualifying Stage that follows, all without risk of elimination by the judges. Vehicles were tested on braking speed, lane change ability, acceleration and refuelling/recharging time, among other elements. During the **Knockout Stage**, to narrow the field of competitors, PIAXP officials re-conducted inspections and certified readiness for knockout stage challenges. In order to pass this stage, teams demonstrated that their vehicles could achieve at least two-thirds of the stated 100 MPGe (miles per gallon or energy equivalent) goal while also meeting expectations for range, emissions, and real world performance. Achieving emissions thresholds proved a significant hurdle for teams in this stage as will the "hill climb" challenge. The **Final Stage** was designed to identify the top finalists in each class, with the remaining teams competing in scored on-track challenges, and a "coast down" exercise to gain key performance information about the aerodynamics and rolling resistance to properly prepare the vehicles for the validation stage. The **Final Validation Stage** was the final technical event, with the top finalists in both the Mainstream and Alternative classes undergoing dynamometer testing under controlled laboratory conditions at certified labs to verify technical performance results. The results of this testing, combined with the speed, efficiency and emissions results from the earlier events at Michigan International Speedway determined the winners of the PIAXP.

**Competition Outcomes**

During the period between the PIAXP announcement in March 2006 and the close of submissions in August 2009, the PIAXP attracted 111 teams with 136 vehicles, including 80 Mainstream vehicles (4+ passengers, 4+ wheels) and 56 Alternative vehicles (2+ passengers, no requirement on number of wheels). Within the context of the staged competition process, of the 136 registered vehicles that entered in to design judging, 56 passed into the next round in November 2010. Of those 56, only 33 actually participated in the Shakedown in April 2010. Of those 33 only 28 made it to the knock-out stage in June 2010, with 15 moving to the finals in July 2010 and 9 reaching validation in August 2010. At the completion of the finals and validation there were 3 winners announced in September 2010: one from the mainstream category, one from the alternative-tandem category, and one from the side-by-side category. Table 4 provides details of the number of vehicles entered in each of the prize categories.

| No of vehicles | Registered | Entered Design Judging | Entered Shakedown | Entered Knockout | Entered Finals / Validation | Winners |
|---|---|---|---|---|---|---|
| **Mainstream** | 80 | 80 -> 31 passed | 12 | 8 | 2 | 1 of 2 |
| **Alternative - Tandem** | 56 | 56 -> 25 passed | 8 | 7 | 5 | 1 of 2 |
| **Alternative - Side-by-Side** | | | 13 | 13 | 8 | 1 of 5 |
| **Total** | 136 | 136 -> 56 passed | 33 | 28 | 15 | 3 of 9 |

**Table 3: Entries by PIAXP Competition Stage**

**Empirical Methods: A Mixed Methodology Approach**

More than 100 teams from around the world, with varied experience and backgrounds entered the Progressive Automotive XPRIZE competition. These teams form the basis of our detailed data-driven analysis of PIAXP. The PIAXP case provided a unique opportunity to study innovation teams responding to prize-based incentives in real time. Supervised by Professor Fiona Murray and supported by Dr Erika Wagner, Professor Alan McCormack, Professor Scott Stern and Ms. Elaine Backman, I analyzed the teams who participated in the PIAXP, examining the types of organizations that entered, what motivated them to enter, what resources they committed to meeting their technical goals, what organizational approaches they took to innovate, what alternative technical approaches they employed and ultimately, the performance outcomes of their innovation efforts.

Our empirical exploration of PIAXP extended over the full duration of the staged competition. We began interacting with teams in September 2009, following the April announcement of the 111 registered PIAXP teams, and continued until January 2011, following the September 2010 announcement of the 3 winners. Four basic types of empirical data were collected over the course of our study to allow us to understand the incentives provided by the prize, the organizational efforts induced and the final technical outcomes including periodic quantitative surveys, qualitative interviews,

observations at key events, and centralized data on the teams and vehicles from the XPRIZE Foundation. These methods build on a strong and proven tradition in social science research that compares the incentives, organization and performance of innovation teams focused on similar goals (see, for example, Allen 1960; Clark & Fujimoto 1990; MacCormack et al, 2001).

**Survey Analysis:** Data presented in this thesis are from four qualitative PIAXP surveys. The first survey was designed for the 43 qualified PIAXP teams, representing 56 vehicles, and sent in December 2010, following the initial knock-out based on technical and business plan submissions. The survey request was addressed to the team leader or core team member, who was asked to answer the questions on behalf of the whole team. It contained 77 questions designed to collect basic information on team composition and prior experience, organizational structure, technical solutions, in addition to information on team motivations, strategy, effort, and progress. Questions were based on prior survey methods, but the content was adapted after trial surveys and feedback from PIAXP participants. The second survey was sent shortly after the first to the remaining 68 PIAXP teams who did not qualify passed the design judging phase. This survey design was similar to the first, although a few irrelevant questions that did not receive a high response rate in the first survey were removed. The third survey was sent to all 111 PIAXP competitors after the Michigan on-site testing phase. It contained 71 questions and was designed to identify information about team motivations, effort, progress, and competition experience. Again, this survey was designed for the team leader to complete on behalf of their team. The fourth survey was designed for individual core team members, and designed to explore individual motivations, effort, and competition experience. It was sent out with the third survey with a request to the team leaders to pass it on to their core team members. Email addresses for the 43 design phase teams were collected during a research trip to Las Vegas. The remaining team contact information was provided by the XPRIZE Foundation. As finally implemented, each questionnaire was accompanied by a brief letter explaining who we were and what we were trying to do. We did follow up with teams by sending one email reminder and a follow-up call but, to minimize intrusion, we stopped after that. We also provided an e-mail address for anyone who wanted to contact us to complain or comment. All survey questions are available in the appendix.

Our research group was fortunate enough to secure comprehensive access from the X PRIZE Foundation to the teams and to the centralized PIAXP data. We were therefore able to attend many of the PIAXP events and build strong relationships with participating PIAXP teams. We had members of our research group on site for the first team gathering in Las Vegas in November 2010, during the shakedown, knockout, and finals events during the summer of 2010, and for the award ceremony in

September 2010. I was present at all events mentioned. As a result of this strategy, we attended a reasonably high response rate for our first survey with a team response rate of 81%, representing 43 teams and 271 core team members. The second survey had a slightly lower response rate. The third and forth surveys were mainly completed by teams we had interacted with during the knockout and final competition events. 54 individual team members responded to survey 4 (at least one team from most of the teams that competed in the final stage). Response rates for survey 1 and 2 can be seen in table x.

**Interviews & Observation:** Given our close connection with the X PRIZE Foundation and the opportunity to attend on-site events, we were able to collect a considerable amount of qualitative data to support our quantitative findings. I was able to complete in-depth qualitative interviews with all teams that participated in the final competition (~30 teams), in depth qualitative interviews with the PIAXP Director of Team Development and Relations, Julie Zona; the VP of Prize Operations for the X PRIZE Foundation, Cristin Lindsey; the team who designed the judging criteria and prize structure including John Shore; and the Founder and Chairman of the X PRIZE Foundation, Peter Diamondis. Observations at key events including the introductory event in Las Vegas in November 2009, PIAXP ground and media events in Michigan in the summer 2010, and PIAXP award ceremony in Washington DC in Sept 2010 also were valuable for understanding the mechanisms behind a large incentive competition. The XPRIZE Foundation also provided us with centralized data from PIAXP including team business plans, judging criteria and media coverage statistics.

<table>
<tr><th>no of vehicles</th><th>Registered</th><th>Entered Design Judging</th><th>Entered Shakedown</th><th>Entered Knockout</th><th>Entered Finals / Validation</th><th>Winners</th></tr>
<tr><td>Mainstream</td><td>80</td><td>31 passed</td><td>12</td><td>8</td><td>2</td><td>1 of 2</td></tr>
<tr><td>Alternative - Tandem</td><td rowspan="2">56</td><td rowspan="2">25 passed</td><td>8</td><td>7</td><td>5</td><td>1 of 2</td></tr>
<tr><td>Alternative - Side-by-Side</td><td>13</td><td>13</td><td>8</td><td>1 of 5</td></tr>
<tr><td>Vehicle Total</td><td>70 of 136 (51%)</td><td>43 of 56 (77%)</td><td>27 of 33 (82%)</td><td>17 of 28 (61%)</td><td>9 of 15 (60%)</td><td>2 of (3 of 9) (67%)</td></tr>
<tr><td>Team Total</td><td>58 of 111 (52%)</td><td>35 of 43 (81%)</td><td>21 of 31 (67%)</td><td>12 of 26 (46%)</td><td>7 of 13 (54%)</td><td>2 of 3 (67%)</td></tr>
</table>

**Table 4: Survey Responses by Competition Stage**

## Chapter 4: Empirical Results

## Proposed PIAXP Inputs: Motivators and Prize Design

My exploration of The Progressive Automotive XPRIZE (PIAXP) began with an investigation of the motivators that were intentionally incorporated into the competition, in the context of the expectations of the XPRIZE Foundation and the motivation literature. Information was gathered from multiple prior press releases (from the PIAXP website) and qualitative interviews performed with Peter Diamondis, Founder of the XPRIZE Foundation, Cristin Lindsay, VP of Prize Operations, and Julie Zona, Director of Team Development and Relations.

Unlike competitions before it, the Progressive Automotive XPRIZE (PIAXP) was specifically designed to incorporate incentives beyond the prize purse to attract diverse participants and accelerate progress. For that reason, when the Automotive XPRIZE (as it was described before Progressive Insurance came on board as a sponsor) was first launched in 2006, they ran a marketing effort with duel focus.

First, PIAXP highlighted the large prize purse and recognition (mainly vehicle validation and publicity) that would be associated with participating in the competition. According to the first press release, after the initial announcement of PIAXP, "the **$10 million competition** [was] expected to travel through multiple cities while **broadcast to a global audience** in 2009 and 2010, building consumer demand for vehicles in the competition and demonstrating many practical, clean and affordable vehicle options". The intention here was to demonstrate to the teams that PIAXP could provide teams with a platform to exhibit their impressively efficient and affordable vehicles in front of consumers. Although the PIAXP competition design changed significantly during the competition, a strong focus on vehicle marketing remained.

Second, the PIAXP emphasized the opportunity for the teams to accelerate progress of their business and vehicle(s) during the competition. The PIAXP offered teams an opportunity to validate their vehicles through association with the high profile PIAXP sponsors such as the Department of Energy, Consumer Reports and Progressive Automotive Insurance. Demanding objectives and due diligence of the judging progress was also highlighted as playing a role in the validation of vehicles. PIAXP provided teams with support through technical feedback sessions during on-site events and online business training. According to Julie Zona, PIAXP "helped teams find funding and develop their business in a variety of ways- educational presentations, webinars on sponsorship generation, a "how to deck" on marketing. We also provided them with a voucher program for emissions testing and safety consulting sponsored by the DoE. We want them to be ready to launch after the XPRIZE!"

Furthermore, a great deal of thought went into developing the rules to make the competition attractive to a diverse audience. The intention of PIAXP committee was to attract both the large auto-makers and garage entrepreneurs to highlight and help develop all ideas that could possibly meet the competition objectives. As John Shore, Senior Advisor to PIAXP and one of the original rule-makers said "balancing the judging criteria- technical quality and highly efficient vehicle in a realistic timeframe and resources required was the hardest thing". The goal was to set "ambitious yet achievable objectives but not to define solutions". These rules were flexible enough to allow anyone with a workable solution to participate and impressive enough that the media still paid attention, and teams still thought it was worth competing. He followed on to give a specific example to emphasize his point: A vehicle had to be "production capable, not necessarily a production prototype. Do the PIAXP cars need airbags? No. It turns out that it is very expensive and time consuming for a company to do- you need good relationships with suppliers and it takes a lot of engineering- but that said we need our PIAXP vehicles to be designed so that they can meet federal safety standards. So, for the competition, we required that teams carry the weight equivalent to this part and have the vehicle designed so that they could be integrated- in other words production capable". This approach allowed for teams who couldn't afford certain safety testing to leave the required part out of the vehicle but also to have the space and weight allowances to incorporate it eventually.

Other elements incorporated into PIAXP, intended to attract diverse participation, include the design and length of the competition stages, and the reward categories (mainstream and alternative). The competition was initially launched in 2006, but business plans were not due until 2008, and prototypes until 2009. This long-term structure was intended to provide teams with ideas time to develop their solutions without the external pressure of imposing deadlines. It also allowed teams time to build vehicles from the bottom-up as opposed to just attracting existing vehicles. Furthermore, the rules were designed to have a reasonably low barrier to entry but increase in difficulty throughout the competition. This structure allowed for teams to enter who may not have had the time or resources to full develop their ideas prior to the competition. The categories were also designed to promote diversity as they had different requirements in order to appeal to the different groups. The mainstream category was designed to compare regular vehicles and the alternative division was designed specifically "as an outlet for innovation", with much broader requirements.

According to the theory and evidence posed in the literature, on the one hand, the constraining rules and dominance of extrinsic motivators could hinder effort (Deci & Ryan, 1985). On the other hand, the long-term reward structure could allow for exploration and thus promote creative behaviour

(Manso, 2007). Furthermore, the feedback, support and high levels of initial intrinsic drive prior to the competition could counteract the negative extrinsic effects (Amabile, 1996). However, it is difficult to predict the outcomes for PIAXP as there are no empirical studies that assess the motivations in a large incentive competition environment.

| PIAXP Goal | Input | Prize Design/ mechanism |
|---|---|---|
| **Attract diverse teams** | Compensation | -Large prize purse that was paid on delivery of solution |
| | Recognition | -Validation- through association with prestigious sponsors<br>-Publicity through onsite public events/ media outreach |
| | Rules | -Objectives set rather than solution defined<br>-Ambitious but achievable goals<br>-Low barriers to entry<br>-Flexible to allow for mistakes |
| | Structure | -Long-lead times and tolerance of early failure<br>-Staged rounds |
| | Categories | -Multiple categories to increase confidence of winning, not only because less people would be in the pool but one can associated more with the problem |
| | Support | Technical and business support offered |
| **Accelerate team progress** | Recognition<br>1) Validation<br>2) Publicity | Press releases<br>Team blogging |
| | Specific performance motivators:<br>3) Deadlines / milestones | Multiple rounds<br>Realistic but challenging |
| | 4) Opportunity for teams to learn | Online and onsite events<br>Judging feedback<br>Documentation |
| | 5) Technical support | Online and onsite events<br>Judging feedback<br>Documentation |

**Table 5: A summary table of the motivators intentionally incorporated into PIAXP and the mechanisms/ strategy used to promote desired motivators/ objectives.**

## Observed PIAXP Inputs

### Survey data

As highlighted in table 5, intentionally incorporated motivators of PIAXP include reward, recognition, and performance accelerators. It is also interesting to assess the actual reasons why teams chose to compete- the observed motivator inputs. To determine the motivator inputs that influenced PIAXP competitors, two questions were devised. The first question, which was incorporated into the first survey and sent in November 2009, was designed to determine the reasons why teams entered the PIAXP. The survey was completed by the team leader, but they were asked to fill it out from the perspective of the team. The second question, which was incorporated into the survey sent to individual team members in November 2010, was designed to determine the reasons why individuals participated and exerted effort in the PIAXP.

Figure 4 displays results on team motivators, measured by the strength of agreement for choosing to compete in the PIAXP from the team's perspective (n=54). The graph shows that teams were incentivized to enter PIAXP for both extrinsic and intrinsic reasons. Over 75% of teams agreed that extrinsic recognition variables including publicity, entering a new market, and reputation were reasons for entering PIAXP. Over 75% of teams also agreed that intrinsic environmental concerns and fun motivated them to enter PIAXP. Publicity was the strongest motivating factor; 55% of teams strongly agreed that they entered PIAXP to publicize their vehicle. This finding is in line with the XPRIZE Foundation's marketing intentions which focused attention on the opportunity for teams to market their vehicles during PIAXP, and the economic open source literature that suggests that recognition (and delayed benefits) is a powerful motivator for inducing effort (Lerner & Tirole 2009; Villarroel & Tucci, 2007). In support of the Lakhani's Innocentive findings (Lakhani 2008), winning the prize was less important to PIAXP entrants; only 27% of teams strongly agreed that it was a reason for entering PIAXP. In fact 45% of teams who answered my final survey claimed that they would have entered PIAXP without a prize purse. These findings do not directly support the economic literature that suggests compensation is a dominant motivator or the psychology literature that suggests intrinsic motivators are dominant.

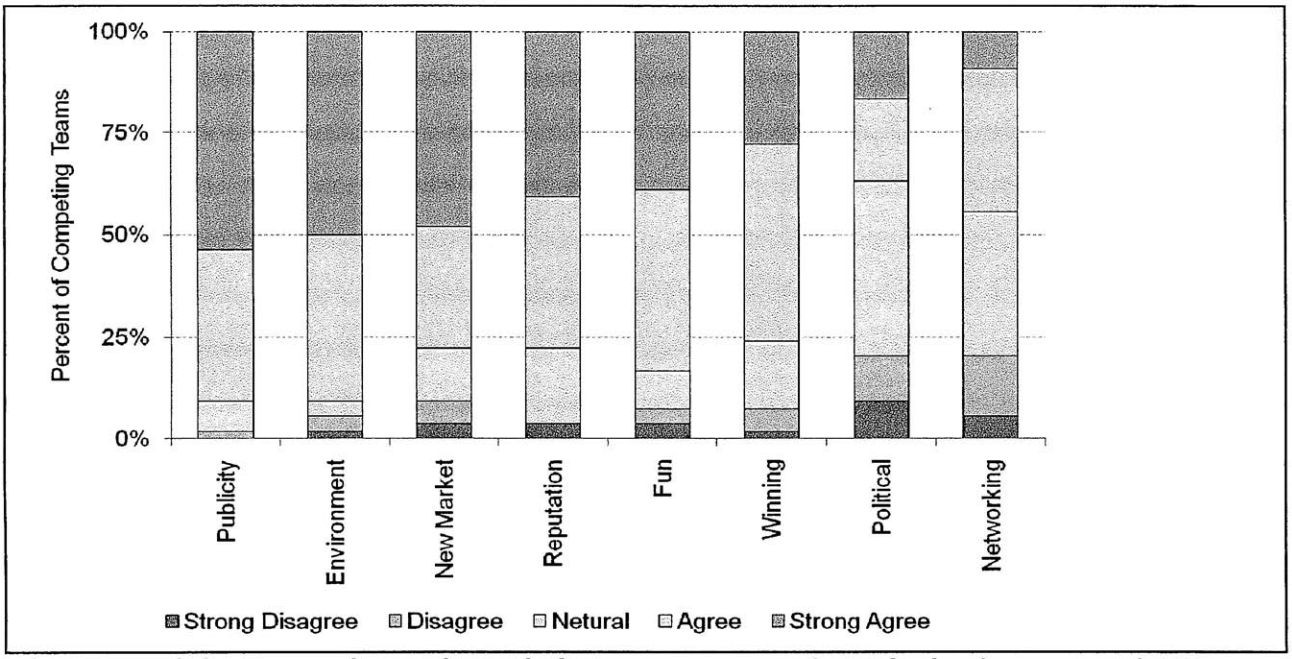



**Figure 4: A graph that measures the teams' strength of agreement on team motivators for choosing to compete in PIAXP.**

Figure 5 displays results on individual motivators, measured by the individual's strength of agreement for choosing to compete in the PIAXP from the individual's perspective. The means and standard deviations for the individual's strength of agreement on the motivators can be found in table A1 (see appendix 1).

Here, intrinsic motivators are shown to be more influential than extrinsic motivators. The average PIAXP individual strongly agrees that intrinsic motivators such as "passion for the cause" (n=50, $\mu$=4.4, sd= 0.88) and "intellectual challenge" (n=50, $\mu$=4.35, sd=0.88) were reasons for entering PIAXP. The average PIAXP individual also agrees that fun (n=51, $\mu$=3.98, sd=0.99) and "thrill of the competition" (n=50, $\mu$=3.76, sd=1.17) were reasons for entering PIAXP. The average PIAXP individual does not necessarily agree that extrinsic reasons are a reason for participation, they are more neutral in this respect, particularly for the variables "impressing my colleagues" (n=50, $\mu$=2.70, sd=1.22), "receiving individual compensation" (n=48, $\mu$=2.81, sd=1.38), and "gaining recognition in my organization" (n=50, $\mu$ =3.26, sd=1.32). A notable exception to this finding includes "gaining recognition in the industry" because here the average individual strongly agrees that this factor motivated them to participate in PIAXP (n=51, $\mu$ =3.92, sd=1.29). Participants also agree that "winning the award money for the team" was a reason for participating (n=48, $\mu$ =3.60, sd=1.2). It is interesting to note that the average person believes that "company compensation" is more influential as a motivator than "personal compensation", and "recognition for their organization" is more influential than "personal recognition". Learning and skill development also rank highly as a reason for PIAXP participation. These findings are

consistent with the PIAXP intention of attracting teams who were interested in developing and publicising their vehicles. People were also interested in developing themselves. The average participant is in disagreement with the notion that "internal pressure" and general job dissatisfaction" motivated them to participate in PIAXP.

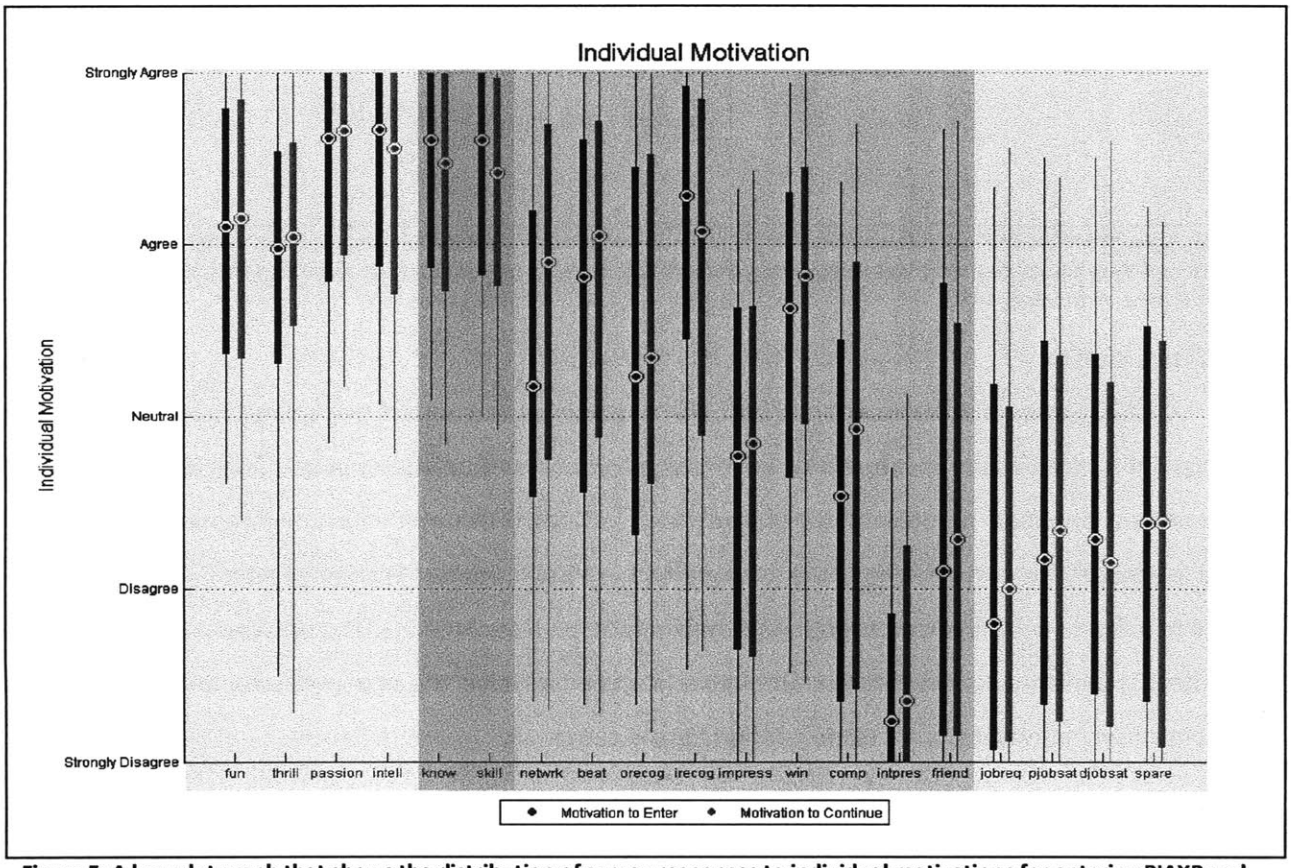



**Figure 5: A box-plot graph that shows the distribution of survey responses to individual motivations for entering PIAXP and for continuing in PIAXP. The black line represents motivators to enter, and the red line represents motivators to participate. The intrinsic motivators are to the far left, the extrinsic motivators are in the centre, and other motivators are towards the right.**

Teams were also very confident in their ability to win the PIAXP, which must have influenced their decision to enter the PIAXP. Indeed, over half of sample teams were at least 50% confident that they would win the PIAXP, with 23% of those being 90-100% sure of winning. On the other hand, 13% of teams were 0% confident that they would win the PIAXP (figure 6). This finding implies that additional benefits were associated with PIAXP, beyond the $10 million.

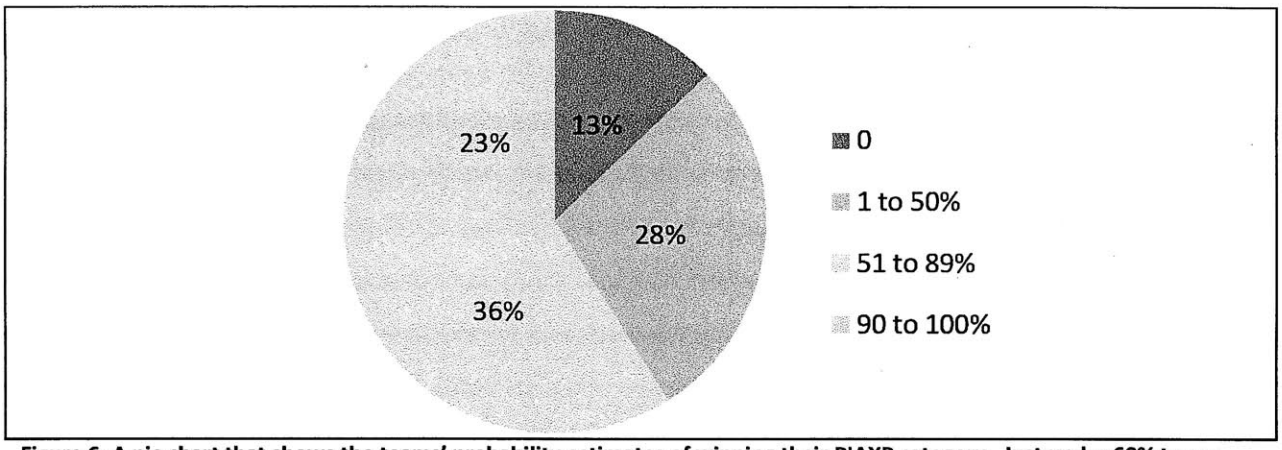



**Figure 6: A pie chart that shows the teams' probability estimates of winning their PIAXP category. Just under 60% teams believed that they had more than a 50% chance of winning their category. 13% of teams believed that they had a zero percent chance of winning PIAXP.**

***Qualitative studies***

Qualitative interviews completed with PIAXP participants support the quantitative findings but also highlight additional motivators that were not incorporated into the original survey questions and differentiated between participant types (see next section). The motivators highlighted directly by teams as reasons for participating and exerting effort in PIAXP include: 1) compensation, 2) recognition (desire to validate vehicle, draw attention to their vehicle and/or company, and prestige associated with the prize), 3) performance acceleration (desire to learn and develop the team, vehicle), and themselves, and 4) intrinsic motivators, particularly passion for the cause.

## Observed PIAXP Outputs

**Who was motivated to participate in PIAXP?**

Given the diverse set of motivator inputs and the broadly design structure of PIAXP, it is not surprising that the PIAXP attracted a greatly diverse set of entrants in terms of organizational structure, composition, size, and origin. Eleven countries were represented in the competition by twenty three international teams with twenty nine vehicles. From the USA alone, twenty five states were represented by eighty eight teams and one hundred and seven vehicles (table 6). Competitors ranged from large cooperation's such as Tata Motors, budding start-ups like Edison2, university teams such as WWU, and a state high school team from West Philadelphia. Table A2 summarizes some of the salient characteristics of PIAXP participants from our team sample (n=54) (see appendix 1).

| Geographic Representation | Details |
|---|---|
| Total U.S. States | 25 (88 U.S. teams; 107 U.S. vehicles) |
| List of U.S. States | AZ, CA, CO, CT, FL, GA, IA, IL, IN, LA, MA, MD, ME, MI, NM, NY, NV, OH, OR, PA, TN, TX, VA, WA, WV |
| Total Countries | 11 (23 international teams; 29 international vehicles) |
| List of Countries | Australia, Brazil, Canada, Finland, Germany, Italy, Netherlands, Switzerland, Thailand, UK, USA |

**Table 6: Geographical representation of PIAXP participants**

**Organization:** Teams with a range of organizational structures entered PIAXP. From my sample, just over half the PIAXP teams are not part of a wider organization (44% of teams; n=54). Of the 56% sample teams that are part of a wider organization, 81% are previously incorporated private or public firms (n=32) and the other 19% are associated with educational institutions (9% in total). Some of the sample organizations are young, founded in 2009, and some are old, founded in 1945; some sample organizations are large, and some are small (n=54; no. of employees: range: 1-23000; sales: range: 0-1.4Xe10). Despite the diversity in organizational structure, there is little diversity in terms of funding type. PIAXP seemed to motivate mainly self-funded teams either through their parent organization (42%) or themselves (46%) (figure 7).

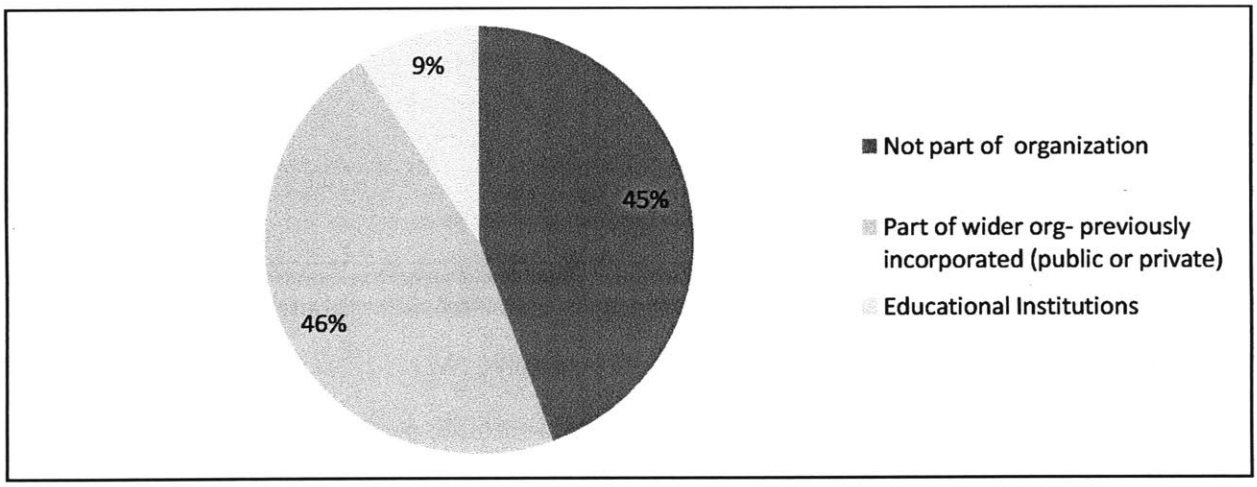



**Figure 7: Pie chart that shows the distribution of organizational structures of PIAXP entrants.**

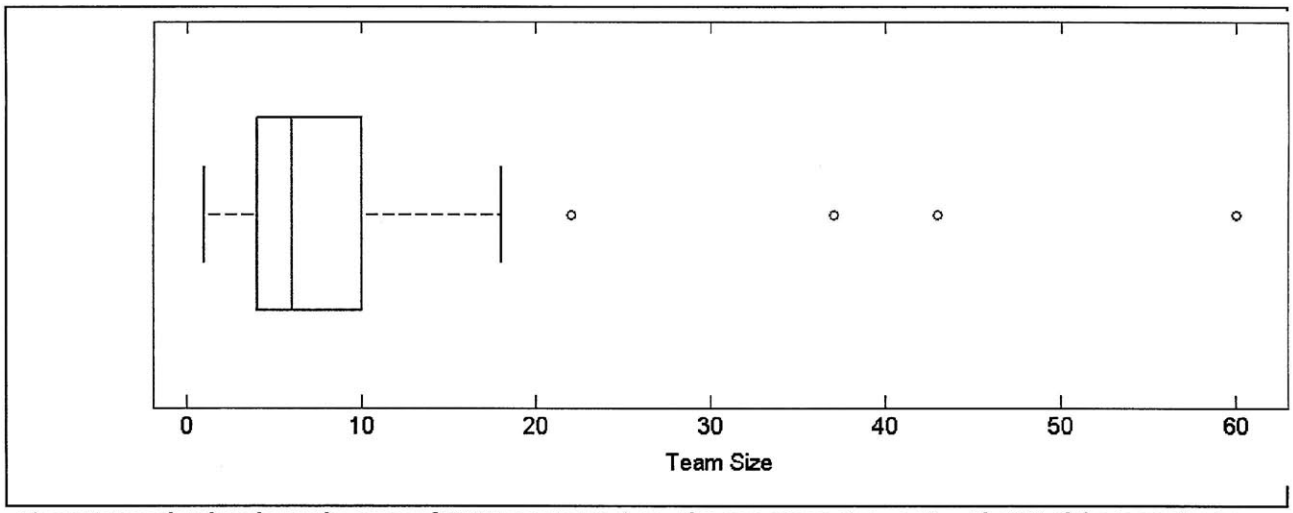



**Figure 8: Box plot that shows the range of PIAXP core team sizes. The mean team size was 6, with 50% of the teams having less than 10 members. 5 teams had more than 20 people.**

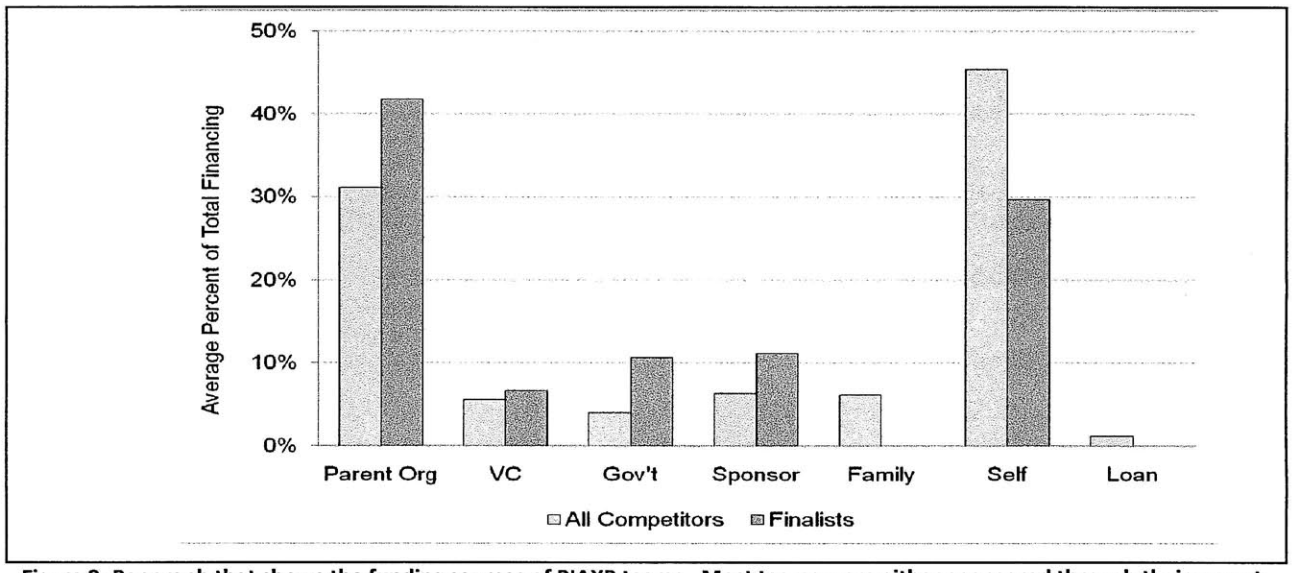



**Figure 9: Bar graph that shows the funding sources of PIAXP teams. Most teams were either sponsored through their parent organization or through personal funds. Not many teams were sponsored through traditional means such as VC or government.**

**Team Composition:** Teams that entered PIAXP were also diverse in terms of composition, although some traits appeared more dominant than others. The size of sample core PIAXP teams ranges from 1 to 40 with an average of 7 members per team (n=54; sd= 8.1). The majority of sample teams have an average age of 30 to 50 (69%) but some teams are primarily composed of members under the age of 30 (13%), and some primarily composed of members over the age of 50 (18%). The highest level of education ranges from PhD (9%), through Bachelor's (49%), Master's (21%) and high school (21%).

36% of teams were non-volunteer groups. The other 64% of teams viewed themselves as volunteer groups (n=33).

Despite this diversity, some similarities exist between sample teams. For instance, almost all survey respondents have team experience in mechanical and electrical engineering (see graph x). Furthermore, many of the teams have at least some expertise in relevant activities including starting a business (81% of sample), working in the auto-industry (65% of sample), energy efficiency (80% of sample), racing (63% of sample), and even competing in prizes (56% of sample). This finding is in contradiction with the Lakhani study on Innocentive that implies that solvers have backgrounds or expertise that are different from that of the problem, although he bases his analysis on the motivators of successful solvers, not all solvers (Lakhani, 2007).

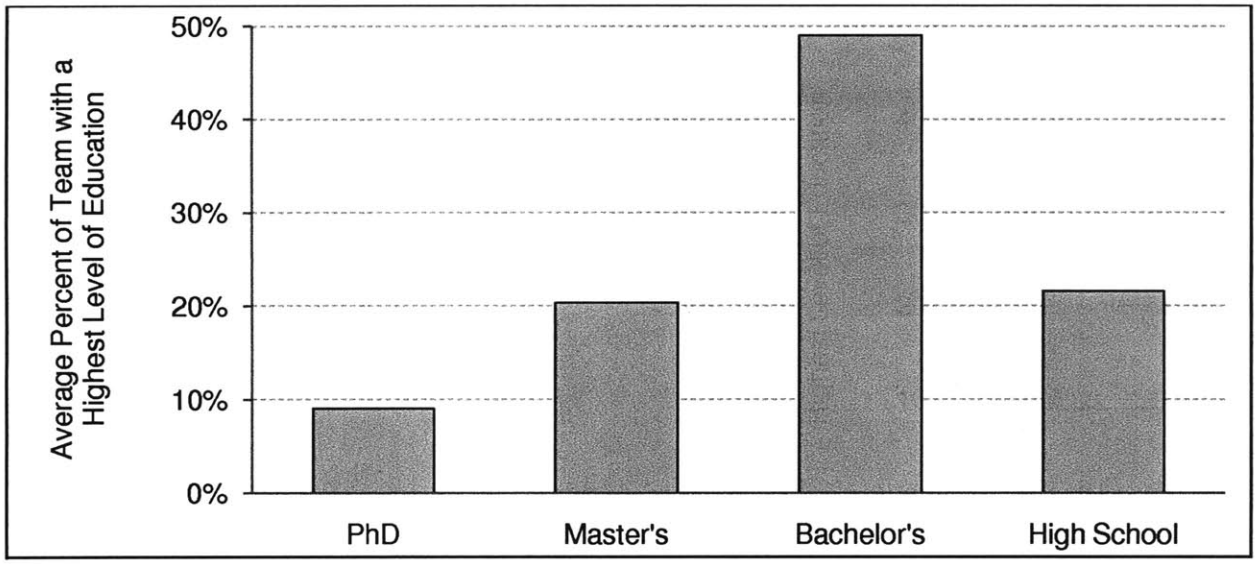



**Figure 10: A bar graph that shows the distribution of team education (by highest education level)**

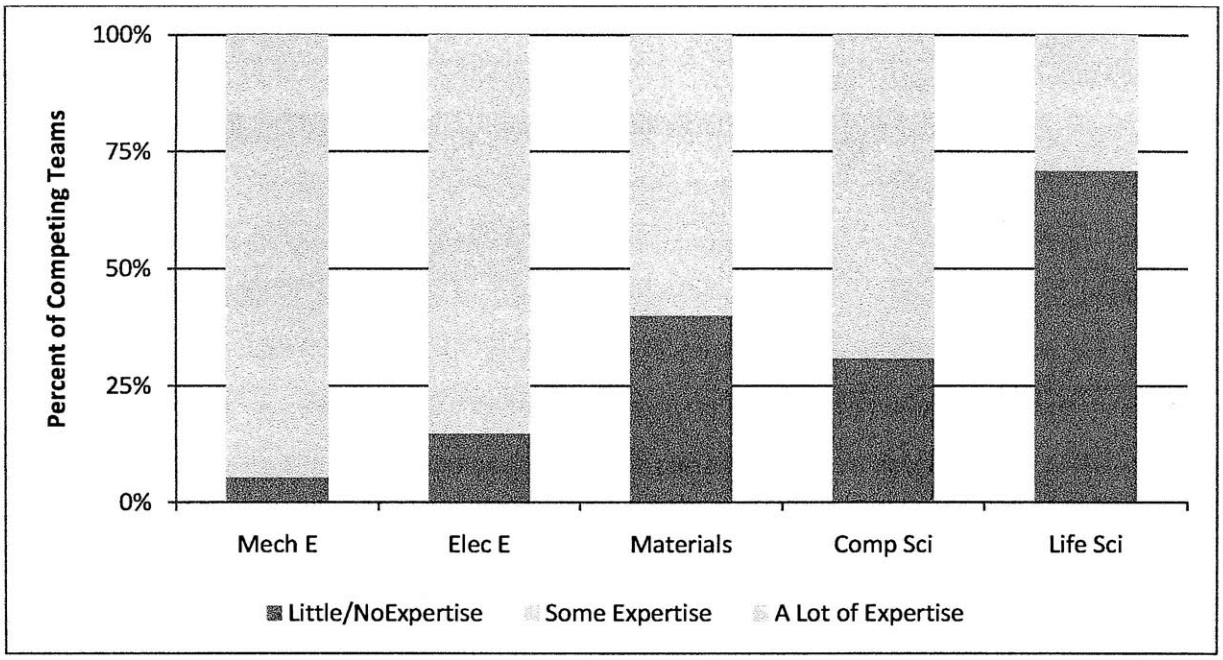



**Figure 11: Bar graph that shows expertise of competing teams in different technical arenas (n=55)**

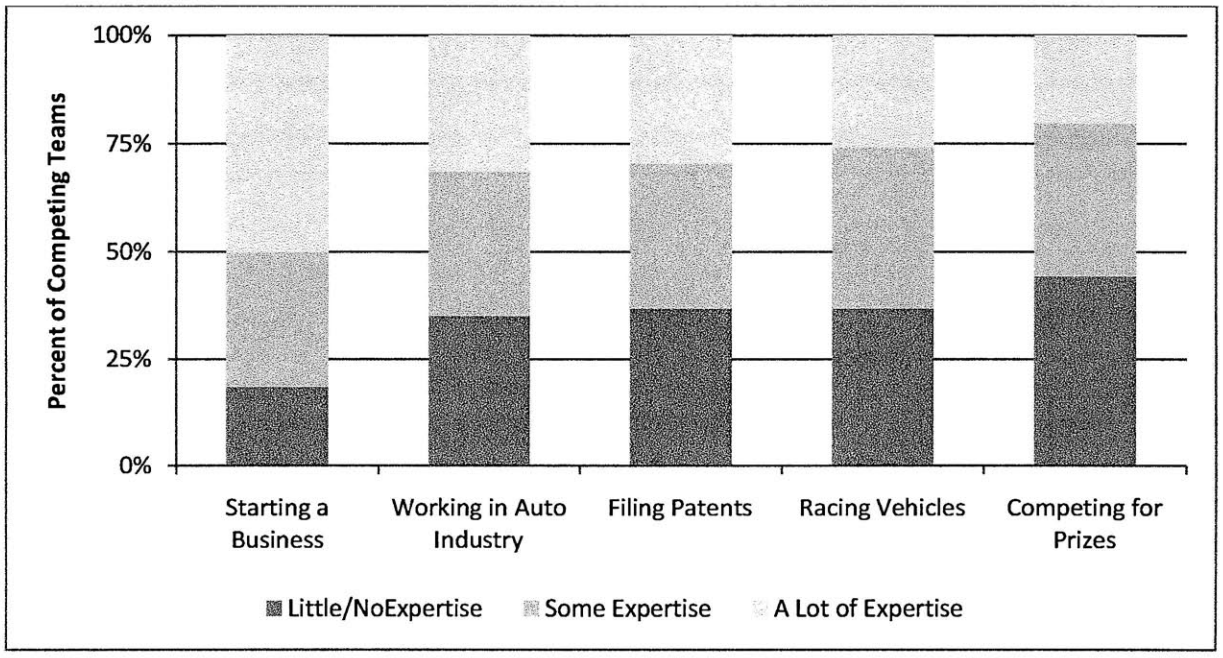



**Figure 12: Bar graph that shows the capabilities of Competing Teams in Different Activities**

**Solutions:** With a diverse set of participants, came a diverse set of innovative technologies. Team solutions included 14 different fuel types, and ranged from full electric and hybrid to combustion engine (figure 13). Around half of the teams developed their own system, bought custom designs, or

significantly modified existing products, and the other half of the sample teams used of the shelf components or bought products and made minor modifications (figure 14).

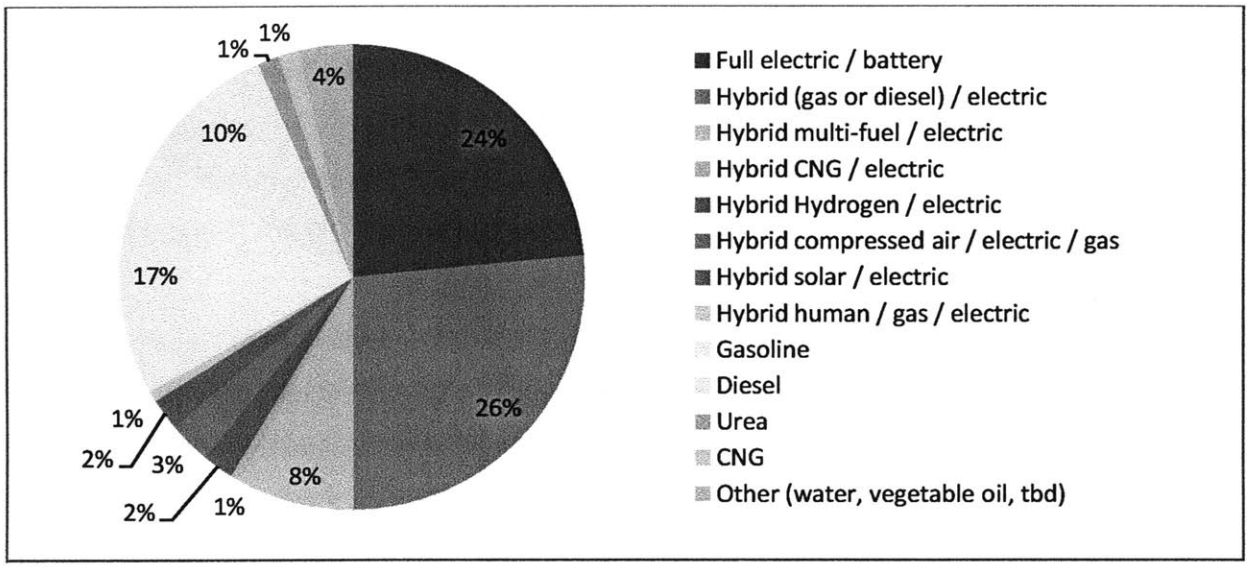



**Figure 13: A pie chart that shows a full set of technical solutions entered into the PIAXP**

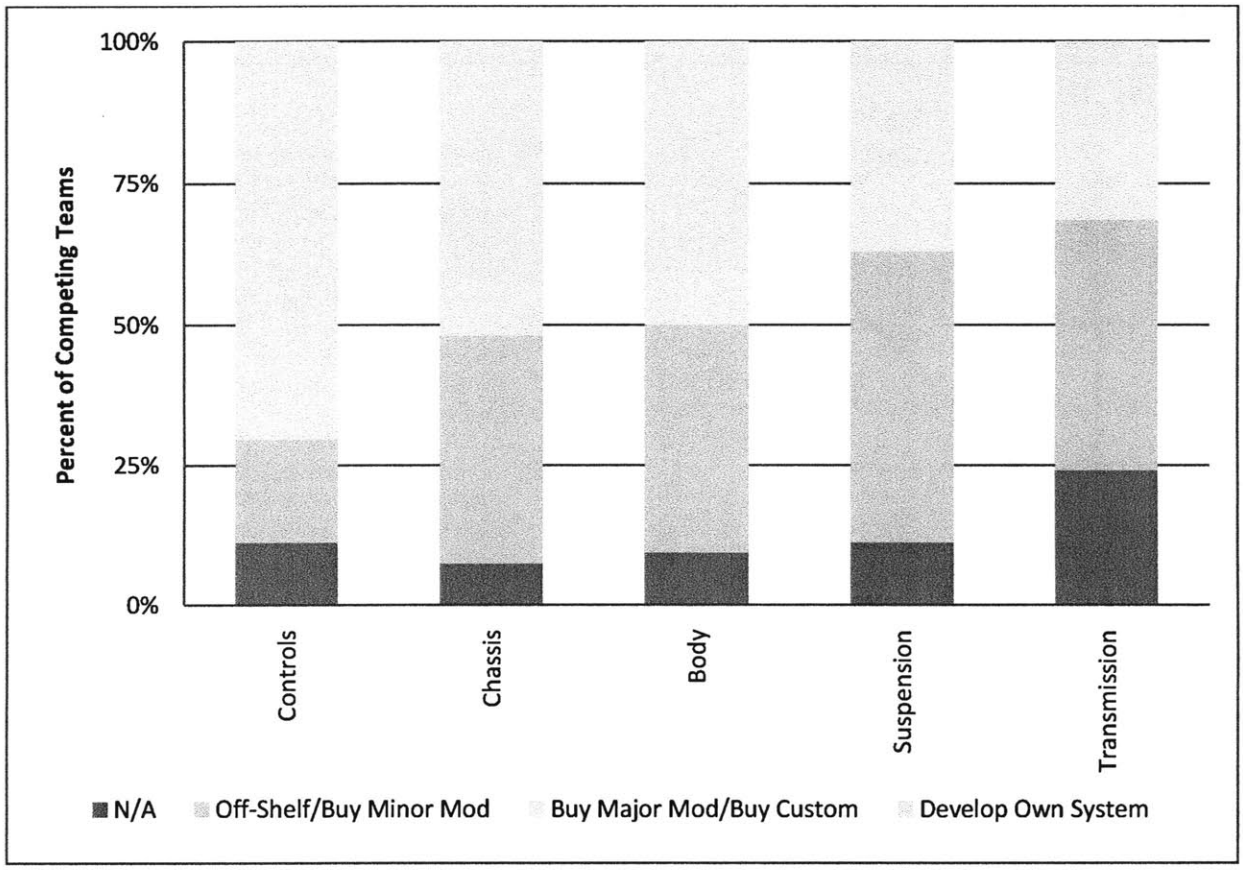



**Figure 14: Bar graph that shows the technical solutions of sample teams measured by the amount of work done to the vehicle components**

## Behavioural Outputs: Participation, Effort, and Creativity

***What were the participants motivated to do?***

From the perspective of the policymaker or prize designer, it is important to understand the effect competition can have on solvers and solutions and whether they can positively influence behaviour. This section looks at the impact of PIAXP on effort in terms of money and time, and performance. The results will help to identify whether the PIAXP competition just acted to "crowdsource" existing teams and solutions, or whether the competition actually induced effort and accelerated performance.

**Team Formation/ Idea Generation:** One of the most interesting findings from the sample data is that PIAXP both crowdsourced existing teams/ideas and induced the formation of new teams/ ideas. PIAXP motivated individuals to form new teams, informal pre-existing teams to formalize their companies and ideas, and formal teams to focus the existing products on a specific problem. Indeed over 35% of the sample teams claimed they did not exist before. Of the 65% of teams that did exist before, 30% were informal and 83% of them were vehicle related (n=37). This is summarized in figure 15.

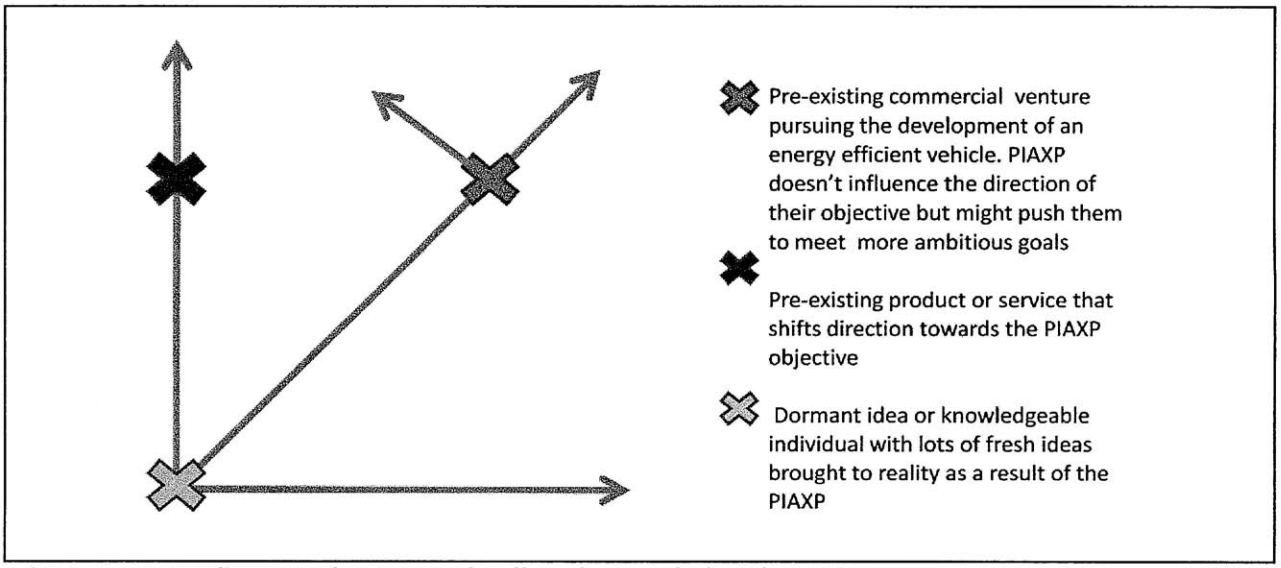



**Figure 15: A vector diagram to demonstrate the effects the PIAXP had on ideas and innovators. Competitions act to crowdsource and facilitate existing ideas, and inspire and nurture the growth of new ideas.**

**Effort during PIAXP:** Effort was induced during the PIAXP in terms of both time and money. Prior to the competition, the average core team exerted 18.09hrs/week (n=32, $\mu$=18.09, sd=23.11, range:0-100) and, at the time of the survey in November 2010 (2 years after the announcement of PIAXP and 3 months after registration closed), sample teams were exerting an average of 46.66hrs/week ($\mu$=46.66, sd=43.07, range:0-240). Similar behavioural patterns were observed for peripheral team members and

contractors associated with teams. It is also important to note that some teams were not putting in any effort at all. An average of 1152 man hours was spent by teams specifically on the PIAXP competition (n=44, μ=1152.08, sd=2221, range: 0.1-11000).Sample teams spent an average of $8,330,625 before the competition which is almost double the amount of money that was spent before the competition began (prior to PIAXP: n=48;μ=$4,904,802, sd=$1588273, range- $0-$10,000,000// since PIAXP: μ=$1323543;sd=$4283998; range: $0-$27000000). The average sample individual spent 43.67hr/week on the PIAXP project (n=45; sd=28.55; range: 4-100), and spent $22228.30 (sd=$53862.83; range: $0-$250,000). Team size increased during the PIAXP competition. Prior to PIAXP beginning, the average core team size was 3.43 (sd= 4.16, range: 0-25) but at the time of the survey (in November) the average core team size was 7 (sd=8.1, range: 0-36). Peripheral team size and number of contactors also increased during the competition.

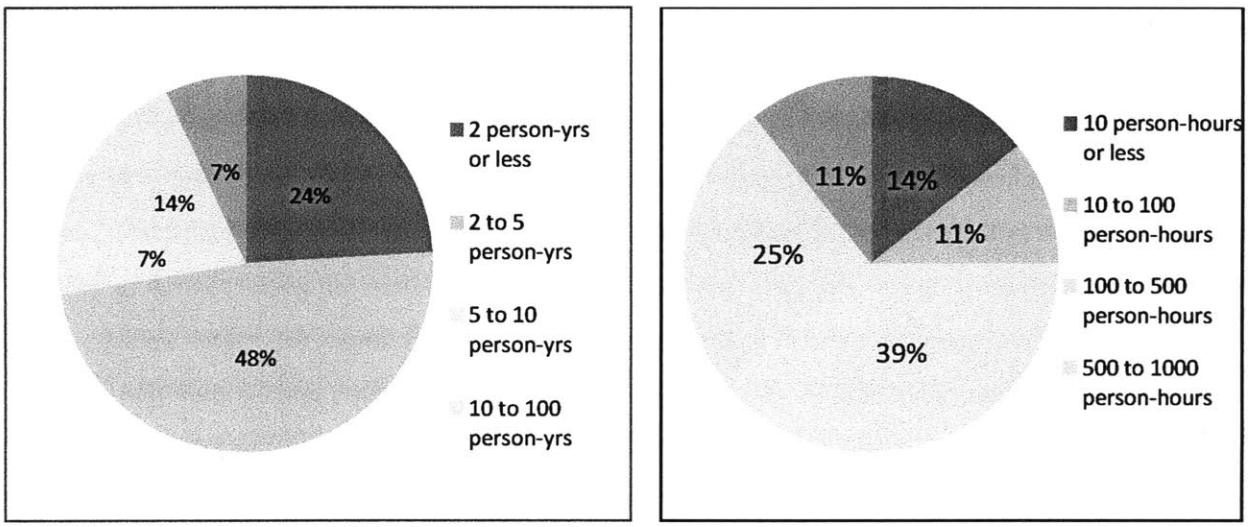



**Figure 16: Pie charts to show the huge amount of time and effort put in by PIAXP team members. The left-hand pie chart shows the time commitment teams dedicated to PIAXP. 86% of teams dedicated more than 2 person-hrs of time. 11% dedicated more than 1000 person-hours of time. This result implies that teams valued the competition enough to participate in time consuming activities, despite not adding any direct value to the vehicle.**

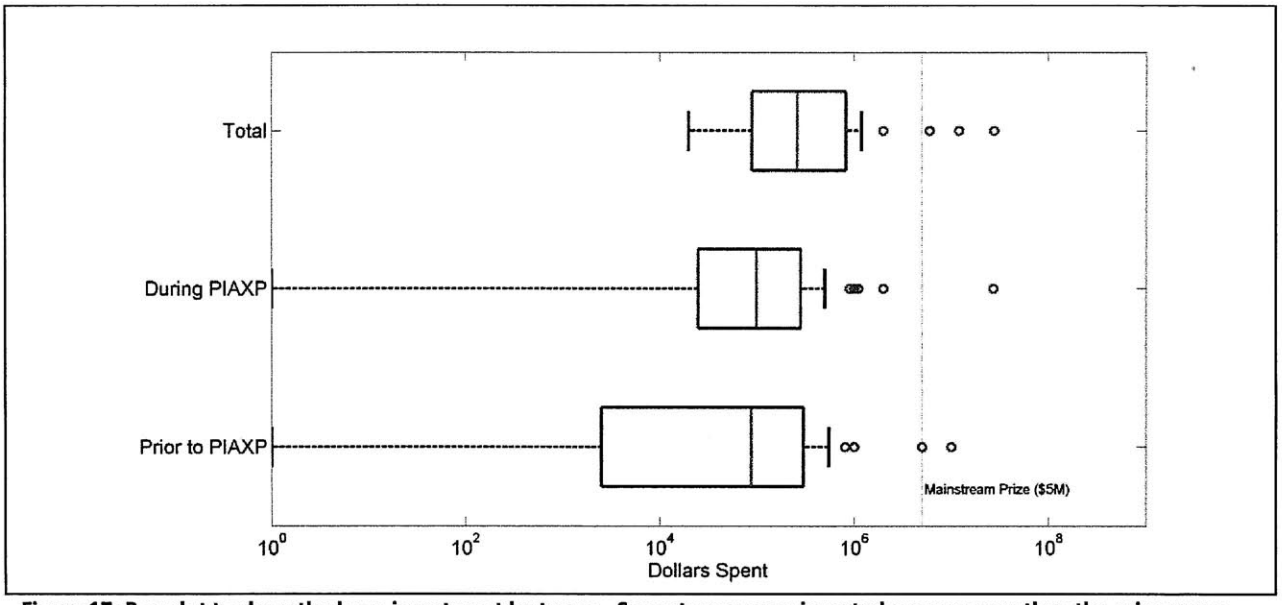



**Figure 17: Box plot to show the huge investment by teams. Some teams even invested more money than the prize purse.**

**Performance Improvements/ Acceleration:** The results of this effort are demonstrated through the competition achievements of the PIAXP teams. At the time of our original survey, only 45% of sample teams had prototypes (n=32), and only a few teams claimed that they had actually achieved the competition objectives (despite their confidence in being able to achieve the goals- see figure 14). 28 teams made through Shakedown and in to the Knockout rounds, which implies that their vehicles were technically and mechanically suitable. Of those 28, 15 entered final which implies they had met the competition criteria, including the 100 MPGe. By the end of the competition, 9 out of the 136 PIAXP vehicles passed validation (which included safety testing in the national labs).

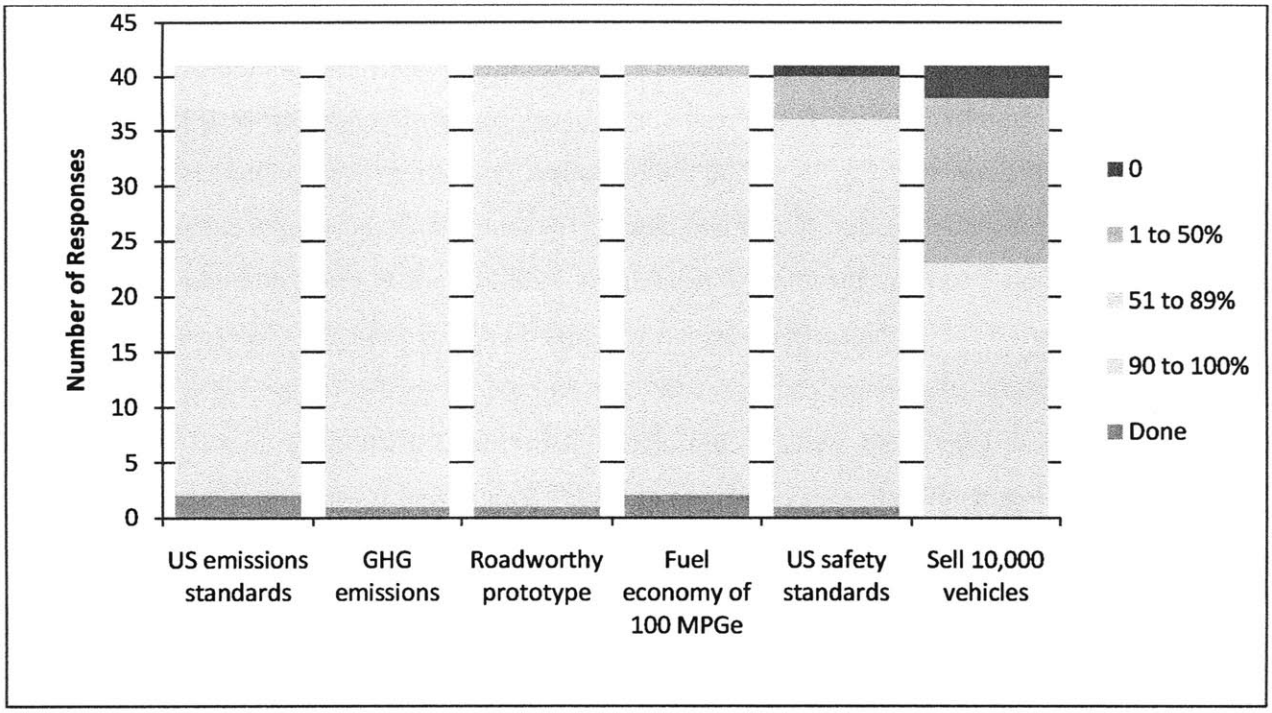



**Figure 28: A bar chart describing team prediction to hit PIAXP competition targets**

Furthermore, significant improvements were made to the vehicles during the competition between knockouts and finals. 11 teams that had already achieved the 100MPGe improved their score even further (see figure 19).

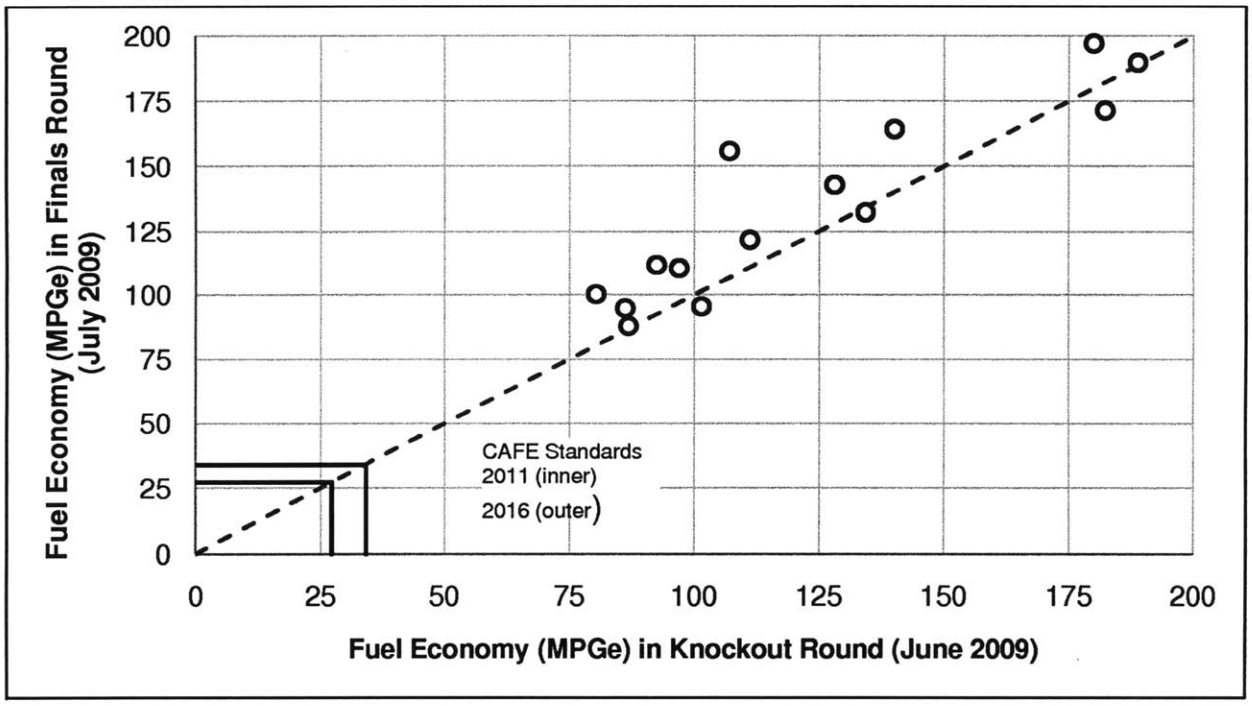
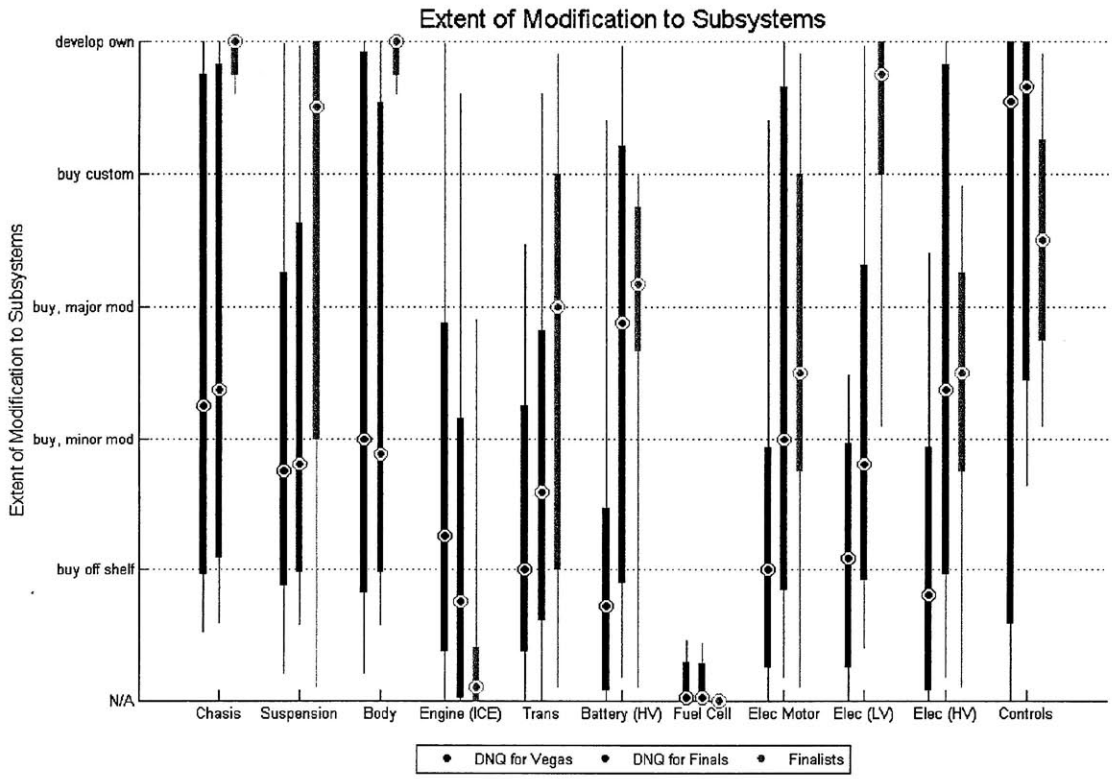



**Figure 19: Performance improvements between PIAXP rounds**

**Creativity:** In terms of creativity, PIAXP seemed to attract innovative solutions and the more innovative teams seem to do better in the later stages of the competition (see figure 16). It is however difficult to determine whether the PIAXP had a direct affect on the creativity exhibited or whether all the innovation occurred before the competition began. The teams might have been passed the point of requiring innovation. Rather, they might have been inducing effort (time and money) to make incremental improvements. The survey question was asked in November 2009, which was two years after the competition was announced but only two months in to the formal PIAXP proceedings. Interestingly, 67% of teams had workable prototypes at the time PIAXP began (n=51) which implies teams either developed innovative ideas because of PIAXP. Sample teams with prototypes did do better in the competition as the competition progressed. By the final round 81% of my sample teams had prototypes prior to the PIAXP (n=6).




| | Chasis | Suspension | Body | Engine (ICE) | Trans | Battery (HV) | Fuel Cell | Elec Motor | Elec (LV) | Elec (HV) | Controls |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vegas | 0.74 | 0.84 | 0.88 | 0.19 | 0.30 | 0.00 | 1.00 | 0.09 | 0.04 | 0.04 | 0.15 |
| Shakedown | 0.25 | 0.39 | 0.36 | 0.37 | 0.94 | 0.06 | 1.00 | 0.74 | 0.19 | 0.32 | 0.54 |
| Knockout | 0.02 | 0.23 | 0.01 | 0.17 | 0.08 | 0.06 | 1.00 | 0.41 | 0.02 | 0.61 | 0.23 |
| Finals | 0.01 | 0.24 | 0.01 | 0.19 | 0.29 | 0.15 | 1.00 | 0.35 | 0.01 | 0.50 | 0.24 |

**Figure 20: A box-plot graph that shows the distribution of survey responses to subsystem development, and the level of success related to the subsystem. The average team was more successful if they developed their own, or significantly modified their chassis, body, battery and high voltage system (i.e. BMS).**

## Relationship between Motivator Inputs and Output

### Motivators and Diversity

The results of this study so far imply that PIAXP was successful at inducing a diverse set of participants with innovative solutions to enter and exert effort towards a pre-defined objective. It is also clear that multiple motivators act to induce the PIAXP participants to compete, and that the motivator preferences of participants seem to be almost as diverse as the participants themselves (see figure 3). To gain some more insight into the motivator types that drive this diverse participation, I dive a little deeper into the data to uncover whether there are any similarities between groups of PIAXP competitors.

My qualitative interviews provide the most insight into the different types of PIAP competitor and their motivators. I identify four different types of PIAXP team that can be grouped based on their motivations for participating in the PIAXP. These four groups are as follows.

**Type 1:** Formal group that existed before the PIAXP, who were previously pursuing a commercial energy efficient vehicle venture. This group includes ***previously incorporated private or public firms and start-up companies***. Although PIAXP did not motivate these teams to generate ideas and initiate new vehicle companies, it did motivate them to focus on achieving the specific PIAXP objectives, which entailed improving the performance of their vehicles. Only 2 or 3 companies claimed to achieve the PIAXP goals prior to the launch of PIAXP, the rest of the teams' exerted effort to meet the criteria during the competition (see figure 28).

**Motivators:** Motivators that act to advance the company are most dominant for this group. These motivators include vehicle validation, publicity, and other performance accelerators. Large corporations and start-ups are both interested in delayed extrinsic benefits but do seem to have different slightly different priorities in some respects.

*Large Corporation:* A team member representing a large company told me that his company was participating in PIAXP because they plan to launch into a new market and needed to communicate their company's support for the energy efficient industry. A team member representing another large corporation, which again is trying to break into a new industry, told me they were used the PIAXP as a "strategic long-term plan- it helps people track us and show people what we capable of. We want people to say- wow that car looks cool- maybe I will check out the XL Truck. And we are using the same technology for the truck".

*Start-Up:* The main driver for start-ups is also associated with recognition, particularly validation and publicity. As one of the team member from a start-up told me:

"XPRIZE is not tangible to our business, it is core. We're a new company. Safety- we have it in the spades, but we don't have a history for consumers to base their assessment of our vehicle's reliability or durability. XPRIZE gave us the opportunity for third-party validation of the claim of being the most energy efficient. So, coming here and being tested by Consumer's Union and the DoE and being sponsored by Progressive, it has the sense of credibility that we are doing, what we said we were doing. The most valuable outcome would be to see reports of our performance from the likes of a consumer union, where they say it is credible, solid and high performance. "

Start-ups also benefited from the prize's rigid structure. One team member believes that the PIAXP helped them be more innovative- "it gave us a very rigid timetable- no room for error. As very small, lean company, that is challenging. If your Ford or GM and you are on a strict deadline- you throw more people on the project. We don't have those numbers which forces us to be smarter- we have to be as efficient in our thinking and in our design and development actions as we are in the execution of the car. When engineers are left up t o their own devices, they can iterate themselves into oblivion – you have to hold yourself to a certain timetable".

Other extrinsic benefits for start-ups include the potential to learn about the industry and interact with the solving community. One team member emphasized the benefits of feedback and support: "the feedback is very helpful- we have some pretty good minds at our company but building a highway capable vehicle is a new order of magnitude for our company- XPRIZE is giving us a lot of direction and feedback we probably won't have in house- XPRIZE has helped tremendously- not just with technical knowledge but also social media".

Much of the motivators so far focus on the reasons why one entered PIAXP but community spirit seems to be an important element of the prize to motivate people through the difficult times, as one team member describes "a week ago [beginning of knockout round] I was ready to it up because I figured there was no way I could meet the schedule of getting the data acquisition system and everything hooked up. And then, all of a sudden, teams just started showing up, and started pitching in- at least 10 engineers. They just started helping out and everyone pitched in- it was amazing, I was just flamboyant. The XPRIZE is like a big family".

**Type 2:** Formal groups that existed before who were already working on a vehicle project or vehicle parts but were not necessarily working on energy efficient vehicles and were not looking to

commercialize their vehicle venture. This group **includes school and university teams.** The PIAXP motivated this group to focus and accelerate their progress, and highlight their technologies.

**Motivators:** This group seem to have slightly different priorities compared to the other groups. The schools participate for two reasons: 1) as an educational opportunity and 2) publicity for the school. As one teacher told me, "If we do well, we can inspire others to do join the program in the future. There are people who walk by our dept every day and have no idea what we are doing". From the student's perspective, they seem to be very motivated by personal career benefits. At least three students got hired by other XPIRZE teams after the competition finished. One student told me: "I didn't take classes this last quarter and took 2 credits the quarter before that. I just spent time on this project because I see this as being much more beneficial – to my career not degree. This is what I want to do- I can prove myself here. I should be able to walk up to any company I beat and say- you should hire me".

Educational teams also seemed to exhibit intrinsic motivation, more so than other participants. As one team member put it: "the XPRIZE is fun too"- it's a cool project to work on! We basically get to do what we want to do- build a crazy carbon fibre electric hybrid race car- that's cool!" The students are also very proud: "it is hard to believe we have made our car so nice- every time I look at it, I just feel so overwhelmed because we have put so much work and time into it, and suddenly it is working!"

The technical standards and judging feedback also helped motivate the students during the competition to improve the quality of their vehicle: "They didn't throw us out- they told us to go away and work things out. We worked day and night, and delivered. We moved our 100mpg vehicle to a safe 100mpg vehicle".

**Type 3:** Informal groups who may or may not have existed before but were not previously building vehicles. This group consists of **"garage entrepreneurs"**. The PIAXP motivated this group to formalize their group and idea to focus on a new challenge.

**Motivators:** Compensation seemed to be a driving force for some of the garage entrepreneurs. A story about Oliver Kuttner, CEO of Edison2, exemplifies this point. He was attracted to PIAXP by the huge potential gains. He entered because of the confidence he had in his ability to deliver a winning solution. Although a commercial real estate developer, he was also a car enthusiast with vast experience in vehicle racing and light-weighting of vehicles. The prospect of winning the $10 million purse motivated Oliver to build a winning team and vehicle from the bottom-up. In total, he hired over 100 specialized individuals to work on their XPRIZE entry (Edison2 website, 2011); he recruited engineers with vast experience in aerodynamics and design, and even two highly qualified race drivers-

Emanuele Pirro, five times Le Mans winner, and Brad Jaeger, an upcoming endurance racer who is now R&D Director for the company.

Once Oliver had formed his team, they went about designing and building their winning vehicle. They went through the PIAXP rules with a toothcomb and, starting from the bottom-up, designed their vehicles to meet every specification. Rather ironically, this strategy resulted in using an internal combustion engine running on E85, as opposed to a battery or hybrid system[20] "our early analysis of efficiency pointed to the unequivocal virtues of light-weight and low aerodynamic drag, instead of lugging around hundreds of pounds of batteries"[21].

His determination to win also motivated him to build and enter five vehicles. This logic came from his racing days where he learned that "cars fail, especially under extreme conditions, and that it is just too risky to enter one vehicle when you are investing all this time and effort to win"[22]. "You never know when they might fail- e.g. with this sliver car we had heating issues and electronics in the throttle body decided to quit on us- For a $10M prize you cannot risk having just one vehicle because over 22,000 miles you could have one flat tire and you're done- we entered 5 cars is to hedge our bets". Teams with existing vehicles were also attracted by the prize purse. They had already demonstrated the potential of their vehicle, and the prize purse was large enough to say "why not?"

Similar to start-ups, garage entrepreneurs also seemed motivated by the performance accelerators.

**Type 4:** Informal groups or individuals that may have had ideas or prototypes but were not looking to commercialize. This group consists of "garage tinkerers".

**Motivators:** Like the students, the garage tinkerers seemed to be motivated by personal extrinsic benefits including the desire to be recognized and fun. As described by a competitor "The XPRIZE is fun- BSing with teams, driving fast cars, racing- a lot of people enjoy this kind of competition." These guys did not seem to want to commercialize their vehicle but still want to get their ideas out in the open: "Personally I don't want to start a company- I don't know how I would. I had an idea how to build a car. I knew how to make it efficient- and well find out from here if I have done a good enough job. Still do it for the competition- I have never won of these. Winning means everything to me right now".

These motivators and groups are summarized in the two figures below. These categories and associated motivators have important implications for the justification of competition as a policy incentive mechanism. It shows that the diverse motivators incorporated into competition, can motivate those who wouldn't otherwise participate in solving a problem. If one wants to promote diversity of solver and solution within a competition, all motivators mentioned need to be emphasized. None of these teams would have participated in solving this specific challenge without the additional incentives and support structure of the PIAXP competition.

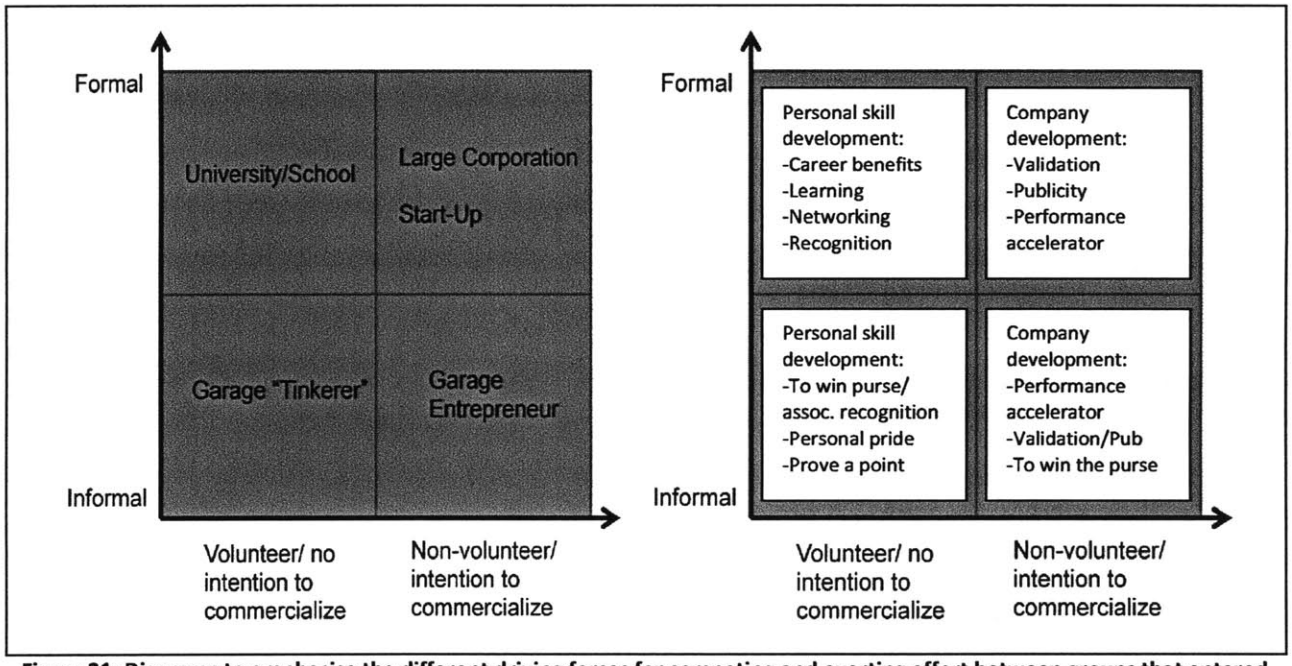



**Figure 21: Diagrams to emphasise the different driving forces for competing and exerting effort between groups that entered PIAXP**

## Motivators and Performance (success and effort)

In order to formally assess the relationship between motivator inputs and performance, I carried out three statistical tests using a similar method of analysis as Lakhani in his Innocentive paper. First I examined the relationship between individual motivators and success. As discussed earlier, although this does not directly lead to any conclusions about effort, it does provide some insight into the ability for motivators to influence outcomes. Second, I examined the relationship between team motivators and effort (total money and time by team). Finally, I examined the relationship between individual motivators and effort (personal time and money spent on PIAXP).

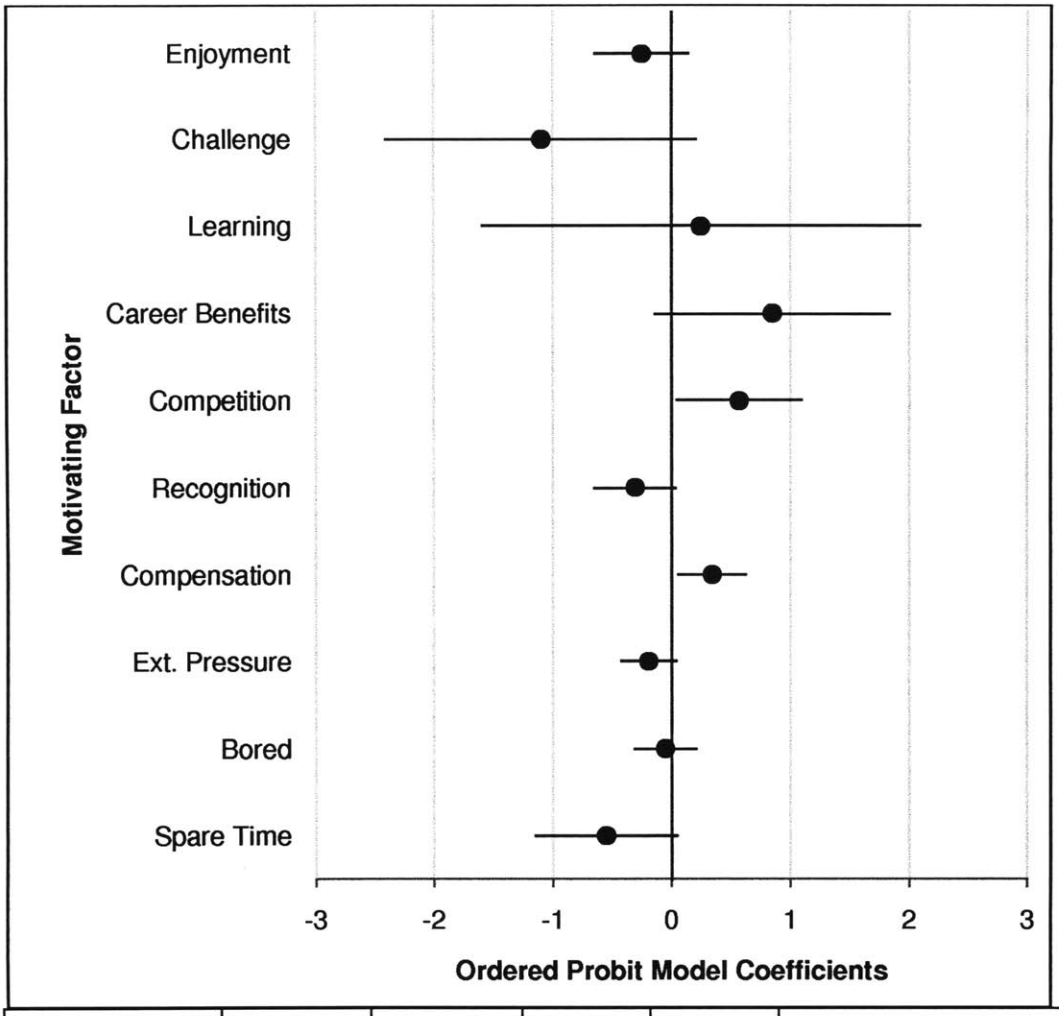
Further analysis is required to investigate the relationship between creativity and the individual motivators.

**Success:** Although compensation and winning were not dominant motivating factors for participating in PIAXP for the average PIAXP team, they were found to be the only motivators to positively and significantly correlate to success (figure 22). Recognition, a strong motivating factor, on the other hand was found to be negatively correlated to success. Total money spent is correlated with success (figure 23) which implies that although the competition acts to attract diverse participation, it can weed out diversity unintentionally along the way.

**Team Effort:** The relationship between motivators and success seem to differ to that of motivators and effort. The only positively significant motivator correlated with time spent on the vehicle is reputation. Publicity, entering new market, and fun are negatively correlated with total time spent on the vehicle. In other words, the more time one invests in a project, the more they care about the reputation of their vehicle (note- the more man-years spent on the vehicle, the more likely the team was to exist prior to the PIAXP).

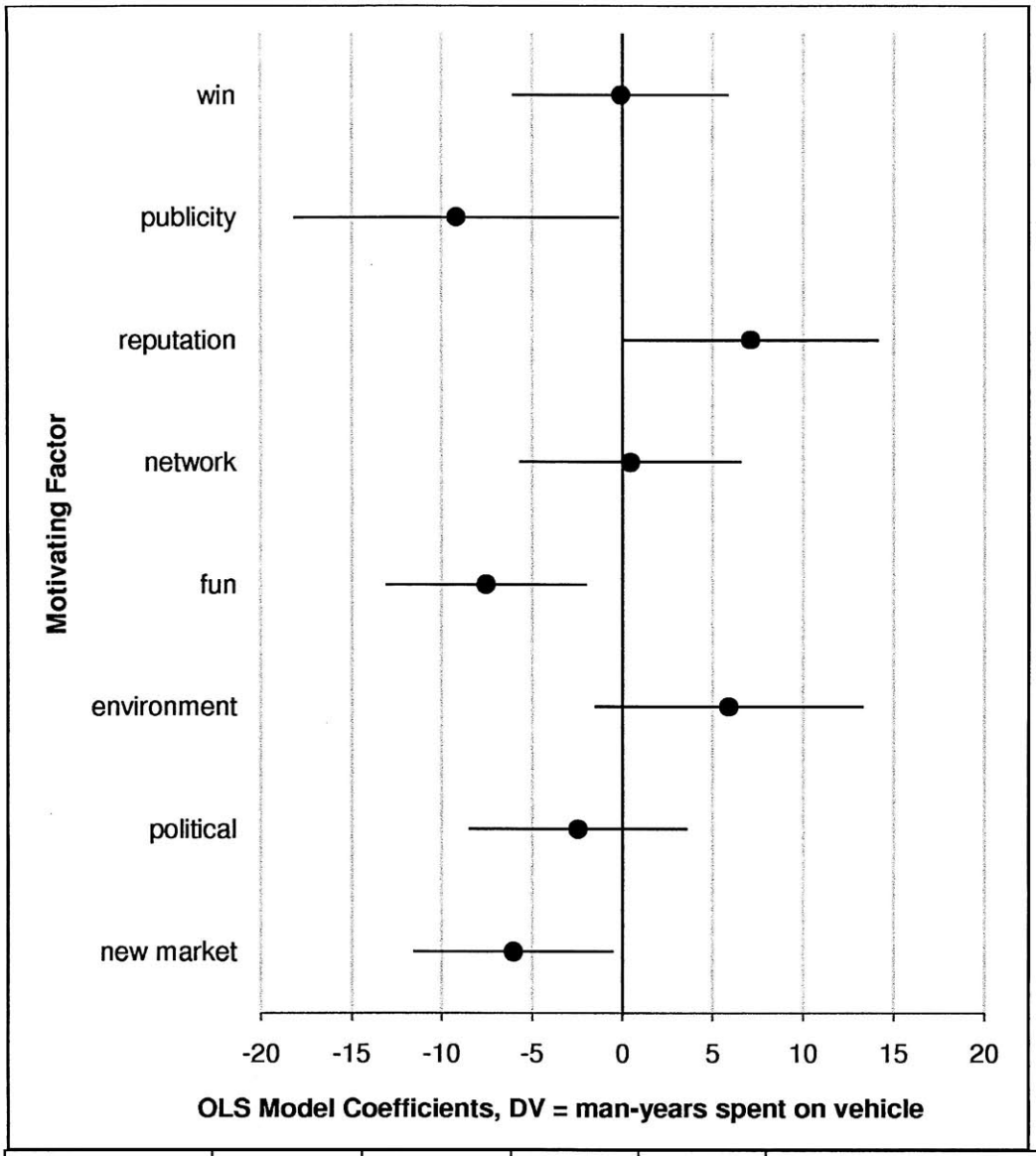
The only significant variable to correlate with money spent is fun, and it is a negative relationship. In other words, if one participates for fun, they are less likely to spend significant amounts of money.

**Individual Effort:** There were no significant findings in this analysis



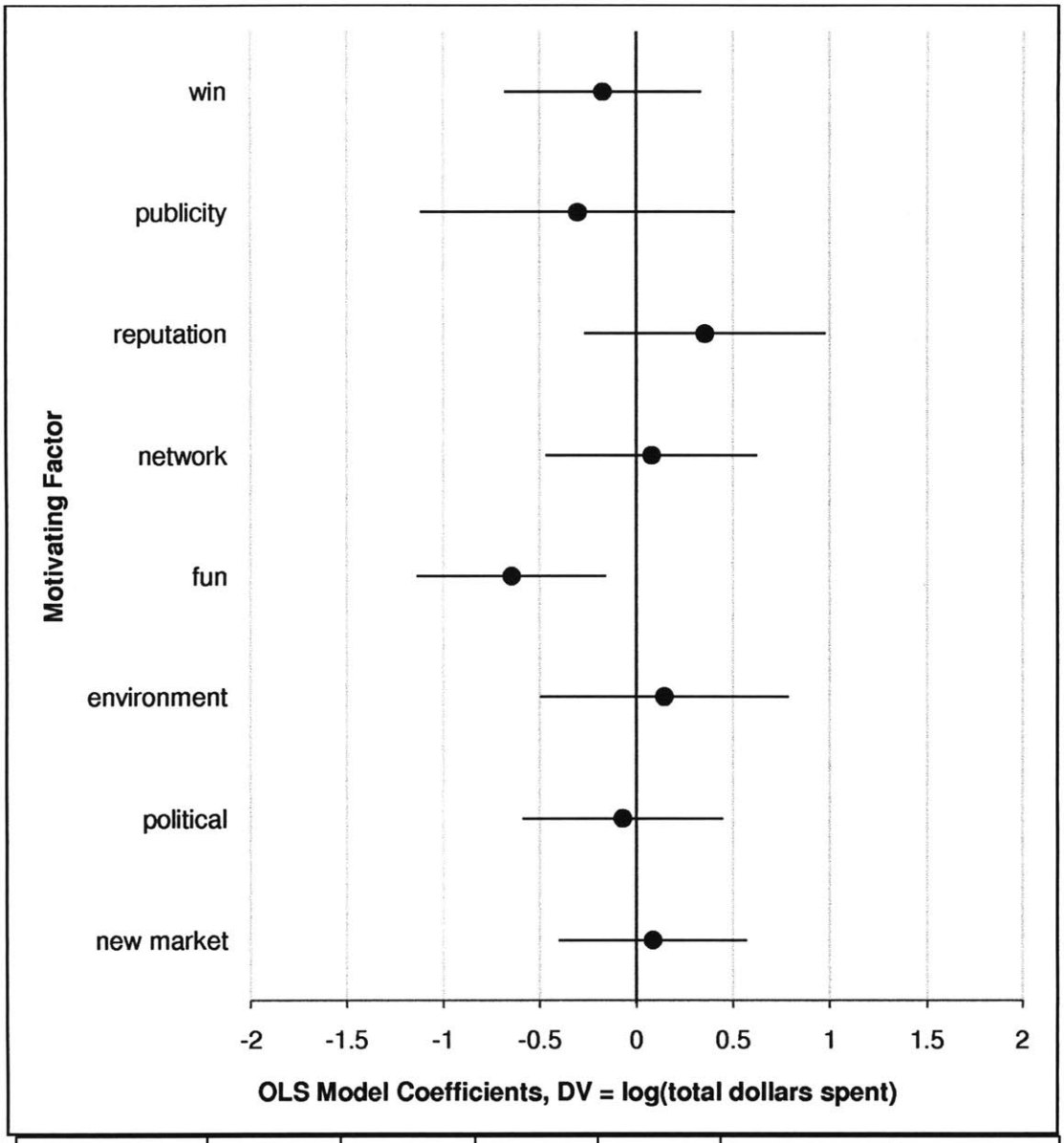

| | Coef | SE | z | p | CI | |
|---|---|---|---|---|---|---|
| Enjoyment | -0.24911 | 0.204571 | -1.22 | 0.223 | -0.65007 | 0.151837 |
| Challenge | -1.09572 | 0.67007 | -1.64 | 0.102 | -2.40903 | 0.217597 |
| Learning | 0.2486 | 0.942743 | 0.26 | 0.792 | -1.59914 | 2.096342 |
| Career Benefits | 0.851394 | 0.505687 | 1.68 | 0.092 | -0.13973 | 1.842522 |
| Competition | 0.572431 | 0.270488 | 2.12 | 0.034 | 0.042283 | 1.102578 |
| Recognition | -0.30567 | 0.178957 | -1.71 | 0.088 | -0.65642 | 0.045078 |
| Compensation | 0.344564 | 0.147672 | 2.33 | 0.02 | 0.055133 | 0.633995 |
| Ext. Pressure | -0.19068 | 0.12127 | -1.57 | 0.116 | -0.42836 | 0.047009 |
| Bored | -0.0503 | 0.134992 | -0.37 | 0.709 | -0.31487 | 0.214284 |
| Spare Time | -0.54987 | 0.308077 | -1.78 | 0.074 | -1.15369 | 0.053949 |

**Figure 22: Ordered probit model to demonstrate the relationship between motivators and success**



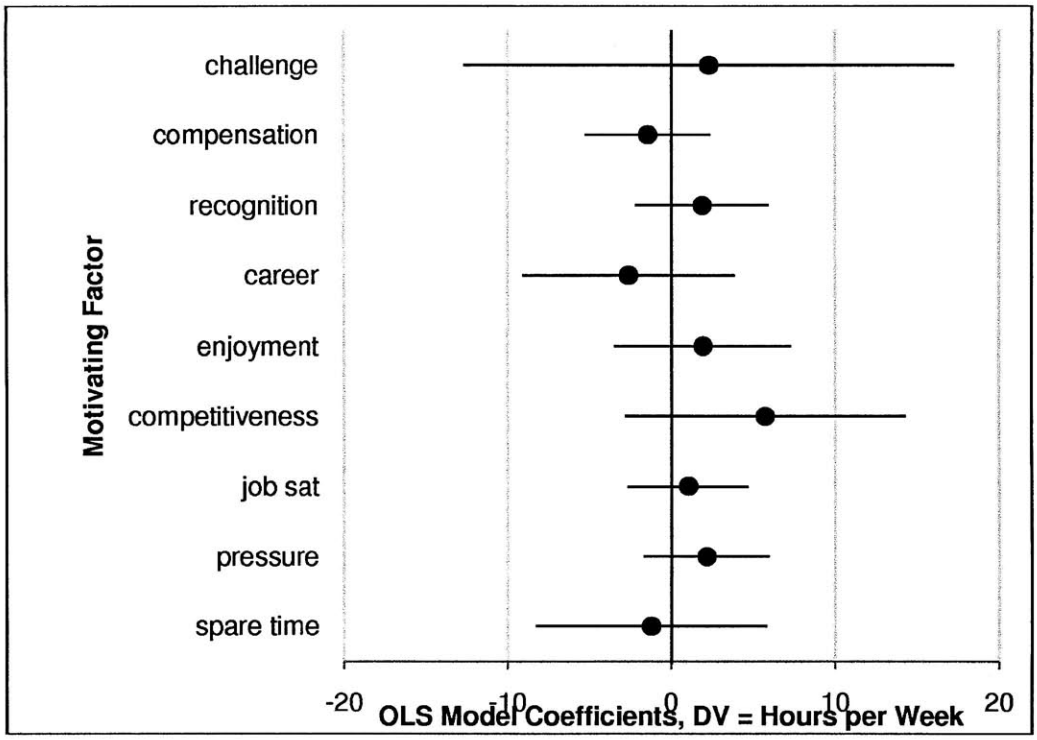

| | Coef | SE | z | p | CI | |
|---|---|---|---|---|---|---|
| Total Team Man Hours Spent | | | | | | |
| win | -0.07812 | 2.946412 | -0.03 | 0.979 | -6.03304 | 5.8768 |
| publicity | -9.18192 | 4.450252 | -2.06 | 0.046 | -18.1762 | -0.18762 |
| reputation | 7.094988 | 3.493179 | 2.03 | 0.049 | 0.03501 | 14.15497 |
| network | 0.448986 | 3.025156 | 0.15 | 0.883 | -5.66508 | 6.563055 |
| fun | -7.53979 | 2.741495 | -2.75 | 0.009 | -13.0806 | -1.99902 |
| environment | 5.899158 | 3.665687 | 1.61 | 0.115 | -1.50947 | 13.30779 |
| political | -2.45348 | 2.980429 | -0.82 | 0.415 | -8.47715 | 3.570191 |
| new market | -6.02295 | 2.730084 | -2.21 | 0.033 | -11.5407 | -0.50524 |
| | 46.97809 | 19.81759 | 2.37 | 0.023 | 6.925251 | 87.03094 |

**Figure 22: Ordered probit model to demonstrate the relationship between motivators and money invested by teams**



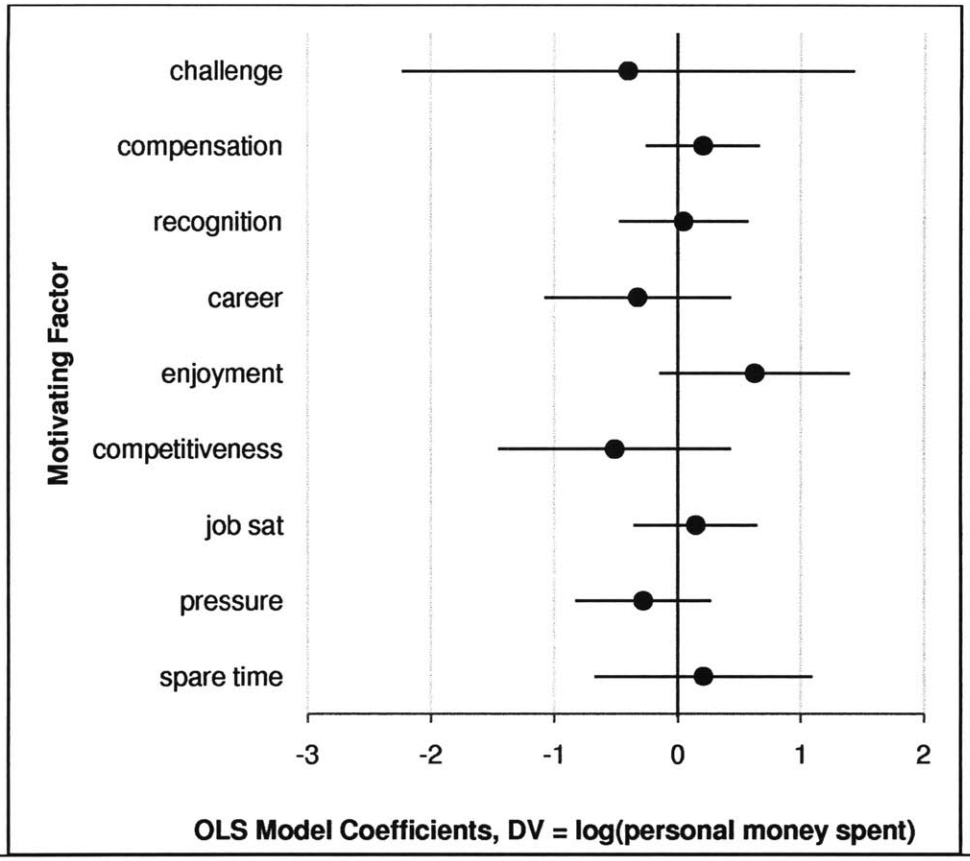

| | Coef | SE | z | p | CI | |
|---|---|---|---|---|---|---|
| Total Team Dollars Spent | | | | | | |
| Win | -0.1734 | 0.250305 | -0.69 | 0.493 | -0.67969 | 0.332889 |
| publicity | -0.30284 | 0.401162 | -0.75 | 0.455 | -1.11427 | 0.508586 |
| reputation | 0.354165 | 0.307242 | 1.15 | 0.256 | -0.26729 | 0.97562 |
| network | 0.078333 | 0.269663 | 0.29 | 0.773 | -0.46711 | 0.623777 |
| Fun | -0.64472 | 0.240773 | -2.68 | 0.011 | -1.13173 | -0.15771 |
| environment | 0.144014 | 0.316271 | 0.46 | 0.651 | -0.49571 | 0.783733 |
| political | -0.07121 | 0.255104 | -0.28 | 0.782 | -0.58721 | 0.444784 |
| new market | 0.084634 | 0.23967 | 0.35 | 0.726 | -0.40015 | 0.569413 |
| _cons | 14.22397 | 1.769801 | 8.04 | 0 | 10.64421 | 17.80373 |

**Figure 23: Ordered probit model to show the relationship between individuals ad motivators**



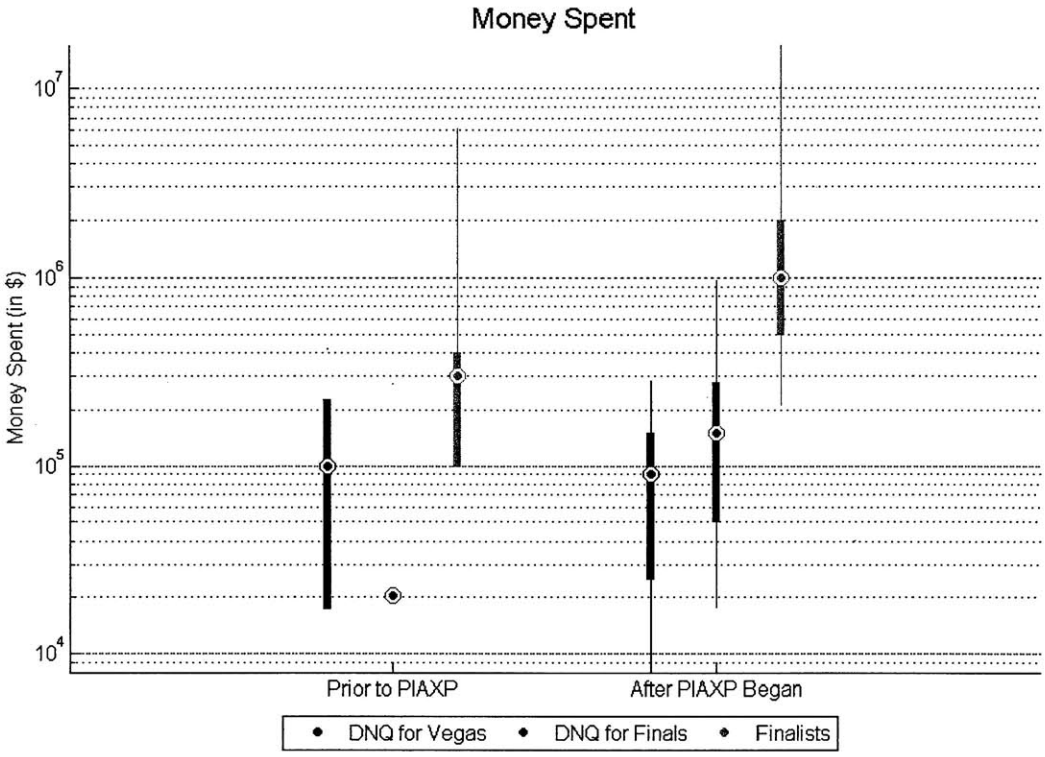

| Individual Hours/ Week | | | | | | |
|---|---|---|---|---|---|---|
| Enjoyment | 2.310405 | 7.350447 | 0.31 | 0.755 | -12.6275 | 17.24831 |
| Challenge | -1.41499 | 1.876225 | -0.75 | 0.456 | -5.22794 | 2.397954 |
| Learning | 1.912502 | 2.000026 | 0.96 | 0.346 | -2.15204 | 5.977044 |
| Career Benefits | -2.58964 | 3.179843 | -0.81 | 0.421 | -9.05186 | 3.872574 |
| Competition | 1.943924 | 2.657364 | 0.73 | 0.469 | -3.45649 | 7.344338 |
| Recognition | 5.749334 | 4.201515 | 1.37 | 0.18 | -2.78917 | 14.28784 |
| Compensation | 1.05278 | 1.806675 | 0.58 | 0.564 | -2.61883 | 4.724386 |
| Ext. Pressure | 2.181889 | 1.886576 | 1.16 | 0.256 | -1.6521 | 6.015873 |
| Bored | -1.20037 | 3.465333 | -0.35 | 0.731 | -8.24277 | 5.842039 |
| Spare Time | -5.85296 | 29.0767 | -0.2 | 0.842 | -64.9439 | 53.23802 |

**Figure 24: Ordered probit to show the relationship between individual motivators and individual time exerted**




| Personal Money Spent | | | | | | |
|---|---|---|---|---|---|---|
| Enjoyment | -0.40145 | 0.873628 | -0.46 | 0.651 | -2.22998 | 1.427072 |
| Challenge | 0.20455 | 0.218917 | 0.93 | 0.362 | -0.25365 | 0.662748 |
| Learning | 0.04775 | 0.249057 | 0.19 | 0.85 | -0.47353 | 0.569031 |
| Career Benefits | -0.32483 | 0.359888 | -0.9 | 0.378 | -1.07808 | 0.428428 |
| Competition | 0.623268 | 0.366221 | 1.7 | 0.105 | -0.14324 | 1.389776 |
| Recognition | -0.51104 | 0.448818 | -1.14 | 0.269 | -1.45043 | 0.428342 |
| Compensation | 0.14619 | 0.237713 | 0.61 | 0.546 | -0.35135 | 0.643728 |
| Ext. Pressure | -0.27914 | 0.260972 | -1.07 | 0.298 | -0.82537 | 0.267076 |
| Bored | 0.208693 | 0.419627 | 0.5 | 0.625 | -0.6696 | 1.086982 |
| Spare Time | 7.094362 | 3.434387 | 2.07 | 0.053 | -0.09389 | 14.28262 |

**Figure 25: Ordered probit model to show the relationship between individual motivator inputs and money invested by individuals**




| | Prior | After | Total |
|---|---|---|---|
| Vegas | **0.66** | **0.08** | **0.30** |
| Shakedown | **0.83** | **0.24** | **0.59** |
| Knockout | **0.73** | **0.31** | **0.62** |
| Finals | **0.08** | **0.02** | **0.02** |

**Figure26: A box-plot graph that shows the distribution of survey responses to money spent, and the level of success related to the money spent. The average team who spent more money was significantly more successful than teams who didn't spend as much.**

## Chapter 5: Lessons for the Literature, Policymakers & Prize Design

The previous chapter (my results) determines the motivators incorporated into one large incentive competition- the Progressive Automotive XPRIZE, and the effectiveness of these motivators to 1) focus solvers on the specific challenge, and 2) encourage them to exert effort and develop creative solutions to meet the prize objectives. Although my results are generated from the data of one case study, and thus cannot be overly generalized, they do provide valuable insight into the mechanisms behind large incentive competitions. These insights include: the types of individual and organization that can be influenced by a large incentive competition, the motivators behind active participation for the various participants, and the relationship between the participants' motivators and success, effort, and creativity.

This information, supplemented by further insight from the motivation literature, can be used to:

- Help determine the role of large incentive prizes in society amongst the other conventional policy mechanisms such as patents and procurement
- Determine the motivators and prize environment that can promote participation, and induce effort and creativity so that they can be utilized by future policymakers and prize designers.

### Role of Large Incentive Competitions in Innovation Policy

The results from this thesis imply that large incentive competitions have the potential to effectively supplement conventional innovation policies such as patents and procurement. More specifically, the results highlight two unique features of large incentive competitions that can promote innovation.

First, competition can effectively act to attract and focus a diverse set of solvers on a specific problem, who otherwise would not or could not pursue the defined objective(s). For the PIAXP, the nature of the incorporated motivators and supporting prize design motivated informal teams to formalize their idea/ ventures to meet the demanding prize objectives, formal organizations with existing products to adapt or improve designs to meet the demanding prize objectives, and for auto-enthusiasts ("garage entrepreneurs" or "garage tinkerers") to set their mind to a new and demanding challenge. These teams were not funded through traditional means such as government grants or

venture capital; in fact, most teams were self-funded. This diversity arose from the many incentives incorporated into the competition, ranging from current and delayed extrinsic reward to intrinsic passion for the cause. In addition, the exploration time at the beginning of PIAXP, the broad and flexible rules, the competition stages with a low barrier to entry, and institutional support such as technical feedback, all allowed for teams who had not necessarily fully developed their ideas or built prototypes to participate in the competition and compete on a level playing field.

According to the findings, the PIAXP attracted and focused four types of solver: formal companies (both large organizations and start-up companies), academic teams, "garage entrepreneurs", and garage "tinkerers". From the qualitative data, it appears that the large companies were primarily motivated to participate in PIAXP to draw public attention to their high efficiency achievements. Participating PIAXP start-ups were primarily motivated by their desire to validate their vehicles through meeting the prize objectives and being compared against other vehicles of similar quality. The academic teams were primarily motivated by their desire to market themselves and have fun. The "garage entrepreneurs" were primarily motivated by their desire to launch their company and benefited significantly from the performance accelerators incorporated in the competition. The "garage tinkerers" were primarily motivated by the desire to be personally recognized for their achievements. Confidence in the team's ability to win the prize also seemed to play a dominant role in the decision to enter the competition.

Second, in addition to "crowdsourcing" a diverse set of participants, large incentive competitions can also facilitate the development of the participating teams and ideas, and thus innovation. In the PIAXP, teams actively exerted effort (through money and time) and significantly improved the performance of their vehicles during the competition. Prize design that supported this development included technical and business support (through online webinars and interactions with participants/ experts at onsite events), expert feedback from judges, and imposed milestones (although the initial deadlines were reasonably far apart, and the rules appeared reasonably flexible). Furthermore, through partnerships with the Department of Energy and Consumer Reports, the competition was able to provide teams with means to carry out important work such as safety testing. Most teams would not have had access to these facilities outside of the prize.

The findings in this thesis partially support and partially contradict existing motivation literature. According the economic literature, compensation was argued to be the most influential motivator, however, in PIAXP it appears that recognition and performance accelerators are more dominant (although arguably these motivators are still associated with delayed compensation through the

eventual financial success of the participating company). Also, psychologists argue that constraining conditions such as deadlines and extrinsic reward hinder effort and creativity. However, the PIAXP induced participants to exert effort. This may have been a result of the complimentary conditions such as positive feedback, openness of rules, and long lead times. Furthermore, the fact that participants entered with high level of intrinsic motivation, may have counteracted the negative impact of the competition constraints.

**Lessons for Prize Design**

In terms of prize design, the PIAXP findings imply that diverse motivators are useful for promoting diverse participation. These motivators include: financial reward, recognition (in the form of vehicle validation, highlighting vehicle performance and associated company, and individual prestige associated with winning), and performance accelerators (both at the company and individual level). An objective that can trigger intrinsic motivation also seems important to competition design in terms of the effort and creativity exerted during the competition. In terms of prize design, the length, structure and staging must be thought through carefully. If the goal is to attract diverse ideas, it is important to realize that the ideas out there may not be fully developed and that the length and goal posts of the prize must accommodate this issue.

Despite these general conclusions, it is important to note that they are based on the assessment of only one competition. This thesis emphasizes the important of prize design and motivators to influence behaviour and thus outcomes, but does not necessarily provide the perfect prize template for future prizes. When one is designing a prize, one should interact with potential participants directly to determine why they would want to participate, and then design the prize accordingly. Competition must provide motivators that benefit all competitors, whether or not they win the competition. In other words, the best competitions are those where everyone is a winner.

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## Appendix

Table A1: Descriptive Statistics by Individual (motivation, personal compensation, and personal effort)

| | | n | mean | stdev | min | max |
|---|---|---|---|---|---|---|
| Motivation to enter PIAXP | To win the award money for my team | 51 | 3.41 | 1.20 | 1 | 5 |
| | To receive individual compensation | 51 | 2.53 | 1.29 | 1 | 5 |
| | To gain recognition in my organization | 50 | 3.26 | 1.32 | 1 | 5 |
| | To gain recognition in the industry | 51 | 3.92 | 1.29 | 1 | 5 |
| | To challenge myself intellectually | 50 | 4.40 | 0.88 | 1 | 5 |
| | To expand my knowledge | 50 | 4.34 | 0.96 | 1 | 5 |
| | To enhance my skills | 50 | 4.32 | 0.98 | 1 | 5 |
| | To network with PIAXP participants | 51 | 3.22 | 1.24 | 1 | 5 |
| | To have fun | 51 | 3.98 | 0.99 | 1 | 5 |
| | To impress my colleagues | 50 | 2.70 | 1.22 | 1 | 5 |
| | To beat other participants | 50 | 3.52 | 1.34 | 1 | 5 |
| | Because I was passionate about the cause | 51 | 4.31 | 0.97 | 1 | 5 |
| | Because it was part of my job requirement | 50 | 2.20 | 1.34 | 1 | 5 |
| | Because my previous job was not satisfying enough | 50 | 2.44 | 1.33 | 1 | 5 |
| | Because my day job is not satisfying enough | 50 | 2.48 | 1.30 | 1 | 5 |
| | Because I experienced internal pressure from my organization | 50 | 1.46 | 0.76 | 1 | 4 |
| | Because I had some spare time available | 51 | 2.47 | 1.24 | 1 | 5 |
| | Because I enjoy the thrill of competition | 50 | 3.76 | 1.17 | 1 | 5 |
| | Because my friend(s) asked me to | 50 | 2.46 | 1.46 | 1 | 5 |
| Motivation to stay involved | To win the award money for my team | 48 | 3.60 | 1.20 | 1 | 5 |
| | To receive individual compensation | 48 | 2.81 | 1.38 | 1 | 5 |
| | To gain recognition in my organization | 47 | 3.34 | 1.34 | 1 | 5 |
| | To gain recognition in the industry | 47 | 3.77 | 1.31 | 1 | 5 |
| | To challenge myself intellectually | 47 | 4.23 | 1.05 | 1 | 5 |
| | To expand my knowledge | 47 | 4.19 | 1.08 | 1 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | To enhance my skills | 47 | 4.19 | 1.06 | 1 | 5 |
| | To network with PIAXP participants | 48 | 3.60 | 1.35 | 1 | 5 |
| | To have fun | 47 | 3.96 | 1.10 | 1 | 5 |
| | To impress my colleagues | 47 | 2.74 | 1.26 | 1 | 5 |
| | To beat other participants | 47 | 3.68 | 1.37 | 1 | 5 |
| | Because I was passionate about the cause | 47 | 4.43 | 0.83 | 2 | 5 |
| | Because it was part of my job requirements | 47 | 2.23 | 1.31 | 1 | 5 |
| | Because my previous job was not satisfying enough | 47 | 2.43 | 1.31 | 1 | 5 |
| | Because my day job is not satisfying enough | 45 | 2.36 | 1.33 | 1 | 5 |
| | Because I experienced internal pressure from my organization | 46 | 1.65 | 0.90 | 1 | 4 |
| | Because I had some spare time available | 47 | 2.32 | 1.29 | 1 | 5 |
| | Because I enjoy the thrill of competition | 47 | 3.77 | 1.25 | 1 | 5 |
| | Because my friend(s) asked me to | 47 | 2.47 | 1.44 | 1 | 5 |
| | Participation with no financial reward | 54 | 0.65 | 0.48 | 0 | 1 |
| Compensation offered | Salary | 54 | 0.24 | 0.43 | 0 | 1 |
| | Intellectual property ownership | 54 | 0.11 | 0.32 | 0 | 1 |
| | A share in the prize purse | 54 | 0.31 | 0.47 | 0 | 1 |
| | Equity in your company | 54 | 0.13 | 0.34 | 0 | 1 |
| Personal Effort | Personal money spent on the PIAXP project [in US$] | 47 | 22228 | 53862 | 0 | 250000 |
| | Hours/ week spent on the PIAXP project | 45 | 43.67 | 28.55 | 4 | 100 |

Table A2: Descriptive Statistics by Team

| | n | mean | Std | min | max |
|---|---|---|---|---|---|
| ENTRY | 55 | 1 | 0 | 1 | 1 |
| VEGAS | 55 | 0.6 | 0.494413 | 0 | 1 |
| SHAKEDOWN | 55 | 0.363636 | 0.485479 | 0 | 1 |
| KNOCKOUT | 55 | 0.2 | 0.403687 | 0 | 1 |
| FINALS | 55 | 0.109091 | 0.314627 | 0 | 1 |
| VALIDATION | 55 | 0.109091 | 0.314627 | 0 | 1 |
| WIN | 55 | 0.036364 | 0.188919 | 0 | 1 |
| CORE_FIRST_LEARN | 54 | 3.425926 | 4.160016 | 0 | 25 |
| CORE_REG | 54 | 5.259259 | 4.953311 | 0 | 25 |
| CORE_CURRENT | 54 | 7 | 8.10078 | 0 | 40 |
| CORE_INCREASE | 32 | 5.6875 | 8.467919 | 0 | 36 |
| PERIPH_FIRST_LEARN | 54 | 1.962963 | 3.961908 | 0 | 20 |
| PERIPH_REG | 54 | 5 | 11.15584 | 0 | 80 |
| PERIPH_CURRENT | 54 | 6.685185 | 8.058335 | 0 | 40 |
| PERIPH_INCREASE | 32 | 5.5 | 7.683245 | 0 | 35 |
| CONTRACT_FIRST_LEARN | 54 | 0.277778 | 0.998426 | 0 | 6 |
| CONTRACT_REG | 54 | 0.962963 | 2.073762 | 0 | 10 |
| CONTRACT_CURRENT | 54 | 2.166667 | 4.508901 | 0 | 30 |
| CONTRACTOR_INCREASE | 32 | 2.59375 | 5.375328 | 0 | 30 |
| CORE_AGE_UN30 | 54 | 4.092593 | 8.887703 | 0 | 56 |
| CORE_AGE_30_50 | 54 | 5.111111 | 10.34074 | 0 | 70 |
| CORE_AGE_OV50 | 54 | 1.666667 | 1.737489 | 0 | 10 |
| CORE_AGE_MAJ | 54 | 1.833333 | 0.746059 | 0 | 3 |
| NONUSA | 52 | 0.711538 | 0.457467 | 0 | 1 |
| PCENT_TEAM_HQ | 52 | 71.86538 | 31.20899 | 0 | 100 |
| NO_OF_LOC | 52 | 2.346154 | 1.898241 | 0 | 10 |
| CAR_NO_MS | 31 | 0.612903 | 0.760588 | 0 | 3 |
| CAR_NO_ALT | 31 | 0.677419 | 0.599283 | 0 | 2 |
| ORG_STRUCTURE | 55 | 2.054545 | 0.989167 | 1 | 4 |
| ORG_STRU_YN | 55 | 0.563636 | 0.500505 | 0 | 1 |
| ORG_STR_PNP | 32 | 0.8125 | 0.396558 | 0 | 1 |
| ORG_YR_FOUNDED | 24 | 2000.208 | 13.91271 | 1945 | 2009 |
| ORG_EMPLOY_NUM | 25 | 937.92 | 4596.372 | 1 | 23000 |
| ORG_SALES | 25 | 5.66E+08 | 2.8E+09 | 0 | 1.4E+10 |
| ORG_PIAXP_PERCENT | 26 | 56.5 | 39.87104 | 0 | 100 |
| ORG_PIAXP_PERCENT_YN | 17 | 0.294118 | 0.469668 | 0 | 1 |
| ORG_INFLUENCE_VIS | 55 | 0.109091 | 0.314627 | 0 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| ORG_INFLUENCE_PER | 55 | 0.072727 | 0.262082 | 0 | 1 |
| ORG_INFLUENCE_FIN | 55 | 0.2 | 0.403687 | 0 | 1 |
| ORG_INFLUENCE_TECH | 55 | 0.090909 | 0.290129 | 0 | 1 |
| ORG_INFLUENCE_NA | 55 | 0.618182 | 0.49031 | 0 | 1 |
| CAT_AUTO_MAN | 54 | 0.185185 | 0.392095 | 0 | 1 |
| CAT_SUBSYS_COMP_MAN | 54 | 0.148148 | 0.358583 | 0 | 1 |
| CAT_FE_CAR | 54 | 0.203704 | 0.406533 | 0 | 1 |
| CAT_MAT | 54 | 0.037037 | 0.190626 | 0 | 1 |
| CAT_ENERGY | 54 | 0.074074 | 0.264351 | 0 | 1 |
| PRIOR_PIAXP_ACTIVITY | 55 | 1.8 | 1.432429 | 0 | 4 |
| PRIOR_PIAXP_ACTIVITY_TEAM | 55 | 0.654545 | 0.479899 | 0 | 1 |
| PRIOR_PIAXP_ACTIVITY_VEHREL | 37 | 0.837838 | 0.373684 | 0 | 1 |
| PRIOR_PIAXP_ACTIVITY_FORMAL | 37 | 0.702703 | 0.463373 | 0 | 1 |
| TEAM_YR_FORM | 54 | 2006.296 | 4.254319 | 1984 | 2009 |
| CORE_ED_PHD | 54 | 0.851852 | 2.00384 | 0 | 13 |
| CORE_ED_MASTERS | 54 | 1.555556 | 1.722949 | 0 | 8 |
| CORE_ED_UNGRAD | 54 | 4.185185 | 5.298893 | 0 | 30 |
| CORE_ED_SKL | 54 | 2.462963 | 6.468247 | 0 | 46 |
| CORE_ED_MAJ | 55 | 2.836364 | 0.976836 | 0 | 4 |
| CORE_SKILL_ELECENG | 55 | 2.363636 | 0.778499 | 0 | 3 |
| CORE_SKILL_MECHENG | 55 | 2.618182 | 0.652372 | 0 | 3 |
| CORE_SKILL_AERO | 55 | 1.272727 | 1.177797 | 0 | 3 |
| CORE_SKILL_MATSCI | 55 | 1.654545 | 1.004032 | 0 | 3 |
| CORE_SKILL_COMPSCI | 55 | 1.945455 | 1.043821 | 0 | 3 |
| CORE_SKILL_LIFESCI | 55 | 1.090909 | 0.967485 | 0 | 3 |
| CORE_SKILL_FIN_BUS | 55 | 2.109091 | 0.936359 | 0 | 3 |
| CORE_EX_BUS | 54 | 2.222222 | 0.964789 | 0 | 3 |
| CORE_EX_RACE | 54 | 1.666667 | 1.098885 | 0 | 3 |
| CORE_EX_PRIZE | 54 | 1.5 | 1.094584 | 0 | 3 |
| CORE_EX_PATENT | 54 | 1.759259 | 1.06284 | 0 | 3 |
| CORE_EX_AUTO | 54 | 1.777778 | 1.093146 | 0 | 3 |
| CORE_EX_ENGY_EFF | 54 | 2.222222 | 0.984151 | 0 | 3 |
| BUS_YN | 54 | 0.814815 | 0.392095 | 0 | 1 |
| RACE_YN | 54 | 0.62963 | 0.487438 | 0 | 1 |
| PRIZE_YN | 54 | 0.555556 | 0.50157 | 0 | 1 |
| PATENT_YN | 54 | 0.62963 | 0.487438 | 0 | 1 |
| AUTO_YN | 54 | 0.648148 | 0.482032 | 0 | 1 |
| ENEFF_YN | 54 | 0.796296 | 0.406533 | 0 | 1 |
| LSHIP_STRUC | 54 | 1.37037 | 0.708341 | 0 | 3 |
| KEY_DEC_VISION | 54 | 1.481481 | 0.63664 | 1 | 3 |
| KEY_DEC_PERSONNEL | 54 | 1.537037 | 0.66483 | 1 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| KEY_DEC_FINANCE | 54 | 1.351852 | 0.482032 | 1 | 2 |
| KEY_DEC_TECH | 54 | 1.851852 | 0.737344 | 1 | 3 |
| CONTRIB_UNI_PRIOR | 54 | 0.333333 | 0.800943 | 0 | 4 |
| CONTRIB_UNI_REG | 54 | 0.666667 | 1.149241 | 0 | 5 |
| CONTRIB_UNI_CURRENT | 54 | 1.166667 | 1.633956 | 0 | 8 |
| COLLAB_UNI | 32 | 0.71875 | 1.054464 | 0 | 5 |
| CONTRIB_RLAB_PRIOR | 32 | 0.03125 | 0.176777 | 0 | 1 |
| CONTRIB_RLAB_REG | 32 | 0.0625 | 0.245935 | 0 | 1 |
| CONTRIB_RLAB_CURRENT | 32 | 0.125 | 0.421212 | 0 | 2 |
| COLLAB_RLAB | 32 | 0.09375 | 0.390151 | 0 | 2 |
| CONTRIB_NONPROF_PRIOR | 32 | 0.03125 | 0.176777 | 0 | 1 |
| CONTRIB_NONPROF_REG | 32 | 0.15625 | 0.447889 | 0 | 2 |
| CONTRIB_NONPROF_CURRENT | 32 | 0.28125 | 0.92403 | 0 | 5 |
| COLLAB_NONPROF | 32 | 0.25 | 0.915811 | 0 | 5 |
| CONTRIB_FORPROF_PRIOR | 32 | 0.34375 | 1.003522 | 0 | 5 |
| CONTRIB_FORPROF_REG | 32 | 0.8125 | 1.533234 | 0 | 5 |
| CONTRIB_FORPROF_CURRENT | 32 | 4.84375 | 13.2278 | 0 | 75 |
| COLLAB_FORPROF | 31 | 2.225806 | 3.180248 | 0 | 13 |
| CONTRIB_OTHTEAM_PRIOR | 32 | 0 | 0 | 0 | 0 |
| CONTRIB_OTHTEAM_REG | 32 | 0.03125 | 0.176777 | 0 | 1 |
| CONTRIB_OTHTEAM_CURRENT | 32 | 0.125 | 0.553581 | 0 | 3 |
| COLLAB_OTHTEAM | 32 | 0.125 | 0.553581 | 0 | 3 |
| MOTIV_WIN | 54 | 2.944444 | 0.919735 | 0 | 4 |
| MOTIV_PUB | 54 | 3.425926 | 0.716434 | 1 | 4 |
| MOTIV_REP | 54 | 3.111111 | 0.964789 | 0 | 4 |
| MOTIV_NETWORK | 54 | 2.277778 | 1.017149 | 0 | 4 |
| MOTIV_FUN | 54 | 3.111111 | 0.984151 | 0 | 4 |
| MOTIV_ENVIRO | 54 | 3.333333 | 0.868744 | 0 | 4 |
| MOTIV_POLITICAL | 54 | 2.240741 | 1.148176 | 0 | 4 |
| MOTIV_NEWMKT | 54 | 3.12963 | 1.082385 | 0 | 4 |
| SUCCESS_WIN | 31 | 3.451613 | 0.675214 | 2 | 4 |
| SUCCESS_TECH_PURCH | 31 | 3.16129 | 1.185939 | 0 | 4 |
| SUCCESS_JOB | 31 | 1.806452 | 1.447281 | 0 | 4 |
| SUCCESS_INVESTOR | 31 | 3.322581 | 0.871286 | 0 | 4 |
| SUCCESS_ATTENTION | 31 | 3.451613 | 0.675214 | 2 | 4 |
| SUCCESS_CAR_READY | 31 | 3.032258 | 1.139704 | 0 | 4 |
| FUND_SOURCE_ORG | 40 | 41.775 | 45.09675 | 0 | 100 |
| FUND_SOURCE_VC | 35 | 8 | 22.72599 | 0 | 100 |
| FUND_SOURCE_GOV | 35 | 5.828571 | 11.67825 | 0 | 45 |
| FUND_SOURCE_PHIL | 35 | 10.14286 | 17.90686 | 0 | 60 |
| FUND_SOURCE_FAM | 39 | 8.205128 | 17.45246 | 0 | 80 |

| | | | | | |
|---|---|---|---|---|---|
| FUND_SOURCE_TEAM | 46 | 51.86957 | 40.81591 | 0 | 100 |
| FUND_SOURCE_LOAN | 33 | 1.818182 | 5.422491 | 0 | 25 |
| CORE_HR_PRIOR | 32 | 18.09375 | 23.11034 | 0 | 100 |
| CORE_HR_REG | 32 | 28 | 24.27264 | 0 | 100 |
| CORE_HR_CURRENT | 32 | 46.65625 | 43.07129 | 5 | 240 |
| CORE_INCREASE_HR | 32 | 28.5625 | 38.25377 | 0 | 200 |
| PERIPH_HR_PRIOR | 32 | 5.125 | 12.77788 | 0 | 50 |
| PERIPH_HR_REG | 32 | 7.40625 | 12.89876 | 0 | 50 |
| PERIPH_HR_CURRENT | 32 | 13.96875 | 23.56937 | 0 | 120 |
| PERIPH_INCREASE_HR | 32 | 9.15625 | 21.17684 | 0 | 120 |
| CONTRACT_HR_PRIOR | 32 | 2.9375 | 8.389462 | 0 | 40 |
| CONTRACT_HR_REG | 32 | 5.5625 | 9.986887 | 0 | 40 |
| CONTRACT_HR_CURRENT | 32 | 11.75031 | 15.5125 | 0 | 50 |
| CONTRACTOR_INCREASE_HR | 32 | 9.250313 | 14.69674 | 0 | 50 |
| DOL_SPENT_PRIOR | 48 | 490480.2 | 1588273 | 0 | 10000000 |
| DOL_SPENT_SINCE | 48 | 833062.5 | 3878406 | 0 | 27000000 |
| TOTAL_DOL_SINCE | 48 | 1323543 | 4283998 | 20000 | 27400000 |
| MANYR_CAR | 50 | 3010.099 | 21211.76 | 0 | 150000 |
| MANHR_NOTCAR | 44 | 1152.082 | 2221.111 | 0.1 | 11000 |
| CORE_EQUITY | 32 | 3.625 | 7.001152 | 0 | 37 |
| CORE_PAID | 32 | 2.71875 | 3.621035 | 0 | 18 |
| CORE_OTHER_EMPLOY | 32 | 3.71875 | 5.618141 | 0 | 29 |
| PERIPH_EQUITY | 32 | 2.03125 | 6.850874 | 0 | 35 |
| PERIPH_PAID | 32 | 0.5625 | 1.848059 | 0 | 10 |
| PERIPH_OTHER_EMPLOY | 32 | 5.75 | 8.688145 | 0 | 35 |
| PCENT_WORK_CORE | 32 | 3.5625 | 0.564401 | 2 | 4 |
| M_PROB_WIN | 18 | 57.88889 | 35.39672 | 0 | 100 |
| A_PROB_WIN | 19 | 58.62105 | 33.42812 | 0 | 100 |
| PATENT_NO_CURRENT | 51 | 2.27451 | 3.55009 | 0 | 16 |
| PATENT_NO_FUTURE | 53 | 0.716981 | 0.454776 | 0 | 1 |
| LICENSE_IP_FROM_OTHER | 30 | 0.2 | 0.406838 | 0 | 1 |
| PRIZE_DISTRIBUTE | 24 | 2.208333 | 0.832971 | 1 | 3 |
| CORE_PCENT_SHARE_PRIZE | 7 | 80 | 32.1455 | 20 | 100 |
| IP_DISTRIBUTE_POSTPIAXP | 31 | 1.483871 | 0.851311 | 1 | 4 |
| CONTRACTS_PRIZE_IP | 31 | 0.548387 | 0.505879 | 0 | 1 |
| CONTINUE_CAR | 31 | 0.967742 | 0.179605 | 0 | 1 |
| x_DOL_NEED | 27 | 346970.4 | 476401.8 | 200 | 2000000 |
| FUT_FUND_METHOD_ORG | 31 | 0.451613 | 0.505879 | 0 | 1 |
| FUT_FUND_METHOD_VC | 31 | 0.225806 | 0.425024 | 0 | 1 |
| FUT_FUND_METHOD_ANGEL | 31 | 0.354839 | 0.486373 | 0 | 1 |
| FUT_FUND_METHOD_GOV | 31 | 0.16129 | 0.373878 | 0 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| FUT_FUND_METHOD_PHIL | 31 | 0.677419 | 0.475191 | 0 | 1 |
| FUT_FUND_METHOD_FAM | 31 | 0.193548 | 0.40161 | 0 | 1 |
| FUT_FUND_METHOD_TEAM | 31 | 0.548387 | 0.505879 | 0 | 1 |

Table A3: Descriptive Statistics by Vehicle

| | n | mean | std | min | max |
|---|---|---|---|---|---|
| VEGAS | 55 | 0.618182 | 0.49031 | 0 | 1 |
| SHAKEDOWN | 55 | 0.618182 | 0.49031 | 0 | 1 |
| KNOCKOUT | 55 | 0.2 | 0.403687 | 0 | 1 |
| FINALS | 55 | 0.109091 | 0.314627 | 0 | 1 |
| validation | 55 | 0.109091 | 0.314627 | 0 | 1 |
| WIN | 55 | 0.036364 | 0.188919 | 0 | 1 |
| index | 57 | 27.21053 | 20.84272 | 1 | 99 |
| tier1 | 57 | 0.315789 | 0.468961 | 0 | 1 |
| tier2 | 57 | 0.508772 | 0.504367 | 0 | 1 |
| tier3 | 57 | 0.192982 | 0.440722 | 0 | 2 |
| CAR_NO | 57 | 1.140351 | 0.639157 | 0 | 5 |
| MULT_CAR | 57 | 0.192982 | 0.398147 | 0 | 1 |
| CAR_TYPE | 54 | 1.37037 | 0.487438 | 1 | 2 |
| CAR_ID | 54 | 1 | 0 | 1 | 1 |
| 1NEW | 54 | 0.907407 | 0.292582 | 0 | 1 |
| 2NEW | 54 | 0.722222 | 0.452109 | 0 | 1 |
| MAJNEW | 54 | 0.518519 | 0.863095 | 0 | 5 |
| SUBSYS_CHASS | 54 | 2.851852 | 1.917225 | 0 | 5 |
| SUBSYS_SUSPEN | 54 | 2.444444 | 1.77686 | 0 | 5 |
| SUBSYS_BODY | 54 | 2.851852 | 1.984919 | 0 | 5 |
| SUBSYS_ENG | 54 | 1.351852 | 1.638653 | 0 | 5 |
| SUBSYS_TRANS | 54 | 1.703704 | 1.632565 | 0 | 5 |
| SUBSYS_BAT_HV | 54 | 2.037037 | 1.842506 | 0 | 5 |
| SUBSYS_FUELCELL | 54 | 0.148148 | 0.737344 | 0 | 5 |
| SUBSYS_ELECMOT | 54 | 2.092593 | 1.845632 | 0 | 5 |
| SUBSYS_ELEC_LV | 54 | 2.092593 | 1.740402 | 0 | 5 |
| SUBSYS_ELEC_HV | 54 | 2.203704 | 1.916951 | 0 | 5 |
| SUBSYS_CONTROL | 54 | 3.537037 | 1.787936 | 0 | 5 |
| INN_NO | 56 | 1.678571 | 1.41559 | 0 | 7 |
| INN_1PLUS | 56 | 0.767857 | 0.426021 | 0 | 1 |
| INN_2PLUS | 57 | 0.631579 | 0.616197 | 0 | 3 |
| NEW_INN_CHASS | 54 | 1.648148 | 1.048942 | 0 | 3 |
| NEW_INN_SUSPEN | 54 | 1.407407 | 0.921822 | 0 | 3 |
| NEW_INN_BODY | 54 | 1.62963 | 1.014913 | 0 | 3 |
| NEW_INN_ENG | 54 | 0.981481 | 1.090105 | 0 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| NEW_INN_TRANS | 54 | 0.981481 | 0.921253 | 0 | 3 |
| NEW_INN_BAT_HV | 54 | 1.222222 | 1.040077 | 0 | 3 |
| NEW_INN_FUELCELL | 54 | 0.12963 | 0.477663 | 0 | 3 |
| NEW_INN_ELECMOT | 54 | 1.462963 | 1.02263 | 0 | 3 |
| NEW_INN_ELEC_LV | 54 | 1.203704 | 0.786193 | 0 | 3 |
| MS1_NEW_INN_ELEC_HV | 54 | 1.425926 | 1.056906 | 0 | 3 |
| NEW_INN_CONTROL | 54 | 1.981481 | 1.090105 | 0 | 3 |
| CHANGELAUNCH_YN | 57 | 0.385965 | 0.700877 | 0 | 3 |
| CHANGE_LAUNCH | 52 | 1.75 | 1.026607 | 0 | 3 |
| CHANGE_TECHGOAL_YN | 57 | 0.315789 | 0.571898 | 0 | 2 |
| CHANGE_TECH_GOAL | 52 | 1.596154 | 1.014785 | 0 | 3 |
| CHANGE_TECHAPP_YN | 57 | 0.263158 | 0.551825 | 0 | 2 |
| CHANGE_TECH_APP | 52 | 1.557692 | 0.937528 | 0 | 3 |
| PRTYPE | 51 | 0.666667 | 0.476095 | 0 | 1 |
| MS1_HRS_DRIVE | 20 | 288.556 | 531.9886 | 0.12 | 2136 |
| MS1_MONTHS_PROTOTYPE | 14 | 21.14286 | 39.38734 | 1 | 100 |
| ROADWORTH | 52 | 92.27404 | 21.07324 | 0.25 | 100 |
| 100MPG | 53 | 87.55566 | 26.62144 | 0 | 100 |
| 200GMI | 53 | 92.83774 | 20.31074 | 0.4 | 100 |
| SAFESTAND | 53 | 83.24528 | 31.93317 | 0 | 100 |
| EMISSION | 50 | 94.778 | 16.95585 | 5 | 100 |
| MS1_PCENT_SELL10000 | | | | | |

Table A4: Order Probit tables for success and effort

**Team Success**

| | **Coef** | **SE** | **z** | **p** | **CI** | |
|---|---|---|---|---|---|---|
| Enjoyment | -0.24911 | 0.204571 | -1.22 | 0.223 | -0.65007 | 0.151837 |
| Challenge | -1.09572 | 0.67007 | -1.64 | 0.102 | -2.40903 | 0.217597 |
| Learning | 0.2486 | 0.942743 | 0.26 | 0.792 | -1.59914 | 2.096342 |
| Career Benefits | 0.851394 | 0.505687 | 1.68 | 0.092 | -0.13973 | 1.842522 |
| Competition | 0.572431 | 0.270488 | 2.12 | 0.034 | 0.042283 | 1.102578 |
| Recognition | -0.30567 | 0.178957 | -1.71 | 0.088 | -0.65642 | 0.045078 |
| Compensation | 0.344564 | 0.147672 | 2.33 | 0.02 | 0.055133 | 0.633995 |
| Ext. Pressure | -0.19068 | 0.12127 | -1.57 | 0.116 | -0.42836 | 0.047009 |
| Bored | -0.0503 | 0.134992 | -0.37 | 0.709 | -0.31487 | 0.214284 |
| Spare Time | -0.54987 | 0.308077 | -1.78 | 0.074 | -1.15369 | 0.053949 |
| **Individual Hours/ Week** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Enjoyment | 2.310405 | 7.350447 | 0.31 | 0.755 | -12.6275 | 17.24831 |
| Challenge | -1.41499 | 1.876225 | -0.75 | 0.456 | -5.22794 | 2.397954 |
| Learning | 1.912502 | 2.000026 | 0.96 | 0.346 | -2.15204 | 5.977044 |
| Career Benefits | -2.58964 | 3.179843 | -0.81 | 0.421 | -9.05186 | 3.872574 |
| Competition | 1.943924 | 2.657364 | 0.73 | 0.469 | -3.45649 | 7.344338 |
| Recognition | 5.749334 | 4.201515 | 1.37 | 0.18 | -2.78917 | 14.28784 |
| Compensation | 1.05278 | 1.806675 | 0.58 | 0.564 | -2.61883 | 4.724386 |
| Ext. Pressure | 2.181889 | 1.886576 | 1.16 | 0.256 | -1.6521 | 6.015873 |
| Bored | -1.20037 | 3.465333 | -0.35 | 0.731 | -8.24277 | 5.842039 |
| Spare Time | -5.85296 | 29.0767 | -0.2 | 0.842 | -64.9439 | 53.23802 |
| **Personal Money Spent** | | | | | | |
| Enjoyment | -0.40145 | 0.873628 | -0.46 | 0.651 | -2.22998 | 1.427072 |
| Challenge | 0.20455 | 0.218917 | 0.93 | 0.362 | -0.25365 | 0.662748 |
| Learning | 0.04775 | 0.249057 | 0.19 | 0.85 | -0.47353 | 0.569031 |
| Career Benefits | -0.32483 | 0.359888 | -0.9 | 0.378 | -1.07808 | 0.428428 |
| Competition | 0.623268 | 0.366221 | 1.7 | 0.105 | -0.14324 | 1.389776 |
| Recognition | -0.51104 | 0.448818 | -1.14 | 0.269 | -1.45043 | 0.428342 |
| Compensation | 0.14619 | 0.237713 | 0.61 | 0.546 | -0.35135 | 0.643728 |
| Ext. Pressure | -0.27914 | 0.260972 | -1.07 | 0.298 | -0.82537 | 0.267076 |
| Bored | 0.208693 | 0.419627 | 0.5 | 0.625 | -0.6696 | 1.086982 |
| Spare Time | 7.094362 | 3.434387 | 2.07 | 0.053 | -0.09389 | 14.28262 |

| **Success** | **Coef** | **SE** | **z** | **P** | **CI** | |
|---|---|---|---|---|---|---|
| **Total Team Man Hours Spent** | | | | | | |
| Win | -0.07812 | 2.946412 | -0.03 | 0.979 | -6.03304 | 5.8768 |
| publicity | -9.18192 | 4.450252 | -2.06 | 0.046 | -18.1762 | -0.18762 |
| reputation | 7.094988 | 3.493179 | 2.03 | 0.049 | 0.03501 | 14.15497 |
| network | 0.448986 | 3.025156 | 0.15 | 0.883 | -5.66508 | 6.563055 |
| Fun | -7.53979 | 2.741495 | -2.75 | 0.009 | -13.0806 | -1.99902 |
| environment | 5.899158 | 3.665687 | 1.61 | 0.115 | -1.50947 | 13.30779 |
| political | -2.45348 | 2.980429 | -0.82 | 0.415 | -8.47715 | 3.570191 |
| new market | -6.02295 | 2.730084 | -2.21 | 0.033 | -11.5407 | -0.50524 |
| | 46.97809 | 19.81759 | 2.37 | 0.023 | 6.925251 | 87.03094 |
| **Total Team Dollars Spent** | | | | | | |
| Win | -0.1734 | 0.250305 | -0.69 | 0.493 | -0.67969 | 0.332889 |
| publicity | -0.30284 | 0.401162 | -0.75 | 0.455 | -1.11427 | 0.508586 |
| reputation | 0.354165 | 0.307242 | 1.15 | 0.256 | -0.26729 | 0.97562 |
| network | 0.078333 | 0.269663 | 0.29 | 0.773 | -0.46711 | 0.623777 |
| Fun | -0.64472 | 0.240773 | -2.68 | 0.011 | -1.13173 | -0.15771 |
| environment | 0.144014 | 0.316271 | 0.46 | 0.651 | -0.49571 | 0.783733 |

| | | | | | | |
|---|---|---|---|---|---|---|
| political | -0.07121 | 0.255104 | -0.28 | 0.782 | -0.58721 | 0.444784 |
| new market | 0.084634 | 0.23967 | 0.35 | 0.726 | -0.40015 | 0.569413 |
| _cons | 14.22397 | 1.769801 | 8.04 | 0 | 10.64421 | 17.80373 |

# MIT PIAXP Prize Study

## INTRODUCTION

Welcome to the MIT PIAXP Prize Study! <br><br>

As you will have read from our letter, the objectives of our study are to <br><br>

i) understand how prizes can be used to enhance creativity and innovation in an industry sector, and to <br>
ii) identify the organizational choices that are most correlated with the success of competing teams <br><br>

Please be assured that any information you provide will be treated with the utmost confidentiality.< br><br>

Please read the formal consent form below, and feel free to contact us directly at <a href="mailto: piaxp-research@mit.edu">piaxp-research@mit.edu</a> if you have any questions.<br><br>

Thank you again!

CONSENT TO PARTICIPATE IN SURVEY

Empirical and Policy Analyses of the Link Between Organizational Designs and Innovation in the Context of an Innovation Prize.

You have been asked to participate in a research study conducted by Fiona Murray from the Sloan School of Management at the Massachusetts Institute of Technology (M.I.T.). The purpose of the study is to examine how competitions create value, through an in-depth analysis of the Progressive Insurance Automobile X PRIZE (PIAXP). Our research has been designed to understand what motivates organizations (and individuals) to participate (or not) in a competition; which organizational characteristics best predict innovative performance, and what relationships exist between these characteristics and the technical choices that are made? What is the impact of the competition on the field/industry? In particular, do prizes induce major changes in performance, technology and/or organizational arrangements?

• You were selected as a possible participant in this study because you are a current or past participant in the Progressive Automotive Insurance X Prize. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• This survey is voluntary. You have the right not to answer any question, and to stop the interview at any time or for any reason. We expect that the survey will take less than an hour. You will find a progress bar at the bottom of each page to help you gauge how many questions remain.

• You will not be compensated for this survey.

• In any and all publications that may result from this research, the information you tell us will be confidential.

• This project will be completed by December 2011. All survey results will be stored in a secure work space until 3 years after that date. The records will then be destroyed.

Please contact piaxp-research@mit.edu with any questions or concerns.

If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253-6787

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study.
(Required)

- ○ Yes
- ○ No

# Untitled Page

1. Team Name: (Required)

2. Your Name: (Required)

3. Your role (check all that apply): (Required)
   - ☐ Team Management
   - ☐ Engineering/Technical Lead
   - ☐ Marketing/Promotion Lead
   - ☐ Team Founder
   - ☐ Other (please specify)

4. Your email address: (Required)

5. Would you like a summary of the survey results sent to you?
   - ○ Yes
   - ○ No

# Formal pre-exisiting teams

6. For the purposes of the survey below, we have distinguished between your "team", which we take to be those people working directly on your entry for the PIAXP competition, and your "organization", which in some cases may be a broader company, non-profit, school or other entity with goals outside of PIAXP.

PLEASE PROVIDE SOME DETAILS ABOUT YOUR ORGANIZATION

Which sentence best describes the organization in which your team is embedded:

- ○ There is no wider organization
- ○ We are organized within one or more educational institutions
- ○ We are organized within a previously incorporated private firm
- ○ We are organized within a previously incorporated public firm

7. What is the name of the organization?

8. What year was it founded? [Note: For the purposes of the survey below, we have distinguished between your "team", which we take to be those people working directly on your entry for the PIAXP competition, and your "organization", which in some cases may be a broader company, non-profit, school or other entity with goals outside of PIAXP.]

9. What categories of business did it engage in prior to PIAXP (check all that apply)?

- ☐ Automobile manufacturing/assembly
- ☐ Automotive subsystem or component manufacturing/assembly
- ☐ Highly-fuel efficiency vehicles
- ☐ Materials
- ☐ Energy
- ☐ Other (please specify)

10. How many employees are in the organization (as a whole)?

11. What level of sales (in $US) did your organization have in the last fiscal year?

12. Approximately what percentage of your organization's total personnel does the PIAXP effort involve?

# TEAM COMPOSITION

NOW PLEASE ANSWER SOME QUESTIONS ABOUT YOUR PIAXP TEAM

13. Which sentence best describes what your team was doing prior to the X PRIZE Competition:

- ○ There was no team in place - we came together for the Prize
- ○ We were an informal group working together on a project unrelated to vehicles
- ○ We were an informal group working together on a related vehicle project
- ○ We have a formal group working together on a related vehicle project
- ○ We have a formal group working together on an unrelated (non-vehicle) project

14. In what year was your team formed?

15. For the purpose of our survey we define the "core team" as individuals who contribute to the PIAXP project on a regular basis and/or play an ongoing significant role within the team and the "peripheral team" as those who are occasional contributors. A "contractor" is someone who has been hired to complete specified aspects of the project but you would not consider a formal team member.

Please fill out the following tables with numbers of individuals.

How many individuals were in each of the following categories at the following three time points? (If your team did not exist prior to PIAXP, leave zeroes in column one.)

| | First learned of PIAXP | At PIAXP Registration | Currently |
|---|---|---|---|
| Core Team Members | | | |
| Peripheral Members | | | |
| Contractors | | | |

16. On average, how many hours per week did an individual in each of these categories contribute to your team at the following three time points?

| | Prior to PIAXP | At Registration for PIAXP | Currently |
|---|---|---|---|
| Core Team Members | | | |
| Peripheral Members | | | |
| Contractors | | | |

17. How many individuals receive the following types of compensation for their work with your team?

| | How many members have an ownership in the team | How many members are paid for their PIAXP work | How many members have other employment outside your PIAXP team |
|---|---|---|---|
| Core Team Members | | | |
| Peripheral Members | | | |

18. What % of total PIAXP team work is being done by the core team?

- ○ 0-25%
- ○ 26-50%
- ○ 51-75%
- ○ 76-100%

19. The following questions refer only to your current core team, as listed above

What is the age profile of the core team? [number in each category]

| | |
|---|---|
| Under 30 | |
| 30-50 | |
| Over 50 | |

20. Within the core team, how many individuals hold the following levels of formal education as their highest degree [number in each category]

| | |
|---|---|
| PhD or other doctorate | |
| Masters degree | |
| Undergraduate degree | |
| High School | |

21. Rate your core team's expertise in the following disciplines:

| | None | A little | Some | A lot |
|---|---|---|---|---|
| Electrical Engineering | ○ | ○ | ○ | ○ |
| Mechanical Engineering | ○ | ○ | ○ | ○ |
| Aerospace Engineering | ○ | ○ | ○ | ○ |
| Materials Science, Chemistry or Chemical Engineering | ○ | ○ | ○ | ○ |
| Computer Science or Software Engineering | ○ | ○ | ○ | ○ |
| Life Sciences | ○ | ○ | ○ | ○ |
| Finance/Business | ○ | ○ | ○ | ○ |

22. We are interested in understanding how many external collaborators are helping your team to develop your PIAXP vehicle(s). Please provide the number of collaborating organizations contributing to your team at the following three time points.

| | First learned of PIAXP | At PIAXP Registration | Currently |
|---|---|---|---|
| Universities or other educational establishments | | | |
| Research institutions or laboratories | | | |
| Non-profit or non-governmental organizations | | | |
| For-profit firms | | | |
| Other PIAXP teams | | | |

# TEAM LOCATION, STRUCTURE & PROCESSES

23. What location do you consider to be the headquarters of your team?
- ◯ None in particular - We are distributed
- ◯ We have a headquarters

24. What location do you consider to be the headquarters of your team?

CITY

STATE/PROVINCE

COUNTRY

25. What percentage of the core team works at your team's headquarters?

26. Across how many different locations is the core team spread?

27. How many total team members do you have in:

A different country from your headquarters

A different state/province from your headquarters

A different city but same state/province from your headquarters

28. Overall, what best describes the leadership structure of your core team?
- ◯ We have a single leader who sets the vision and makes most key decisions
- ◯ We have a group of two or three leaders who set the vision and make most key decisions
- ◯ Most or all of the core team members play significant roles in setting the vision and making key decisions

29. More specifically, please identify who makes the following key decisions for your core team:

| | Team Leader | Group of two or three team members | Broadly shared by most or all team members |
|---|---|---|---|
| Setting the team vision | ○ | ○ | ○ |
| Personnel decisions (who's on or off the team) | ○ | ○ | ○ |
| Major financial decisions | ○ | ○ | ○ |
| Technical decisions related to vehicle design | ○ | ○ | ○ |

30. If your team operates in a larger organization, what decisions are made or significantly constrained by the organizational managers or leaders (check all that apply):

- ☐ Setting the team vision
- ☐ Personnel decisions
- ☐ Major financial decisions
- ☐ Technical decisions related to vehicle design
- ☐ Not applicable

31. Please rank how much experience your core team has with the following related activities:

| | None | A little | Some | A lot |
|---|---|---|---|---|
| Starting a business | ○ | ○ | ○ | ○ |
| Racing vehicles | ○ | ○ | ○ | ○ |
| Competing for prizes | ○ | ○ | ○ | ○ |
| Filing patents | ○ | ○ | ○ | ○ |
| Working in the auto industry | ○ | ○ | ○ | ○ |
| Working on energy efficient technologies | ○ | ○ | ○ | ○ |

# MOTIVATION, INCENTIVES & FUTURE PLANS

32. To what degree do you agree or disagree with the following statement: "Our team is competing in PIAXP primarily to:"

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Win the Prize | ○ | ○ | ○ | ○ | ○ |
| Gain publicity | ○ | ○ | ○ | ○ | ○ |
| Enhance our reputation | ○ | ○ | ○ | ○ | ○ |
| Network with other teams | ○ | ○ | ○ | ○ | ○ |
| Have fun, be challenged | ○ | ○ | ○ | ○ | ○ |
| Address environmental concerns | ○ | ○ | ○ | ○ | ○ |
| Address political concerns | ○ | ○ | ○ | ○ | ○ |
| Create new vehicle markets | ○ | ○ | ○ | ○ | ○ |

33. If there is another major motivator for your team, please list it here:

34. To what degree do you agree or disagree with the following statement: "A successful outcome for our team would be..."

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Winning the race | ○ | ○ | ○ | ○ | ○ |
| Having technology purchased or licensed by another organization | ○ | ○ | ○ | ○ | ○ |
| Having team members offered jobs by another organization | ○ | ○ | ○ | ○ | ○ |
| Attracting investors | ○ | ○ | ○ | ○ | ○ |
| Attracting attention to the team | ○ | ○ | ○ | ○ | ○ |
| Having a market-ready vehicle | ○ | ○ | ○ | ○ | ○ |

35. If there is another definition of success for your core team, please tell us here:

36. Have you agreed among the team how the prize will be distributed if you win?

- ○ Organization keeps all prize funds
- ○ Team members share some portion of the funds
- ○ Not yet decided
- ○ Other (please specify):

37. What percentage of the core team will share in the winnings?

38. At this stage what do you plan to do with the intellectual property developed after PIAXP is awarded?

- ○ Organization keeps all intellectual property
- ○ Team members share some portion of the intellectual property
- ○ Not yet decided
- ○ Other

39. What percentage of the core team will share the intellectual property?

40. Do you have any formal or informal contracts among the team, covering these prize and intellectual property arrangements?

- ○ Yes
- ○ No

41. At this stage does your team plan to continue with vehicle development after PIAXP is awarded?

- ○ Yes
- ○ No

# RESOURCES

42. How much total money had your organization(s) spent on developing technology relevant to your PIAXP entry/entries prior to hearing about PIAXP? [in US$]

43. How much money has your organization spent developing your PIAXP entry/entries since the PIAXP announcement? [in US$]

44. How many total person-years of effort have you put into developing your PIAXP vehicle(s)?

45. Approximately how many total person-hours has your team spent on PIAXP work unrelated to your vehicle(s)? (e.g. proposal preparation, blogging, rules compliance, business plan etc.)

46. Approximately what % of your team's funding has come from the following sources since registration:

| | |
|---|---|
| Paid for by internal funds from a parent organization | |
| Venture capital or Angel investors | |
| Government grants and contracts | |
| Private or corporate philanthropy/sponsorship | |
| Friends and family | |
| Self-funded by team members (including working without pay) | |
| Business loans | |

47. Approximately, how much more money do you require to prepare for the PIAXP race events? [in $US]

48. How do you plan to raise it? (check all that apply)

- [ ] Paid for by internal funds from a parent organization
- [ ] Formal venture backing
- [ ] Angel investors
- [ ] Government grants and contracts
- [ ] Private or corporate philanthropy/sponsorship
- [ ] Friends and family
- [ ] Self-funded by team members (including working without pay)

# TECHNICAL RESOURCES & DEVELOPMENT APPROACH

49. How many vehicles are you entering in the Mainstream category?

0
1
2
3

50. How many vehicles are you entering in the Alternative category?

0
1
2

51. Next few questions are regarding your entry number 1 in the Mainstream category:
To what extent are you buying, modifying or newly developing the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

52. For your team's vehicle number 1 in the Mainstream category, to what degree are you developing new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

53. For vehicle number 1 in the Mainstream category: To what extent did the announcement of PIAXP precipitate changes in the vehicle development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

54. Do you currently have any type of working (drivable) prototype of your PIAXP vehicle number 1 in the Mainstream category?

- ○ Yes
- ○ No

55. How many hours of driving tests have you performed related to vehicle number 1 of Mainstream category to date?

56. How many months from today do you anticipate it will be until you have any drivable prototype related to vehicle number 1 in Mainstream category?

57. For vehicle number 1 in Mainstream category: How confident are you that you will achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

- Roadworthy Prototype (as defined by PIAXP)
- Fuel Economy of 100 MPGe
- Total GHG emissions < 200g/mi CO-2 equivalent
- Meet US safety standards
- Meet US Emissions standards

58. For vehicle number 1 in Mainstream category: How confident are you that you will eventually manufacture and sell over 10,000 units/year? (0-100% confidence level)

59. Next few questions are regarding your entry number 2 in the Mainstream category:
To what extent are you buying, modifying or newly developing the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

60. For your team's vehicle number 2 in the Mainstream category, to what degree are you developing new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electrical) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

61. For vehicle number 2 in Mainstream category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

62. Do you currently have any type of working (drivable) prototype of your PIAXP vehicle number 2 in Mainstream category: )?

- ○ Yes
- ○ No

63. How many hours of driving tests have you performed related to vehicle number 2 in Mainstream category: to date?

64. How many months from today do you anticipate it will be until you have any drivable prototype related to vehicle number 2 in Mainstream category?

65. For vehicle number 2 in Mainstream category: How confident are you that you will achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

66. For vehicle number 2 in Mainstream category: How confident are you that you will eventually manufacture and sell over 10,000 units/year? (0-100% confidence level)

67. Next few questions are regarding your entry number 3 in the Mainstream category:
To what extent are you buying, modifying or newly developing the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electric (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

68. For your team's vehicle number 3 in the Mainstream category, to what degree are you developing new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrichemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

69. For vehicle number 3 in Mainstream category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

70. Do you currently have any type of working (drivable) prototype of your PIAXP vehicle number 3 in Mainstream category?

- ○ Yes
- ○ No

71. How many hours of driving tests have you performed related to vehicle number 3 in Mainstream category to date?

72. How many months from today do you anticipate it will be until you have any drivable prototype related to vehicle number 3 in Mainstream category?

73. For vehicle number 3 in Mainstream category: How confident are you that you will achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

74. For vehicle number 3 in Mainstream category: How confident are you that you will eventually manufacture and sell over 10,000 units/year? (0-100% confidence level)

75. Next few questions are regarding your entry number 1 in the Alternative category:
To what extent are you buying, modifying or newly developing the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrichemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

76. For your team's vehicle number 1 in the Alternative category, to what degree are you developing new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

77. For vehicle number 1 in Alternative category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

78. Do you currently have any type of working (drivable) prototype of your PIAXP vehicle number 1 in Alternative category?

- ○ Yes
- ○ No

79. How many hours of driving tests have you performed related to vehicle number 1 in Alternative category to date?

80. How many months from today do you anticipate it will be until you have any drivable prototype related to vehicle number 1 in Alternative category?

81. For vehicle number 1 in Alternative category: How confident are you that you will achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

82. For vehicle number 1 in Alternative category: How confident are you that you will eventually manufacture and sell over 10,000 units/year? (0-100% confidence level)

83. Next few questions are regarding your entry number 2 in the Alternative category:
To what extent are you buying, modifying or newly developing the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrichemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

84. For your team's vehicle number 2 in the Alternative category, to what degree are you developing new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Sofware and Hardware Control | ○ | ○ | ○ | ○ |

85. For vehicle number 2 in Alternative category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

86. Do you currently have any type of working (drivable) prototype of your PIAXP vehicle number 2 in Alternative category?

- ○ Yes
- ○ No

87. How many hours of driving tests have you performed related to vehicle number 2 in Alternative category to date?

88. How many months from today do you anticipate it will be until you have any drivable prototype related to vehicle number 2 in Alternative category?

89. For vehicle number 2 in Alternative category: How confident are you that you will achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

90. For vehicle number 2 in Alternative category: How confident are you that you will eventually manufacture and sell over 10,000 units/year? (0-100% confidence level)

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Last few questions!

91. How many patents or patent filings has your team/organization disclosed that are directly applicable to your PIAXP entry/entries?

92. Does your team plan to file any future patents as a result of ongoing work on your PIAXP entry/ entries?

- ○ Yes
- ○ No

93. Is your team/organization licensing any technologies or intellectual property from another organization?

- ○ Yes
- ○ No

94. As of today, what do you estimate is the probability that you will win your PIAXP category (%)? (Please respond to all that apply)

Mainstream class

Alternative class

# MIT PIAXP Prize Study

## INTRODUCTION

Welcome to the MIT PIAXP Prize Study! <br><br>

As you will have read from our letter, the objectives of our study are to <br><br>

i) understand how prizes can be used to enhance creativity and innovation in an industry sector, and to <br>
ii) identify the organizational choices that are most correlated with the success of competing teams <br><br>

Please be assured that any information you provide will be treated with the utmost confidentiality.< br><br>

Please read the formal consent form below, and feel free to contact us directly at <a href="mailto: piaxp-research@mit.edu">piaxp-research@mit.edu</a> if you have any questions.<br><br>

Thank you again!

CONSENT TO PARTICIPATE IN SURVEY

Empirical and Policy Analyses of the Link Between Organizational Designs and Innovation in the Context of an Innovation Prize.

You have been asked to participate in a research study conducted by Fiona Murray from the Sloan School of Management at the Massachusetts Institute of Technology (M.I.T.). The purpose of the study is to examine how competitions create value, through an in-depth analysis of the Progressive Insurance Automobile X PRIZE (PIAXP). Our research has been designed to understand what motivates organizations (and individuals) to participate (or not) in a competition; which organizational characteristics best predict innovative performance, and what relationships exist between these characteristics and the technical choices that are made? What is the impact of the competition on the field/industry? In particular, do prizes induce major changes in performance, technology and/or organizational arrangements?

• You were selected as a possible participant in this study because you are a current or past participant in the Progressive Automotive Insurance X Prize. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• This survey is voluntary. You have the right not to answer any question, and to stop the interview at any time or for any reason. We expect that the survey will take less than an hour. You will find a progress bar at the bottom of each page to help you gauge how many questions remain.

• You will not be compensated for this survey.

• In any and all publications that may result from this research, the information you tell us will be confidential.

• This project will be completed by December 2011. All survey results will be stored in a secure work space until 3 years after that date. The records will then be destroyed.

Please contact piaxp-research@mit.edu with any questions or concerns.

If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253-6787

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study.
(Required)

- ○ Yes
- ○ No

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1. Team Name: (Required)

2. Your Name: (Required)

3. Your role within your PIAXP team (check all that apply): (Required)
   - ☐ Team Management
   - ☐ Engineering/Technical Lead
   - ☐ Marketing/Promotion Lead
   - ☐ Team Founder
   - ☐ Other (please specify)

4. Your email address: (Required)

5. Would you like a summary of the survey results sent to you?
   - ○ Yes
   - ○ No

# Formal pre-exisiting teams

6. For the purposes of the survey below, we have distinguished between your "team", which we take to be those people who worked directly on your entry for the PIAXP competition, and your "organization", which in some cases may have been or continue to be a broader company, non-profit, school or other entity with goals outside of PIAXP.

PLEASE PROVIDE SOME DETAILS ABOUT YOUR ORGANIZATION

Which sentence best describes the organization in which your PIAXP team was embedded:

- ○ There was no wider organization
- ○ We were organized within one or more educational institutions
- ○ We were organized within a previously incorporated private firm
- ○ We were organized within a previously incorporated public firm

7. What was the name of the organization?

8. What year was it founded? [Note: For the purposes of the survey below, we have distinguished between your "team", which we take to be those people who worked directly on your entry for the PIAXP competition, and your "organization", which in some cases may have been or continue to be a broader company, non-profit, school or other entity with goals outside of PIAXP.]

9. What categories of business did it engage in prior to PIAXP (check all that apply)?

- ☐ Automobile manufacturing/assembly
- ☐ Automotive subsystem or component manufacturing/assembly
- ☐ Highly-fuel efficiency vehicles
- ☐ Materials
- ☐ Energy
- ☐ Other (please specify)

10. How many employees were in the organization (as a whole) at the time of your PIAXP entry?

11. What level of sales (in $US) did your organization have in the last fiscal year?

12. Approximately what percentage of your organization's total personnel did the PIAXP effort involve?

# TEAM COMPOSITION

NOW PLEASE ANSWER SOME QUESTIONS ABOUT YOUR FORMER PIAXP TEAM

13. Which sentence best describes what your team was doing prior to the X PRIZE Competition:

- ◯ There was no team in place - we came together for PIAXP
- ◯ We were an informal group working together on a project unrelated to vehicles
- ◯ We were an informal group working together on a related vehicle project
- ◯ We had a formal group working together on a related vehicle project
- ◯ We had a formal group working together on an unrelated (non-vehicle) project

14. In what year was your team formed?

15. For the purpose of our survey we define the "core team" as individuals who contributed to the PIAXP project on a regular basis and/or played an ongoing significant role within the team and the "peripheral team" as those who were occasional contributors. A "contractor" is someone who was hired to complete specified aspects of the project but you would not have considered as a formal team member.

Please fill out the following tables with numbers of individuals.

How many individuals were in each of the following categories at the following three time points? (If your team did not exist prior to PIAXP, leave zeroes in column one.)

| | First learned of PIAXP | At PIAXP Registration | Just prior to your PIAXP participation ending |
|---|---|---|---|
| Core Team Members | | | |
| Peripheral Members | | | |
| Contractors | | | |

16. The following questions refer only to your core team at the time your participation with PIAXP ended, as listed above

What was the age profile of the core team? [number in each category]

| | |
|---|---|
| Under 30 | |
| 30-50 | |
| Over 50 | |

17. Within the core team, how many individuals held the following levels of formal education as their highest degree [number in each category]

| | |
|---|---|
| PhD or other doctorate | |
| Masters degree | |
| Undergraduate degree | |
| High School | |

18. Rate your core team's expertise in the following disciplines:

| | None | A little | Some | A lot |
|---|---|---|---|---|
| Electrical Engineering | ○ | ○ | ○ | ○ |
| Mechanical Engineering | ○ | ○ | ○ | ○ |
| Aerospace Engineering | ○ | ○ | ○ | ○ |
| Materials Science, Chemistry or Chemical Engineering | ○ | ○ | ○ | ○ |
| Computer Science or Software Engineering | ○ | ○ | ○ | ○ |
| Life Sciences | ○ | ○ | ○ | ○ |
| Finance/Business | ○ | ○ | ○ | ○ |

19. We are interested in understanding how many external collaborators (e.g. universities, for profit, non-profit, other PIAXP teams) helped your team to develop your PIAXP vehicle(s). Please provide the number of collaborating organizations contributing to your team at the following three time points.

| | First learned of PIAXP | At PIAXP registration | Just prior to your PIAXP participation ending |
|---|---|---|---|
| Number of external collaborations | | | |

# TEAM LOCATION, STRUCTURE & PROCESSES

20. Where was your team headquarters?

21. What percentage of the core team worked at your team's headquarters?

22. Across how many different locations was the core team spread?

23. Overall, what would best describe the leadership structure of your core team during PIAXP?

- ◯ We had a single leader who set the vision and made most key decisions
- ◯ We had a group of two or three leaders who set the vision and made most key decisions
- ◯ Most or all of the core team members played significant roles in setting the vision and making key decisions

24. More specifically, please identify who made the following key decisions for your core team:

| | Team Leader | Group of two or three team members | Broadly shared by most or all team members |
|---|---|---|---|
| Setting the team vision | ◯ | ◯ | ◯ |
| Personnel decisions (who's on or off the team) | ◯ | ◯ | ◯ |
| Major financial decisions | ◯ | ◯ | ◯ |
| Technical decisions related to vehicle design | ◯ | ◯ | ◯ |

25. If your team operated in a larger organization, what decisions were made or significantly constrained by the organizational managers or leaders (check all that apply):

- ☐ Setting the team vision
- ☐ Personnel decisions
- ☐ Major financial decisions
- ☐ Technical decisions related to vehicle design
- ☐ Not applicable

26. Please rank how much experience your core team had with the following related activities:

| | None | A little | Some | A lot |
|---|---|---|---|---|
| Starting a business | ○ | ○ | ○ | ○ |
| Racing vehicles | ○ | ○ | ○ | ○ |
| Competing for prizes | ○ | ○ | ○ | ○ |
| Filing patents | ○ | ○ | ○ | ○ |
| Working in the auto industry | ○ | ○ | ○ | ○ |
| Working on energy efficient technologies | ○ | ○ | ○ | ○ |

# MOTIVATION, INCENTIVES & FUTURE PLANS

27. To what degree do you agree or disagree with the following statement: "Our team was competing in PIAXP primarily to:"

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Win the Prize | ○ | ○ | ○ | ○ | ○ |
| Gain publicity | ○ | ○ | ○ | ○ | ○ |
| Enhance our reputation | ○ | ○ | ○ | ○ | ○ |
| Network with other teams | ○ | ○ | ○ | ○ | ○ |
| Have fun, be challenged | ○ | ○ | ○ | ○ | ○ |
| Address environmental concerns | ○ | ○ | ○ | ○ | ○ |
| Address political concerns | ○ | ○ | ○ | ○ | ○ |
| Create new vehicle markets | ○ | ○ | ○ | ○ | ○ |

28. If there was another major motivator for your team, please list it here:

29. Did you stop participating in the PIAXP competition voluntarily, or were you eliminated as part of the judging process?

- ○ Withdrew voluntarily
- ○ Eliminated

30. To what degree do you agree or disagree with the following statements about why you withdrew. "Our team withdrew from the PIAXP competition primarily because:"

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| We did not have enough money to complete the vehicle | ☐ | ☐ | ☐ | ☐ | ☐ |
| We did not have enough people to complete the vehicle | ☐ | ☐ | ☐ | ☐ | ☐ |
| We did not have enough time to complete the vehicle | ☐ | ☐ | ☐ | ☐ | ☐ |
| We could not meet the PIAXP technical requirements | ☐ | ☐ | ☐ | ☐ | ☐ |
| We could not meet the PIAXP business plan requirements | ☐ | ☐ | ☐ | ☐ | ☐ |
| The rules of the competition were not aligned with our goals | ☐ | ☐ | ☐ | ☐ | ☐ |
| The deliverables for the competition incurred too much overhead | ☐ | ☐ | ☐ | ☐ | ☐ |
| We did not want to disclose information on our technology | ☐ | ☐ | ☐ | ☐ | ☐ |
| Our organisation withdrew support for our entry | ☐ | ☐ | ☐ | ☐ | ☐ |
| Our team became dysfunctional | ☐ | ☐ | ☐ | ☐ | ☐ |

31. Did your team continue to work together after your participation in PIAXP ended?
- ○ Yes
- ○ No

32. What is your team working on?
- ○ A vehicle
- ○ A component/ sub-system of a vehicle
- ○ A technology that could have a use in a vehicle
- ○ Other

33. To what extent do you agree or disagree with the following statements about the benefits your team received from competing in PIAXP. "Competing in PIAXP helped us to:"

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Attract Attention | ○ | ○ | ○ | ○ | ○ |
| Attract Investors | ○ | ○ | ○ | ○ | ○ |
| License or Sell our Technology | ○ | ○ | ○ | ○ | ○ |
| Generate Job Offers for Team Members | ○ | ○ | ○ | ○ | ○ |
| Network with Other Teams | ○ | ○ | ○ | ○ | ○ |
| Improve our Technology | ○ | ○ | ○ | ○ | ○ |

34. Do you plan to join or collaborate with a team that remains in the competition?
- ○ Yes
- ○ No

35. Do you plan to join or collaborate with a team that is no longer in the competition?
- ○ Yes
- ○ No

36. Did you agree among the team how the prize would have been distributed if you won?
- ○ Organization would have kept all prize funds
- ○ Team members would have shared some portion of the prize
- ○ Did not decide
- ○ Other (please specify):

37. How was the intellectual property distributed after your PIAXP participation ended?
- ○ Organization kept all intellectual property
- ○ Team members shared some portion of the intellectual property
- ○ Not yet decided
- ○ Other

38. What percentage of the core team shared the intellectual property, after your participation with PIAXP ended?

39. Did you have any formal or informal contracts among the team, covering these prize and intellectual property arrangements?

- ○ Yes
- ○ No

40. Has your team continued with vehicle development since your participation with PIAXP ended?

- ○ Yes
- ○ No

# RESOURCES

41. How much total money had your organization(s) spent on developing technology relevant to your PIAXP entry/entries PRIOR to hearing about PIAXP? [in US$]

42. How much money did your organization spend developing your PIAXP entry/entries AFTER the PIAXP announcement, and up to the point your PIAXP participation ended? [in US$]

43. How many total PERSON-YEARS of effort did your team put into developing your PIAXP vehicle (s) up to the point your PIAXP participation ended?

44. Approximately how many total PERSON-HOURS did your team spend on PIAXP work unrelated to your vehicle(s) up to the point your participation ended with PIAXP? (e.g. proposal preparation, blogging, rules compliance, business plan etc.)

45. Approximately what % of your team's funding came from the following sources, since registration:

| | |
|---|---|
| Paid for by internal funds from a parent organization | |
| Venture capital or Angel investors | |
| Government grants and contracts | |
| Private or corporate philanthropy/sponsorship | |
| Friends and family | |
| Self-funded by team members (including working without pay) | |
| Business loans | |

# TECHNICAL RESOURCES & DEVELOPMENT APPROACH

46. How many vehicles did you enter in the Mainstream category?

0
1
2
3

47. How many vehicles did you enter in the Alternative category?

0
1
2

48. The next few questions are regarding your entry number 1 in the Mainstream category:
To what extent did you buy, modify or newly develop the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

49. For your team's vehicle number 1 in the Mainstream category, to what degree did you develop new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

50. For vehicle number 1 in the Mainstream category: To what extent did the announcement of PIAXP precipitate changes in the vehicle development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

51. At the time your PIAXP participation ended, did you have any type of working (drivable) prototype of your PIAXP vehicle number 1 in the Mainstream category?

- ○ Yes
- ○ No

52. For vehicle number 1 in Mainstream category: How confident were you that you would achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

53. Next few questions are regarding your entry number 2 in the Mainstream category:
To what extent did you buy, modify or newly develop the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

54. For your team's vehicle number 2 in the Mainstream category, to what degree did you develop new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electrical) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

55. For vehicle number 2 in Mainstream category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

56. Did you have any type of working (drivable) prototype of your PIAXP vehicle number 2 in Mainstream category at the time your participation ended with PIAXP?

- ○ Yes
- ○ No

57. For vehicle number 2 in Mainstream category: How confident were you that you would have achieved the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

58. Next few questions are regarding your entry number 3 in the Mainstream category: To what extent did you buy, modify or newly develop the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electric (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

59. For your team's vehicle number 3 in the Mainstream category, to what degree did you develop new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrichemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

60. For vehicle number 3 in Mainstream category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

61. Did you have any type of working (drivable) prototype of your PIAXP vehicle number 3 in Mainstream category at the time your participation ended with PIAXP?

- ○ Yes
- ○ No

62. For vehicle number 3 in Mainstream category: How confident were you that you would have achieved the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

63. Next few questions are regarding your entry number 1 in the Alternative category:
To what extent did you buy, modify or newly develop the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrichemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

64. For your team's vehicle number 1 in the Alternative category, to what degree did you develop new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ |

65. For vehicle number 1 in Alternative category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

66. At the time your participation in PIAXP ended, did you have any type of working (drivable) prototype of your PIAXP vehicle number 1 in Alternative category?

- ○ Yes
- ○ No

67. For vehicle number 1 in Alternative category: How confident were you that you would achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

68. Next few questions are regarding your entry number 2 in the Alternative category: To what extent did you buy, modify or newly develop the following subsystems?

| | N/A for our vehicle | Buy off-the-shelf system | Buy w/ minor in-house modification | Buy w/ major in-house modification | Buy custom system | Developing own system |
|---|---|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrichemical Fuel Cell | ○ | ○ | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ | ○ | ○ |
| Software and Hardware Control | ○ | ○ | ○ | ○ | ○ | ○ |

69. For your team's vehicle number 2 in the Alternative category, to what degree did you develop new innovations in each of the following areas?

| | N/A for our vehicle | No innovation | Minor innovations | Major innovations |
|---|---|---|---|---|
| Chassis | ○ | ○ | ○ | ○ |
| Suspension | ○ | ○ | ○ | ○ |
| Body | ○ | ○ | ○ | ○ |
| Engine (Combustion) | ○ | ○ | ○ | ○ |
| Transmission | ○ | ○ | ○ | ○ |
| Battery (High Voltage) | ○ | ○ | ○ | ○ |
| Electrochemical Fuel Cell | ○ | ○ | ○ | ○ |
| Motor (Electric) | ○ | ○ | ○ | ○ |
| Electrical (Low Voltage) | ○ | ○ | ○ | ○ |
| Electrical (High Voltage) | ○ | ○ | ○ | ○ |
| Sofware and Hardware Control | ○ | ○ | ○ | ○ |

70. For vehicle number 2 in Alternative category: To what extent did the announcement of PIAXP precipitate changes in the vehicle(s) development efforts that you already had ongoing?

| | N/A | None | Minor change | Major change |
|---|---|---|---|---|
| Development schedule (i.e. Target launch date) | ○ | ○ | ○ | ○ |
| Technical goals (i.e. MPGe,Emissions, Speed) | ○ | ○ | ○ | ○ |
| Technical Approach (e.g., body type, powertrain etc.) | ○ | ○ | ○ | ○ |

71. At the time your participation with PIAXP ended, did you have any type of working (drivable) prototype of your PIAXP vehicle number 2 in Alternative category?

- ○ Yes
- ○ No

72. For vehicle number 2 in Alternative category: How confident were you that you would achieve the following objectives in time for the PIAXP final races in 2010? (0-100% confidence level; Or type DONE, if already done)

| | |
|---|---|
| Roadworthy Prototype (as defined by PIAXP) | |
| Fuel Economy of 100 MPGe | |
| Total GHG emissions < 200g/mi CO-2 equivalent | |
| Meet US safety standards | |
| Meet US Emissions standards | |

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Last few questions!

73. How many patents or patent filings did your team/organization disclose that were directly applicable to your PIAXP entry/entries?

74. Does your team plan to file any future patents as a result of work on your PIAXP entry/entries?

- ○ Yes
- ○ No

75. To what extent do you agree or disagree with the following statements about the rules for the PIAXP competition. "The PIAXP rules are:"

| | Strongly disagree | Disagree | Neural | Agree | Strongly agree |
|---|---|---|---|---|---|
| Clear/Transparent | ○ | ○ | ○ | ○ | ○ |
| Stable/Consistent | ○ | ○ | ○ | ○ | ○ |
| Fair/Equitable | ○ | ○ | ○ | ○ | ○ |

76. Who do you think will win the PIAXP competition in your category?

77. We would welcome any comments you have about the design of the PIAXP prize, and ways that similar competitions might be improved upon in the future:

# MIT PIAXP Prize Study

## INTRODUCTION

Welcome to the MIT PIAXP Prize Study! <br><br>

The objectives of our study are to: <br><br>

i) understand how prizes can be used to enhance creativity and innovation in an industry sector, and to <br>
ii) identify the organizational choices that are most correlated with the success of competing teams <br><br>

Please be assured that any information you provide will be treated with the utmost confidentiality.< br><br>

Please read the formal consent form below, and feel free to contact us directly at <a href="mailto: piaxp-research@mit.edu">piaxp-research@mit.edu</a> if you have any questions.<br><br>

Thank you again!

CONSENT TO PARTICIPATE IN SURVEY

Empirical and Policy Analyses of the Link Between Organizational Designs and Innovation in the Context of an Innovation Prize.

You have been asked to participate in a research study conducted by Fiona Murray from the Sloan School of Management at the Massachusetts Institute of Technology (M.I.T.). The purpose of the study is to examine how competitions create value, through an in-depth analysis of the Progressive Insurance Automobile X PRIZE (PIAXP). Our research has been designed to understand what motivates organizations (and individuals) to participate (or not) in a competition; which organizational characteristics best predict innovative performance, and what relationships exist between these characteristics and the technical choices that are made? What is the impact of the competition on the field/industry? In particular, do prizes induce major changes in performance, technology and/or organizational arrangements?

• You were selected as a possible participant in this study because you are a current or past participant in the Progressive Automotive Insurance X Prize. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• This survey is voluntary. You have the right not to answer any question, and to stop the interview at any time or for any reason. We expect that the survey will take less than an hour. You will find a progress bar at the bottom of each page to help you gauge how many questions remain.

• You will not be compensated for this survey.

• In any and all publications that may result from this research, the information you tell us will be confidential.

• This project will be completed by December 2011. All survey results will be stored in a secure work space until 3 years after that date. The records will then be destroyed.

Please contact piaxp-research@mit.edu with any questions or concerns.

If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253-6787

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study.
(Required)

- ○ Yes
- ○ No

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1. Team Name: (Required)

2. Your Name: (Required)

3. Your role within your PIAXP team (check all that apply): (Required)
   - ☐ Team Management
   - ☐ Engineering/Technical Lead
   - ☐ Marketing/Promotion Lead
   - ☐ Team Founder
   - ☐ Other (please specify)

4. Your email address: (Required)

5. Would you like a summary of the survey results sent to you?
   - ○ Yes
   - ○ No

# TEAM STRUCTURE

6. For the purpose of our survey we define the "core team" as individuals who contributed to the PIAXP project on a regular basis and/or played an ongoing significant role within the team and the "peripheral team" as those who were occasional contributors. A "contractor" is someone who was hired to complete specified aspects of the project but you would not have considered as a formal team member.

Please fill out the following tables with numbers of individuals.

How many individuals were in each of the following categories, just prior to your PIAXP participation ending (i.e. just prior to you dropping out, your elimination or victory)?

| | Just prior to your PIAXP participation ending |
|---|---|
| Core Team Members | |
| Peripheral Members | |
| Contractors | |

7. On average, how many hours per week did an individual in your core team contribute during the following time points?

| | Hrs/ week |
|---|---|
| Between Vegas and Shakedown | |
| Between Shakedown and Konckouts | |
| Between Knockouts and Finals | |
| Between Finals and Validation | |
| From Validation until now | |

# TEAM COLLABORATION & COOPERATION

PLEASE ANSWER QUESTIONS REGARDING YOUR INTERACTIONS WITH OTHER ORGANIZATIONS AND INDIVIDUALS DURING PIAXP

8. We are interested in understanding how many external collaborators (e.g. universities, for profit, non-profit, other PIAXP teams) helped your team to develop your PIAXP vehicle(s). Please provide the number of each type of collaborator that contributed to your team during the time you were involved in PIAXP.

| | Number of collaborators just prior to your PIAXP participation ending |
|---|---|
| Universities | |
| Research Institutes | |
| Non-Profit | |
| For-Profit | |
| Other PIAXP Teams | |

9. What percentage of these organizations approached you as opposed to you approaching them?

| | |
|---|---|
| Universities | |
| Research Institutes | |
| Non-Profit | |
| For-Profit | |
| Other PIAXP Teams | |

10. There are number of reasons why a team would choose/ not choose to collaborate with other organizations including incentives associated with sharing ideas, resources and/or equipment. Please could you describe the reasons why your team chose/ did not choose to collaborate with other organizations.

11. Can you tell us about any future collaborations you plan to engage in (with universities, suppliers, automobile companies, other teams etc)?

12. How many PIAXP teams assisted your team/ did your team members assist informally on the following options during the PIAXP competition?

| | No. of teams that your team members assisted | No. of teams that assisted with you |
|---|---|---|
| Technical knowledge | | |
| Business strategy | | |
| Supplier advice | | |
| Man power | | |
| Motivation/ encouragement | | |
| Other (please state) | | |

13. Are you planning to hire any individuals from other PIAXP teams?

- ○ Yes
- ○ No

14. On a scale of one to five, please rate how interactions with other teams influenced your progress and success in the competition?

- ○ No effect
- ○ Neutral
- ○ Very influential
- ○
- ○

15. Please share some examples of collaboration between your team and other PIAXP teams here

# PIAXP EXPERIENCE & FUTURE PLANS

16. Please select one of the following options regarding the reason for your participation in PIAXP ending

- ○ Our team withdrew voluntarily
- ○ Our team was eliminated as part of the judging process before the validation round
- ○ Our team made it to the validation round but did not win
- ○ Our team was one of the category winners

17. Please give a brief description of why your team was eliminated from PIAXP

18. To what degree do you agree or disagree with the following statements about why you withdrew. "Our team withdrew from the PIAXP competition primarily because:"

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| We did not have enough money to complete the vehicle | ☐ | ☐ | ☐ | ☐ | ☐ |
| We did not have enough people to complete the vehicle | ☐ | ☐ | ☐ | ☐ | ☐ |
| We did not have enough time to complete the vehicle | ☐ | ☐ | ☐ | ☐ | ☐ |
| We could not meet the PIAXP technical requirements | ☐ | ☐ | ☐ | ☐ | ☐ |
| We could not meet the PIAXP business plan requirements | ☐ | ☐ | ☐ | ☐ | ☐ |
| The rules of the competition were not aligned with our goals | ☐ | ☐ | ☐ | ☐ | ☐ |
| The deliverables for the competition incurred too much overhead | ☐ | ☐ | ☐ | ☐ | ☐ |
| We did not want to disclose information on our technology | ☐ | ☐ | ☐ | ☐ | ☐ |
| Our organisation withdrew support for our entry | ☐ | ☐ | ☐ | ☐ | ☐ |
| Our team became dysfunctional | ☐ | ☐ | ☐ | ☐ | ☐ |

19. Please give a brief description of why you believe your team did not win PIAXP

20. Please give a brief description of why you believe your team won PIAXP

21. There are many factors that could have contributed to the success of a PIAXP team. Please could you put the following success factors in order from one to eight, with one being the most influential success factor.

(Please mark each option in the desired order: 1 to 8)

- ☐ Level of technical innovation
- ☐ Reliability of the vehicle
- ☐ (Technical) experience level of the team
- ☐ Experience level of the driver
- ☐ Management skills of the team leader
- ☐ Negotiation skills of the team leader
- ☐ Passion
- ☐ Luck

22. Please state any additional factors that contributed to the success of a PIAXP vehicle here

23. Is your team continuing to work together now that your PIAXP participation has ended?

- ○ Yes
- ○ No

24. What percentage of your core PIAXP team are staying involved in your project?

25. What is your team's primary focus at this time?

- ○ A vehicle
- ○ A component/ sub-system of a vehicle
- ○ A technology that could have a use in a vehicle
- ○ Automotive consulting
- ○ Other

26. To what extent do you agree or disagree with the following statements about the benefits your team received from competing in PIAXP. "Competing in PIAXP helped us:"

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Attract Attention | ○ | ○ | ○ | ○ | ○ |
| Attract Investors | ○ | ○ | ○ | ○ | ○ |
| Increased chances of recieving government loans and grants | ○ | ○ | ○ | ○ | ○ |
| License or Sell our Technology | ○ | ○ | ○ | ○ | ○ |
| Generate Job Offers for Team Members | ○ | ○ | ○ | ○ | ○ |
| Network with Other Teams | ○ | ○ | ○ | ○ | ○ |
| Improve our Technology | ○ | ○ | ○ | ○ | ○ |
| Accelerate our Progress | ○ | ○ | ○ | ○ | ○ |
| Test our technology against bechmarks | ○ | ○ | ○ | ○ | ○ |
| Learn about vehicle safety testing | ○ | ○ | ○ | ○ | ○ |

27. Please state any other benefits PIAXP brought you here

28. Please could you tell us about any incentive mechanisms you had in place to promote greater effort from your team, for example prize sharing, internal competition, compensation etc.

29. Did you have any formal or informal contracts among the team covering prize and intellectual property arrangements?

- ○ Yes
- ○ No

30. Did your team participate in the agreement to split the PIAXP prize money with other teams, before the final race?

- ○ Yes
- ○ No

31. Why did your team choose to participate in the agreement to split up the prize money?

32. Why did your team choose not to participate in the agreement to split up the prize money?

33. Please describe how your team's plan for sharing potential PIAXP winnings evolved from registration.

- ☐ We had an explicit plan at registration and we stuck to it
- ☐ We had an explicit plan at registration but it changes significantly
- ☐ We did not have an explicit plan at registration

34. How much of the prize purse did your team receive (in US$)?

35. How would your team have distributed the prize money if you had won PIAXP?

- ○ Organization keeps all prize money
- ○ Team members shared some portion of the prize money
- ○ Did not decide
- ○ Other (please specify)

36. How was the intellectual property distributed after your PIAXP participation ended?

- ○ Organization kept all intellectual property
- ○ Team members shared some portion of the intellectual property
- ○ Not yet decided
- ○ Other

37. How are you planning to distribute the PIAXP prize money?

- ○ Organization keeps all prize money
- ○ Team members share some portion of the prize money
- ○ Not yet decided
- ○ Other

38. How many patents or patent filings did your team/organization disclose that were directly applicable to your PIAXP entry/entries?

39. Please provide a list of the patent reference numbers your team has filed or been awarded

40. Does your team plan to file any future patents as a result of work on your PIAXP entry/entries?

- ○ Yes
- ○ No

41. On a scale of one to five, please rate how different your PIAXP race vehicle is to the vehicle you plan to take to market?

- ○ Very different
- ○ Neutral
- ○ Exactly the same

42. On a scale of one to five, please rate how innovative your PIAXP vehicle is compared to other vehicles in the competition?

- ○ Not innovative at all
- ○ Neutral
- ○ Very innovative

43. On a scale of one to five, please rate how innovative your PIAXP vehicle is compared to other vehicles on the market today?

- ○ Not innovative at all
- ○ Neutral
- ○ Very innovative

44. On a scale of one to five, please rate how reliable your PIAXP vehicle was during the competition?

- ○ Not reliable at all
- ○ Neutral
- ○ Very reliable

45. On a scale of one to five, please rate the technical experience of your PIAXP team

- ○ Not experienced at all
- ○ Neutral
- ○ Very experienced

46. On a one to five scale, please rate the experience of your team's PIAXP primary driver.

- Not experienced at all
- Neutral
- Very experienced

47. On a one to five scale, please rate the management skills of your team leader(s).

- Not skilled at all
- Neutral
- Very skilled

48. On a scale of one to five, please rate the skill of your team leader in negotiating with PIAXP officials during the competition.

- Not good at all
- Neutral
- Very good

49. On a scale one to five, please rate how passionate you believe your team was during PIAXP.

- Not passionate at all
- Neutral
- Very passionate

50. On a scale of one to five, please rate the extent to which luck influenced your PIAXP team's success.

- Not influential at all
- Neutral
- Very influential

51. Please fill in the following table regarding the number of people who were interested in your team and vehicle during the following two time periods

| | During the PIAXP competition (Sept 2009-August 2010) | Since the PIAXP competition ended (Sept 2010- now) |
|---|---|---|
| No. of people interested in purchasing your vehicle | | |
| No. of suppliers interested in supplying parts | | |
| No. of firms interested in purchasing your product and/or partnering with your company | | |
| No. of investors interested in financing your project | | |
| No. of firms interested in hiring your team members | | |
| No. of media organizations that contacted you | | |

52. Looking back at your team's participation over the course of the competition, what best describes the overall leadership structure of your core team?

- ○ We had a single leader who set the vision and made most key decisions
- ○ We had a group of two or three leaders who played significant roles in setting the vision and making key decisions
- ○ Most or all of the core team members played significant roles in setting the vision and making key decisions

53. More specifically, please identify who made the following key decisions for your PIAXP team

| | Team Leader | Group of two or three team members | Broadly shared by most or all team members |
|---|---|---|---|
| Team members | ○ | ○ | ○ |
| Setting the team vision | ○ | ○ | ○ |
| Personnel decisions (i.e. who is on or off the team) | ○ | ○ | ○ |
| Major financial decisions | ○ | ○ | ○ |
| Technical decisions related to vehicle design | ○ | ○ | ○ |

54. Overall, how well did your team work together?

- ○ Not well at all
- ○ Neutral
- ○ Very well
- ○
- ○

# RESOURCES

55. How much money did your organization spend developing your PIAXP entry/entries AFTER the PIAXP announcement, and up to the point your PIAXP participation ended? [in US$]

56. How many total PERSON-YEARS of effort did your team put into developing your PIAXP vehicle (s) up to the point your PIAXP participation ended?

57. Approximately how many total PERSON-HOURS did your team spend on PIAXP work unrelated to your vehicle(s) up to the point your participation ended with PIAXP? (e.g. proposal preparation, blogging, rules compliance, business plan etc.)

58. Approximately what % of your team's funding came from the following sources, since registration:

| | |
|---|---|
| Paid for by internal funds from a parent organization | |
| Venture capital or Angel investors | |
| Government grants and contracts | |
| Private or corporate philanthropy/sponsorship | |
| Friends and family | |
| Self-funded by team members (including working without pay) | |
| Business loans | |

59. Approximately, how much additional money do you require to bring your product to market [in US$]?

60. Approximately, how many additional total PERSON-HOURS of effort does your team require to bring your vehicle to market?

# PIAXP REFLECTION

Last few questions...

61. To what extent do you agree or disagree with the following statements about the rules for the PIAXP competition. "The PIAXP rules were:"

| | Strongly disagree | Disagree | Neural | Agree | Strongly agree |
|---|---|---|---|---|---|
| Clear/Transparent | ○ | ○ | ○ | ○ | ○ |
| Stable/Consistent | ○ | ○ | ○ | ○ | ○ |
| Fair/Equitable | ○ | ○ | ○ | ○ | ○ |

62. Please rate the overall design of the PIAXP competition, on a scale of one to five

- ○ Very well designed
- ○ Neutral
- ○ Very poorly designed
- ○

63. Please rate the overall judging process of the PIAXP competition, on a scale of one to five

- ○ Very well designed
- ○ Neutral
- ○ Very poorly designed
- ○

64. Please rate the overall level of PIAXP public engagement, on a scale of one to five

- ○ High level of engagement
- ○ Neutral
- ○ No engagement
- ○

65. Please rate the quantity of media coverage on your PIAXP vehicle, on a scale of one to five

- ○ Large amount of coverage
- ○ Neutral
- ○ No coverage
- ○

66. Please rate the placement of media coverage on your PIAXP vehicle, on a scale of one to five

- ○ Very well placed
- ○ Neutral
- ○ Very poorly placed
- ○
- ○

67. Was participation in PIAXP worth it for your team?

- ☐ Yes
- ☐ No

68. Are you happy with the overall outcome of PIAXP?

- ☐ Yes
- ☐ No

69. What were the greatest flaws or limitations of the PIAXP competition design from your perspective?

70. Would you have competed in PIAXP if no financial reward was offered?

- ○ Yes
- ○ No

71. We would welcome any comments you have about the design of the PIAXP prize, and ways that similar competitions might be improved upon in the future. e.g. How would you redesign the PIAXP competition if you were in charge, based on what you have learned from the competition?

# MIT PIAXP Prize Study

## INTRODUCTION

Welcome to the MIT PIAXP Prize Study! <br><br>

The objectives of our study are to: <br><br>

i) understand how prizes can be used to enhance creativity and innovation in an industry sector, and to <br>
ii) identify the organizational choices that are most correlated with the success of competing teams <br><br>

Please be assured that any information you provide will be treated with the utmost confidentiality.< br><br>

Please read the formal consent form below, and feel free to contact us directly at <a href="mailto: piaxp-research@mit.edu">piaxp-research@mit.edu</a> if you have any questions.<br><br>

Thank you again!

CONSENT TO PARTICIPATE IN SURVEY

Empirical and Policy Analyses of the Link Between Organizational Designs and Innovation in the Context of an Innovation Prize.

You have been asked to participate in a research study conducted by Fiona Murray from the Sloan School of Management at the Massachusetts Institute of Technology (M.I.T.). The purpose of the study is to examine how competitions create value, through an in-depth analysis of the Progressive Insurance Automobile X PRIZE (PIAXP). Our research has been designed to understand what motivates organizations (and individuals) to participate (or not) in a competition; which organizational characteristics best predict innovative performance, and what relationships exist between these characteristics and the technical choices that are made? What is the impact of the competition on the field/industry? In particular, do prizes induce major changes in performance, technology and/or organizational arrangements?

• You were selected as a possible participant in this study because you are a current or past participant in the Progressive Automotive Insurance X Prize. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• This survey is voluntary. You have the right not to answer any question, and to stop the interview at any time or for any reason. We expect that the survey will take less than an hour. You will find a progress bar at the bottom of each page to help you gauge how many questions remain.

• You will not be compensated for this survey.

• In any and all publications that may result from this research, the information you tell us will be confidential.

• This project will be completed by December 2011. All survey results will be stored in a secure work space until 3 years after that date. The records will then be destroyed.

Please contact piaxp-research@mit.edu with any questions or concerns.

If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253-6787

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study.
(Required)

- ◯ Yes
- ◯ No

# Untitled Page

1. Team Name: (Required)

2. Your Name:

3. Your role within your PIAXP team (check all that apply): (Required)
   - ☐ Team Management
   - ☐ Engineering/Technical Lead
   - ☐ Marketing/Promotion Lead
   - ☐ Team Founder
   - ☐ Other (please specify)

4. Your email address: (Required)

5. Would you like a summary of the survey results sent to you?
   - ○ Yes
   - ○ No

# PIAXP EXPERIENCE

Please answer the following questions about your involvement in PIAXP from your personal perspective, as opposed to answering on behalf of your team members.

6. When did you join your PIAXP team?
   - ○ Prior to registration
   - ○ After registration

7. What month and year did you join your PIAXP team?

8. Are you still with your original PIAXP team?
   - ○ Yes
   - ○ No

9. Please describe briefly why you left your PIAXP team?

10. Have you been hired by another team that participated in PIAXP at any point?
    - ○ Yes
    - ○ No

11. Quite often, factors that motivate an individual to enter a competition shift during the course of the competition. First, on a one to five scale, please state the extent to which you agree with the following statements. "I was motivated to participate in my PIAXP team INITIALLY..."

| | Strongly disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| To win the award money for my team | ○ | ○ | ○ | ○ | ○ |
| To receive individual compensation i.e. a personal financial reward | ○ | ○ | ○ | ○ | ○ |
| To gain recognition in my organization | ○ | ○ | ○ | ○ | ○ |
| To gain recognition in the industry | ○ | ○ | ○ | ○ | ○ |
| To challenge myself intellectually | ○ | ○ | ○ | ○ | ○ |
| To expand my knowledge | ○ | ○ | ○ | ○ | ○ |
| To enhance my skills | ○ | ○ | ○ | ○ | ○ |
| To network with PIAXP participants | ○ | ○ | ○ | ○ | ○ |
| To have fun | ○ | ○ | ○ | ○ | ○ |
| To impress my colleagues | ○ | ○ | ○ | ○ | ○ |
| To beat other participants | ○ | ○ | ○ | ○ | ○ |
| Because I was passionate about the cause | ○ | ○ | ○ | ○ | ○ |
| Because it was part of my job requirement | ○ | ○ | ○ | ○ | ○ |
| Because my previous job was not satisfiying enough | ○ | ○ | ○ | ○ | ○ |
| Because my day job is not satisfying enough | ○ | ○ | ○ | ○ | ○ |
| Because I experienced internal pressure from my organization | ○ | ○ | ○ | ○ | ○ |
| Because I had some spare time availiable | ○ | ○ | ○ | ○ | ○ |
| Because I enjoy the thrill of competition | ○ | ○ | ○ | ○ | ○ |
| Because my friend(s) asked me to | ○ | ○ | ○ | ○ | ○ |

12. Second, on a one to five scale, please state the extent to which you agree with the following statements. "I was motivated to stay involved with my PIAXP team DURING the competition..."

| | Strongly disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| To win the award money for my team | ○ | ○ | ○ | ○ | ○ |
| To receive individual compensation i.e. a personal financial reward | ○ | ○ | ○ | ○ | ○ |
| To gain recognition in my organization | ○ | ○ | ○ | ○ | ○ |
| To gain recognition in the industry | ○ | ○ | ○ | ○ | ○ |
| To challenge myself intellectually | ○ | ○ | ○ | ○ | ○ |
| To expand my knowledge | ○ | ○ | ○ | ○ | ○ |
| To enhance my skills | ○ | ○ | ○ | ○ | ○ |
| To network with PIAXP participants | ○ | ○ | ○ | ○ | ○ |
| To have fun | ○ | ○ | ○ | ○ | ○ |
| To impress my colleagues | ○ | ○ | ○ | ○ | ○ |
| To beat other participants | ○ | ○ | ○ | ○ | ○ |
| Because I was passionate about the cause | ○ | ○ | ○ | ○ | ○ |
| Because it was part of my job requirements | ○ | ○ | ○ | ○ | ○ |
| Because my previous job was not satisfiying enough | ○ | ○ | ○ | ○ | ○ |
| Because my day job is not satisfying enough | ○ | ○ | ○ | ○ | ○ |
| Because I experienced internal pressure from my organization | ○ | ○ | ○ | ○ | ○ |
| Because I had some spare time availiable | ○ | ○ | ○ | ○ | ○ |
| Because I enjoy the thrill of competition | ○ | ○ | ○ | ○ | ○ |

| | Strongly disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Because my friend(s) asked me to | ○ | ○ | ○ | ○ | ○ |

13. Please state any other factors that motivated you to participate in your PIAXP team INITIALLY and that motivated you to work hard for your team DURING the competition

14. Would you have participated in your PIAXP team if no financial reward was offered by PIAXP?

- ○ Yes
- ○ No

15. Were you offered any of the following types of compensation for your work at any time during your PIAXP participation?

- ☐ Salary
- ☐ Intellectual property ownership
- ☐ A share in the prize purse
- ☐ Equity in your company
- ☐ Other (please specify)

16. On average, how much personal money did you spend on the PIAXP project [in US$]?

17. On average, how many hours/ week did you spend on the PIAXP project?

18. Please state any other sacrifices you made for the PIAXP project here

19. Looking back at your team's participation over the course of the competition, what best describes the overall leadership structure of your core team?

- ☐ We had a single leader who set the vision and made most key decisions
- ☐ We had a group of two or three leaders who set the vision and made most key decisions
- ☐ Most or all of the core team members played significant roles in setting the vision and making key decisions

20. More specifically, please identify who made the following key decisions for your core team

| | Team Leader | Group of two or three team members | Broadly shared by most or all team members |
|---|---|---|---|
| Team members | ○ | ○ | ○ |
| Setting the team vision | ○ | ○ | ○ |
| Personnel decisions (i.e. who is on or off the team) | ○ | ○ | ○ |
| Major financial decisions | ○ | ○ | ○ |
| Technical decisions related to vehicle design | ○ | ○ | ○ |

21. Overall, how well did your team work together?

- ○ Not well at all
- ○ Neutral
- ○ Very well
- ○

22. Were you aware of the Ansari space XPRIZE before your participation with PIAXP?

- ○ Yes
- ○ No

23. Please name the 3 most important innovations that PIAXP teams (your team or others) used in their vehicles?

| | Innovation | Team | Comment |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |