INFLUENCE OF GOVERNMENT SUPPORTS ON TECHNOLOGY INNOVATION PROCESS: THE CASE OF LI-ION BATTERY IN THE UNITED STATES

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ABSTRACT

Public support for technology innovation is a policy tool frequently used to foster research and development (R&D) efforts in private firms. It influences firm's R&D motivations, decision making process, and hence innovation performance. Besides factors pertaining to characteristics of firms receiving the support, the strategic behavior of project team, characteristics of the technology and the market, the regulatory environment, and the form and scale of public support can influence its effectiveness. How they influence the effectiveness remains an important policy and research question. This paper reports a study on the influence of two important forms of public support, namely government championship and assistance, in the innovation of Lithium-ion (Li-ion) battery technology.

This technology has experienced significant progress in recent years. Enormous efforts in the private sectors and public support from governments (notably United States, South Korea, and Japan) contributed to this progress. It is one of the most promising technologies to power electric vehicles, and will continue to be a high priority for public support.

A survey was conducted among the project managers or principle investigators of more than 300 Li-ion battery R&D projects that have received financial supports from the U.S. federal government. Two types of government supports—championship and assistance—were studied. The strategic behavior of project teams is also considered, with the organization type and size as control variables.

While our preliminary results confirm most of the findings in previous studies, this study also reveals different influence of government championship and assistance in technology innovation. In particular, the correlation between government assistance and strategic behavior seems significant. Through further analysis, this study will elucidate what government roles, and under what conditions, is more effective in technology innovation.

Key words: government championship, technology innovation process, organization behavior, li-ion battery.

INTRODUCTION

Public support for technology research and development (R&D) efforts by private firms is a policy tool frequently adopted to foster technology innovation. Compared to legislative or fiscal incentives, direct support allows the government to make a more focused impact on private R&D decision-making (Peneder, 2008). Supports take different forms including direct funding of public research facilities, grants to university or private sector researchers, low-interest loan, contracts for specific projects (Bernanke, 2011).

There is a large body of theoretical and empirical literature on how government support influences firms' technology incentives, decision making process, and innovation performance. Through a case-study approach, Morris and Hough (1987) indicated that government could play multiple roles in the innovation process, including owner, sponsor, buyer, regulator, and champion, in major projects. Government intervention is considered one of the crucial factors for the private R&D performance, especially in technology-intensive industries (Josh Lerner, 1999); the effect in low technological industries has also been studied (Caerteling, Halman, Song, & Doree, 2009). By developing a firm behavior model and applying theoretically analysis, C. Y. Lee (2011) identified four potential channels for how public support could affect private R&D incentives: technological-competence-enhancing, demand-creating, R&D cost-reducing and overlap (duplication) effect. For industrial R&D projects, government intervention can take two forms: championship, and financial and technological assistance (Caerteling, Halman, Song, Doree, & Van der Bij, 2013).

Literature also accumulates on the effects of government on technology innovation, while the debate on public R&D support's effectiveness and efficiency continues. Debate among economists is largely focused on the influence of public support on private R&D intensity, especially on the question of whether the public support complements or crowds out private R&D efforts, i.e. whether it increases the firms' incentives to invest in R&D(e.g., Paul A. David, Hall, & Toole, 2000; C.-Y. Lee, 2011). Effectiveness of public support on major projects (Morris & Hough, 1987), government innovation programs (J. David Roessner, 1989), specific technologies (Banales & Norberg-Bohm, 2002; Taylor, Rubin, & Hounshell, 2003) and energy R&D fields (Mansfield & Switzer, 1984) has been studied through various cases. They reveal that under different industry or market environment (C. Y. Lee, 2011) or different firm characteristics and strategies (Caerteling et al., 2013), the support's effects could vary.

The general and eventual objective of public R&D support is producing additional output from technology innovation. As C. Y. Lee (2011) noted, "more attention has been paid to the debate on whether or not public R&D support stimulates technological progress and thus enhances productivity." Caerteling et al. (2013) considered the government roles controlling for the R&D firms' internal factors together to examine relevant independent effects. Knowing attributes of success can facilitate more efficient investments in technology R&D.

The demand for high power and energy density battery systems is driven by the interest in mobile power source and increasing ecological concerns (Patil et al., 2008). In addition to enormous efforts by the private firms, governments have also invested heavily in this area. In United States, the federal government has been devoting more resources to encourage innovation in energy storage technologies including battery technology, among which the lithium-ion (Li-ion) battery was the most common recipient of critical support (Bernanke, 2011; Government Accountability Office, 2012). Funds from the American Reinvestment and Recovery Act of 2009 have played a key role in this industry (Lowe, Tokuoka, Trigg, & Gereffi, 2010). Li-ion technology experienced rapid progress in recent years, and will continue to be a high priority for public support.

Research Question

How much progress of Li-ion battery technologies is attributed to government support and how does government intervention and internal team strategy influence the innovation process? This study attempts to answer these questions in the case of the Li-ion battery in the United States.

RAPID PROGRESS OF LI-ION BATTERY TECHNOLOGIES

Since its invention at 1980's and its commercialization in the early 1990's, the Li-ion battery has emerged as one of the most important energy storage technologies. Its good characteristics make it dominant in portable electronic devices (Jansen et al., 1999); while its excellent potentials set it among the most promising technologies in powering electric vehicles (EVs)(Karimi & Li, 2013). The performance of li-ion battery has been effectively improved, from energy/power density through lifecycle to reliability. These batteries, though still unable to fulfill the requirements set by USABC[1], are used on most commercialized models of plug-ion hybrid electric vehicle (PHEV) and pure electric vehicle (PEV), e.g. Chevrolet Volt, Nissan Leaf, and Tesla Model S.

Lithium (Li) was explored as a potential anode material in the 1960s as the most electropositive and lightest metal; the concept of intercalation led to the so-called Li-ion or rocking-chair battery technology, of which the implementation took almost 10 years (Patil et al., 2008). Yoshio, Brodd, and Kozawa (2009) summarized the prominent patents of li-ion battery: all the top ten patents were filed either in United States or in Japan, among which five were awarded to Japanese companies, and four were hold by American organizations. By 1991, Sony Corporation commercialized the Li-ion cell (Patil et al., 2008).

In the following years, the capacity of the Li-ion cell improved rapidly through engineering and the introduction of advanced anode and cathode materials and electrolyte additives. The energy density of a standard cylindrical 18650 cell, for instance, increased by on average 10% per year from 1992 to 2006 (Yoshio et al., 2009). From the original LiCoO2 to LiMn2O4 and then LiFePO4, a variety of cathode materials is used to meet different performance and safety requirements (Patil et al., 2008). In 1999, a thin-film Li-ion battery technology was commercialized, which offers more shape flexibility and lightness (Patil et al., 2008). Li-ion are not only widely used for portable electronics (e.g., cell phones, and laptop computers) but also considered the most promising existing technology for electric vehicles because its high energy and power density (Lowe et al., 2010). To obtain the electrification shift of transportation system and a more flexible and efficient electric grid, which became more attractive goals under the increasing concerns of climate change and dependence on oil, high-performance batteries are key technologies (Axsen, Burke, & Kurani, 2008).

Li-ion batteries could become the most popular battery type for plug-in and full-battery electric vehicles, and dominate the market by 2017 (Deutsche Bank, 2009). A country that wants to lead the future automotive industry will likely increase its public support for Li-ion battery innovation. Meanwhile, as the capacity of Li-ion battery improves and the costs come down, its applications have been extended to industrial and residential energy storage and stationary scale use, which

[1] United States Council for Automotive Research LLC.
http://www.uscar.org/guest/article_view.php?articles_id=85

could play significant roles for integrating intermittent renewable energy and reducing electricity cost (Kassatly, 2010; Lowe et al., 2010).

The innovation and use of Li-ion battery is technologically intensive and requires a total system approach for the steady improvement of battery capacity (Yoshio et al., 2009). Stable and sufficient investment and cooperation among participants are critical to its progress.

Many governments have dedicated effort and resources to help this industry overcome the barriers. From filing the first patent with the name “Li-ion battery” in 1985 to setting up the earliest manufacturing base for commercial production (Yoshio et al., 2009), Japanese companies have been a leader of this industry in both R&D and manufacturing. The Japanese government offered crucial support during this process. The Lithium Battery Energy Storage Technology Research Association (LIBES), consisting of one research institute and ten companies and established by the New Energy and Industrial Technology Development Organization (NEDO), has been focusing on the R&D of lithium battery. One of its major initiatives, “Development of the Dispersed-type Battery Energy Storage Technology”, is a ten year program started in 1992 with a budget of 14 billion Japanese yen (Iwahori et al., 2000; Koyamada & Ishihara, 1995). China and South Korea started gain larger market share with the national policy and financial supports since early 2000s (Kassatly, 2010; Lowe et al., 2010). While more than half of the Li-ion battery patents filed in United States are held by Japanese companies, South Korea’s share is increasing. Asia countries dominate the manufacturing of Li-ion battery: Japan 57%, South Korea 17%, and China 13% in 2007(METI, 2010) [2]; Japan and Korea together had over 90% of the plug-in car market share for Li-ion batteries since 2010 (Kane, 2014).

Even though U.S. companies have small market share, U.S. researchers made crucial contributions to the progress of Li-ion battery: Bell Laboratories filed an important patent in 1982 based on the finding of lithium intercalation in graphite (Yoshio et al., 2009); important cathode materials were developed in the 1980s at the University of Texas-Austin (Lowe et al., 2010), which is federally sponsored (Bernanke, 2011).

Because of the huge potential benefit, critical federal support was provided to help U.S. companies to catch up (Bernanke, 2011). Private U.S. companies lack the capacity to invest as much as their Asian counterparts do in R&D. In the United States, national laboratories and universities play important roles in Li-ion battery innovation and provide private firms with help (Lowe et al., 2010). The federal government is investing heavily both to encourage R&D progress and to create a domestic Li-ion battery manufacturing capability. Kassatly (2010) summarized different government instruments that have been adopted to support Li-ion battery industry for electric vehicles. They include technology push and market pull measures: public-private partnership initiatives, federally funded R&D, grants for manufacturing, research institute, setting up regulatory standards, tax credits and government procurement. Federal investment in energy storage technologies including batteries is increasing significantly in recent years(Government Accountability Office, 2012). As part of the American Recovery and Reinvestment Act of 2009, the Obama Administration announced $2.4 billion in funding to the development of U.S. manufacturing capability of batteries and electric drive components(Kassatly, 2010; Lowe et al., 2010).

[2] Cited by Lowe et al. (2010) and the original source from METI is in Japanese.

THEORY AND FRAMEWORK

There is a large volume of studies on how government supports influence the technology R&D process such as the incentives, decision making, and innovation effectiveness of private firms. They include both theoretical and empirical studies.

Morris and Hough (1987) analyzed nine major technology projects. They found that government could take different roles as owner, sponsor, buyer, regulator, and/or champion in innovation process, and that the influence could be direct or indirect. As a supporter of the national innovation system, the federal government has extended its assistance to civilian technology field, especially in specific high-technology sectors that are important to both economic competitiveness and national security (Mowery, 1998). In low-technology industries, such as road infrastructure, governments usually play a crucial role as a buyer and first user of technology through championship and procurement policy (Caerteling et al., 2009). C. Y. Lee (2011) developed a theoretical framework, and identified four potential channels of public support that could affect firm R&D, and then tested the empirical data from multiple industries across countries. The four potential channels include technological competence enhancing effect, demand creating effect, R&D cost-reducing effect, and (project) overlap effect. Based on their prior research (Caerteling, Halman, & Doree, 2008; Caerteling et al., 2009), Caerteling et al. (2013) categorized two relevant government roles in technology development: championship and assistance. Government championship was defined as "expressing confidence in the innovation, involving and motivating others to support the innovation, and persisting under adversity" (Howell & Shea, 2001); while government assistance was defined as offering financial or technical support to R&D projects to prevent underinvestment in emerging technologies (Caerteling et al., 2013).

Existing literature includes many studies on whether—and to what extent—public support is effective in stimulating technological progress. Both policy makers and researchers continue to debate on those issues. The effectiveness and efficiency of government support has been analyzed in different industries, investigating various cases and programs from different perspectives. J. D. Roessner (1989) diagnosed the evaluation procedures of government innovation programs in U.S., from what lessons and experience were obtained. Both the evaluation/selection process and effects of the U.S. public-private partnership (PPP) program and Small Business Innovation Research (SBIR) program were examined (Audretsch, Link, & Scott, 2002; Josh Lerner, 1999).

A number of factors can influence the effectiveness of public support. The specific characteristics of an industry, the technological competence level, the size of firms, and the cooperation form can affect government R&D supports (C. Y. Lee, 2011). Caerteling et al. (2013) noticed that two dimensions of team strategic behavior appeared to be dominant in technology development projects: pro-activeness, and defensiveness. Pro-activeness, which is also called "aggressiveness" (Morgan & Strong, 2003), represents a R&D project team's capacity to exploit new opportunities ahead of competition (Caerteling et al., 2013; Venkatraman, 1989). Defensiveness reflects the emphasis on cost-reducing and efficiency-improving methods in a technology development project (Caerteling et al., 2013; Venkatraman, 1989).

Caerteling et al. (2013) derived the model in which technology innovation performance could be affected by the dual government roles of championship and assistance, as well as by different strategic behaviors. Their model was based on the previous research in road construction industry, a low-technology industry. They also applied to manufacturing and pharmaceutical firms for generalizability test. Their research suggested that a project team's strategic behavior is more effective than external factors, and championship is more important than assistance for improving the technology R&D performance (Caerteling et al., 2013). Even though their results did not suggest any difference across industries, we still concern that whether their model applies to high-technology as the literature suggests industry characteristics may matter.

This study follows Caerteling et al. (2013)'s framework (Figure 1), and tests the model in a typical high-technology industry, Li-ion battery.

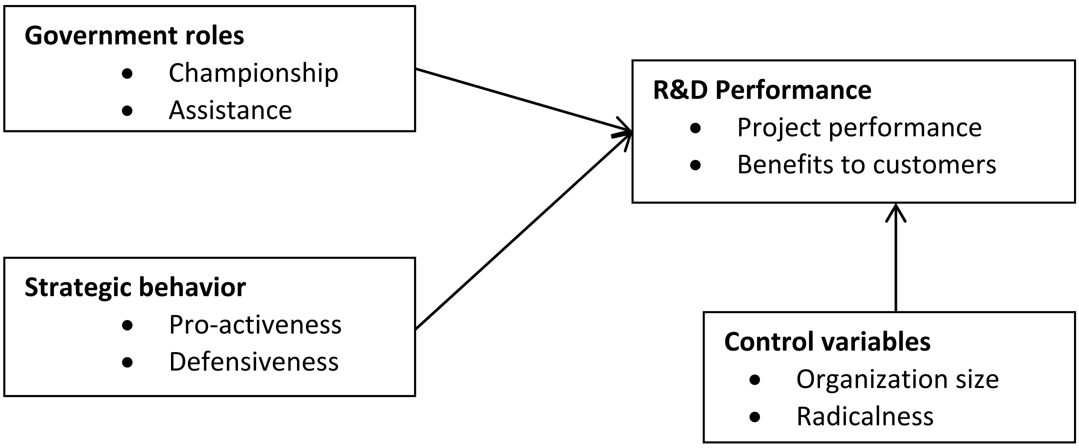

Figure 1 Conceptual Model of Impact of Government Support and Strategic Behavior on Technology Innovation Performance (Caerteling et al., 2013)

Government support

Public resources used to support technology innovation in private industries can mitigate the huge R&D risks and uncertainty (Link, 1999) , overcome barriers, and improve project performance. Government support takes various forms(Bernanke, 2011) and play different roles on the technology innovation process. In this study, two types of government support are considered, championship and financial and technical assistance, as in Caerteling et al. (2013).

Government Championship

The champion behavior consists of communicating confidence, building support and involvement, and persisting in the face of adversity(Howell & Shea, 2001). Government as champion offers an encouraging environment and framework(Morris & Hough, 1987), which can affect R&D project performance in several ways. First, government championship secures top-level support by influencing officials' perceptions of the technologies, labeling them as opportunities (Caerteling et al., 2013; Howell & Shea, 2001). Second, championship behavior emphasizes the benefits of the technology (e.g. the increased reliability or safety, or the reduced costs), therefore promotes the technology's advantages among government officials and targeted customers (Caerteling et al., 2013; Howell & Shea, 2001). Third, the champion involves key decision makers and effective problem solvers, and would be able to overcome regulatory barriers and reduce the development time by expediting the approval and permit procedures (Caerteling et al., 2013; Howell, Shea, & Higgins, 2005). Consequently, government championship has a positive effect on project performance (Caerteling et al., 2013; Markham & Griffin, 1998).

Because of the scarcity of resources, interdependence among different projects, and heterogeneity of goals of different functional areas for R&D (Markham, 2000), external champions may smooth the differences across various perspectives and stimulate information sharing (Caerteling et al., 2013). In addition, since government is eager to create social benefits (Klette, Moen, & Griliches, 2000; Wallsten, 2000), government champions should be more focused on external demand (Caerteling et al., 2013). Therefore, government championship is expected to have positive effect on both project performance and benefits to customers (Caerteling et al., 2013):

Hypothesis 1 (H1): The higher the government championship for a R&D project, the higher (a) the project performance and (b) the benefits to customers.

Government Assistance

Government assistance is considered as an instrument to overcome market failure (Link, 1999; Wallsten, 2000). Underinvestment in R&D usually occurs because the benefit-maximizing firms do not tend to invest in technology innovation at a level high enough to achieve a socially optimal level; while government financial support can compensate the costs to initiate R&D activities (Klette et al., 2000; Wallsten, 2000). Studies suggest that public support crowds out private investment and question its positive effect on simulating R&D incentives (e.g., P. A. David & Hall, 2000; Wallsten, 2000). Government financial assistance, however, can also help attracting private venture capital (C. Y. Lee, 2011; J. Lerner, 2002) and allow the continuation of a R&D project at the intended level of ambition (Wallsten, 2000), especially in an industry with high risk and uncertainty. Furthermore, considering knowledge spillover and the government's preference of technologies with higher benefits to society in general (Klette et al., 2000; Josh Lerner, 1999; Wallsten, 2000), government financial assistance tend to support R&D for social return larger than private returns to firms. Therefore, financial support should have positive effect on both the project performance and the benefits to customers (Caerteling et al., 2013).

Government technical assistance is also used to stimulate R&D. First, it can be considered as a kind of consultancy to compensate for potential information asymmetries (Stoneman & Diederen, 1994), and increase the awareness of relevant developments and technical specifications, thereby speeding up R&D project and improving product quality (Caerteling et al., 2013). Second, technical assistance can help build and enhance the collaborative relationships between the project teams and suppliers, research institutes, venture capitalists, etc.(Rothwell, 1991). Therefore, it could accelerate problem solving, shorten development cycles, and reduce overall R&D time (West & Iansiti, 2003). In addition, technical assistance is considered as a catalyst for improving design and product quality by educating the developers in the sensitivity of parameters and the robustness of design alternatives (Eisenhardt & Tabrizi, 1995).

Government assistance is predicted to be positively related to the project performance and benefits to customers (Caerteling et al., 2013):

Hypothesis 2 (H2): The higher the government assistance to a R&D project, the higher (a) the project performance and (b) the benefits to customers.

Strategic Behavior Dimension

Pro-activeness

Pro-activeness means to grasp an emerging opportunity and allow the project team to respond quickly to environmental changes and risks (Caerteling et al., 2013). The more proactive a R&D project team is, the better potential the team has to differentiate themselves and diversify into new markets (Gatignon & Xuereb, 1997), the higher R&D intensity and more relevant experience and resources the team tends to have (Pavitt, Robson, & Townsend, 1989; Souitaris, 2002), and, therefore, the more likely the team is able to deal efficiently with changes that affect budgetary, quality, and time constraints (Gatignon & Xuereb, 1997).

In addition, pro-activity enables a project team to offer important benefits to customers with first-mover advantages (Caerteling et al., 2013): As a fist supplier of a new technology, the development team has an information advantage to the risk-averse buyers who prefer known brands and suppliers (Kerin, Varadarajan, & Peterson, 1992). Furthermore, the new technology, when appearing first on the market, is likely to attract much attention and affect attributes which buyers perceive as important (Lieberman & Montgomery, 1988).

The pro-activeness dimension thus should be positively related to both the project performance and the benefits to customers (Caerteling et al., 2013):

> *Hypothesis 3 (H3): The higher the pro-activeness dimension of a project team, the higher (a) the project performance and (b) the benefits to customers the project tends to make.*

Defensiveness

A defensive project team is considered to have well-developed management capabilities to execute the project within stringent budget and time constrains (Caerteling et al., 2013), and tends to translate operational excellence into higher sales and margins (Olson, Slater, & Hult, 2005) and pursue efficiency focusing on improving existing technologies(Venkatraman, 1989). The defensive team will prefer targeting core technologies and operating in a stable and narrowly defined market domain (Mckee, Varadarajan, & Pride, 1989; Morgan & Strong, 2003). As a later entrant, the team may achieve cost and differentiation advantages from lower imitation costs, free-rider effects, scope economies, and learning from the pioneer's mistakes(Lieberman & Montgomery, 1988). Consequently, the more a project team emphasizes the defensiveness dimension, the more likely it will achieve the budget, quality, and time objectives (Caerteling et al., 2013).

On the other hand, the focus on operating efficiency also leads to limited supportive activities and adaptive capabilities (Mckee et al., 1989; Olson et al., 2005). Especially for developing technologies with substantial benefits to customers, it requires adaptability and ample time and resources to produce what the customers really want (Mckee et al., 1989; Treacy & Wiersema, 1993). Accordingly, the more defensive a project team is, the more difficult it will be to develop technologies offering significant benefits to customers (Caerteling et al., 2013).

Therefore, the hypothesis is formulated as:

> *Hypothesis 4 (H4): The higher the defensiveness dimension of a project team, (a) the higher the project performance and (b) the lower the benefits to customers the project tends to make.*

Control Variables

Caerteling et al. (2013) considered three control variables were considered. As our study is using the single-industry case, the industry effect, one of the three control variables, is excluded. Two control variables considered in this study are the radicalness of the technology and organization size.

Radicalness indicates the high level of new knowledge produced and the increased uncertainty and risk in the development of a technology, and may impact the R&D performance, especially on the benefits to customers (Garcia & Calantone, 2002; Song & Montoya-Weiss, 1998; Souder & Song, 1997).

The organization size can also affect the project performance since it could mean different resources advantages and capability (Gatignon & Xuereb, 1997). Many studies examined the relationship between innovation and size(Laforet, 2008). This study uses the "team size of the R&D project" as a measure of this variable.

Technology Innovation Performance

How to describe the technology innovation performance and its relationship to government support has always been an open question. This study follows Caerteling et al. (2013)'s methods to measure the performance of technology development projects: process performance of the project, and benefits to the customers.

Project Performance

The process performance of a development project ("project performance" in this study) is evaluated in terms of meeting budget, quality, time, and other requirement goals (Caerteling et al., 2013; Shenhar, Dvir, Levy, & Maltz, 2001). Project performance, also called "project efficiency", is the immediate dimension expressing the efficiency with which the project has been managed (Shenhar et al., 2001). Overruns, which considered as a result of technical difficulties, are more likely to be tolerated in projects involving high-technology than in lower-tech projects (Shenhar et al., 2001).

Benefit to the customer

Benefit to the customers is used to indicate the performance of the technology (Caerteling et al., 2013). Shenhar et al. (2001) stated that the benefits customers gained from different types of projects tend to increase with technological uncertainty: high-tech projects usually involve developing new products based on a collection of new technologies, and address new needs, or provide completely new solutions to previous problems; super-high-tech projects usually address very advanced needs.

RESEARCH METHODS

A survey at project level is conducted to capture the perceptions of R&D managers regarding federal government support on technology progress and product improvement.

This study applies the framework developed by Caerteling et al. (2013). A survey with Li-ion battery R&D projects in different organizations, i.e. universities, national labs, private firms, instead of only firms as in Caerteling et al. (2013)'s study, is conducted. The R&D projects with public support have been identified based on the relevant public funding data. The survey questionnaire are based on the design of Caerteling et al. (2013).

The U.S. Government Accountability Office (GAO) identified 32 relevant initiatives that are supported by the federal government during fiscal years 2009 through 2012 (Government Accountability Office, 2012). Among those initiatives, lithium-ion batteries were the most commonly supported technology. There are 28 lithium-ion batteries initiatives, which are implemented across six agencies including the Departments of Energy (DOE) and Departments of Defense (DOD), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Environmental Protection Agency (EPA), and the National Institute of Standards and Technology (NIST) (Government Accountability Office, 2012).

The program managers of these 28 initiatives in the six federal agencies were contacted to request information about awardees and project managers. According to their suggestions, contact information of the projects managers was collected through government reports and online database. We identified 539 sponsored R&D projects which are relevant to Li-ion battery technology. These projects are managed by 358 principal investigators (PI) or project managers with some of them managing more than one project. The anonymous survey was composed and set up on the Quiltrics platform. The invitation with the link to the questionnaires was sent to those project managers' email addresses on the November 11th, 2014. We received delivery failure notifications for 74 email addresses, which related to 101 projects. In addition, the managers of seven projects replied by email stating they cannot participate in our survey. After two follow-up emails sent on the November 19th and the December 3rd respectively, we received 52 completed responses through one month, representing a response rate of 12% (52/(539-101-7)).

It should be noticed that the sample selection process of this study is different from that of Caerteling et al.'s paper. Instead of randomly selected within an industry, our selected projects are all receiving federal funding support.

Measures

All the measures used are the same as in Caerteling et al. (2013)'s paper except the one for organization or firm size: in this study, we use the number of employee instead of annual revenues. Since this study focuses on one industry, dummy variables for industry categories are unnecessary. Throughout the survey, a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree) was used. More details are provided in the appendix.

Data Analysis

First, the extrapolation method (Armstrong & Overton, 1977) is used to test for possible nonresponse bias as the Caerteling's paper did. The early responses, which were received within one week of the initial email, were compared with the late ones on project performance and benefits to customers. The results showed some significant difference on the project performance, while the changes of other variables' coefficients are not obvious. Therefore the nonresponse bias is not an issue for the analysis of factors' influences. We discuss the details in the following results and discussion part.

Confirmatory factor analysis (CFA) is used to analyze the response to the questionnaire. We constrained each item loading to one factor while its loading to any other factor was set to zero according to the model and questionnaire design, e.g. the loadings of CHAM1~CHAM8 were constrained to zero except its loading for factor1, which was used to indicate government championship (CHAM). The results of CFA suggested each non-zero loading shown in Table 1. We retain all those items that load on its factor over .40 for the next step of factor-scores prediction.

Table 1 Factor Loadings

	Factor1 (CHAM)	Factor2 (ASSIS)	Factor3 (DEF)	Factor4 (PRO)	Factor5 (PERF)	Factor6 (BEN)
CHAM1	.870	0	0	0	0	0
CHAM2	.803	0	0	0	0	0
CHAM3	.908	0	0	0	0	0
CHAM4	.684	0	0	0	0	0
CHAM5	.763	0	0	0	0	0
CHAM6	.833	0	0	0	0	0
CHAM7	.882	0	0	0	0	0
CHAM8	.864	0	0	0	0	0
ASSIS1	0	.760	0	0	0	0
ASSIS2	0	~~.125~~	0	0	0	0
ASSIS3	0	.572	0	0	0	0
ASSIS4	0	.747	0	0	0	0
ASSIS5	0	~~.321~~	0	0	0	0
DEF1	0	0	.782	0	0	0
DEF2	0	0	.902	0	0	0
DEF3	0	0	.881	0	0	0
DEF4	0	0	.831	0	0	0
DEF5	0	0	.895	0	0	0
PRO1	0	0	0	~~.350~~	0	0
PRO2	0	0	0	.899	0	0
PRO3	0	0	0	.514	0	0
PRO4	0	0	0	.843	0	0
PRO5	0	0	0	~~.012~~	0	0
BUD1	0	0	0	0	.482	0
QUAL1	0	0	0	0	.717	0
TIME1	0	0	0	0	.734	0
BUD2	0	0	0	0	.456	0
QUAL2	0	0	0	0	.570	0
TIME2	0	0	0	0	.735	0
BUD3	0	0	0	0	.549	0
QUAL3	0	0	0	0	.777	0
TIME3	0	0	0	0	.823	0
TPRF1	0	0	0	0	0	~~.284~~
TPRF2	0	0	0	0	0	.636
TPRF3	0	0	0	0	0	.847
TPRF4	0	0	0	0	0	.461
TPRF5	0	0	0	0	0	.751
TPRF6	0	0	0	0	0	.677
TPRF7	0	0	0	0	0	~~.329~~

The CFA also gave the covariance between any two latent variables, which shown in Table 2. These offer some interesting information from which we could start our data analysis preparing for regression, model test and other further work.

Table 2 Covariance (Standardized) between Latent Variables by Confirmatory Factor Analysis

	Coef.	P>|z|	[95% Conf. Interval]	
cov(CHAMPION,ASSIS)	.4317	0.003	.1490	.7145
cov(CHAMPION,DEFENSIVE)	.3748	0.003	.1255	.6241
cov(CHAMPION,PROACTIVE)	.2805	0.056	-.0070	.5680
cov(CHAMPION,PERFORMANCE)	*.3555*	*0.008*	*.0939*	*.6171*
cov(CHAMPION,BENEFIT)	*.3738*	*0.006*	*.1091*	*.6384*
cov(ASSIS,DEFENSIVE)	***.8643***	***0.000***	***.7310***	***.9975***
cov(ASSIS,PROACTIVE)	.3241	0.045	.0072	.6410
cov(ASSIS,PERFORMANCE)	*.4535*	*0.002*	*.1697*	*.7372*
cov(ASSIS,BENEFIT)	***.5256***	***0.000***	***.2530***	***.7983***
cov(DEFENSIVE,PROACTIVE)	.3180	0.026	.0379	.5980
cov(DEFENSIVE,PERFORMANCE)	***.4624***	***0.000***	***.2227***	***.7020***
cov(DEFENSIVE,BENEFIT)	***.6212***	***0.000***	***.4196***	***.8228***
cov(PROACTIVE,PERFORMANCE)	***.5541***	***0.000***	***.3203***	***.7879***
cov(PROACTIVE,BENEFIT)	***.5788***	***0.000***	***.3382***	***.8194***
cov(PERFORMANCE,BENEFIT)	.4134	0.003	.1410	.6858

PRELIMINARY RESULTS

The results of CFA estimation for the six latent variables' standardized covariance are summarized in Table 2.

Government Support and R&D Performance

Consistent with the Hypotheses H1a and H1b, the results show significant positive relationships both between government championship and project performance (coef. = .3555) and between government championship and benefits to customers (coef. = .3738) at the significance level $p<0.1$.

The hypothesis H2a is also supported by the results since there is a significant positive relationship between government assistance and project performance (coef. = .4535) at $p<0.005$ level as well as H2b, which is supported by the positive covariance (coef. = .5256) between government assistance and benefits to customers at $p<0.001$ level.

Strategic Behavior and R&D Performance

As H3a and H3b predicted, the results support that pro-activeness has a positive effect on both project performance (coef. = .5541) and benefits to customers (coef. = .5788) at high significance level ($p<0.001$).

The results suggest a positive (coef. = .4624) and significant ($p<0.001$) relationship between defensiveness and project performance as H4a suggested; while the results also support defensiveness's positive (coef. = .6212) and significant ($p<0.001$) effect on benefits to customers, which is different from the prediction of H4b. But it is consistent with the results of Caerteling et al.'s study (2013), i.e., they also found the positive effect being opposite to their hypothesis.

Government Support and Strategic Behavior

There are positive covariance between government intervention and strategic behaviour, especially that the positive relationship between government championship and defensiveness is very significant and high (coef. = .8643, $p<0.001$). The high covariance suggests the possibility that strategic behaviour could be affected by government supports, or vice versa. There is potential problem of the proposed model in which the impact of government intervention on the effectiveness of strategic behavior has been neglected. This is different from the Caerteling study's results. Could it be due to the unique characteristics of Li-ion battery industry?

FUTURE WORK

We will run regressions to confirm the results of CFA. There are two emphases which we need to pay more attention on: (1) the impact of government assistance on benefits to customers, and (2) the relationship between defensiveness and benefits to customers. Our CFA result for the first one is consistent with the theoretical hypothesis. But in the Caerteling's study, the hypothesis was not supported significantly. Does it mean government assistance is more effective for Li-ion battery technology innovation in our study than for those industries in their study? In Caerteling's study, however, a generalized model was offered, and it was proved that the effect of industry category on R&D performance is not significant. We emphasize the latter one because, even though the CFA result for the latter one is consistent with Caerteling's study, it is opposite to the theoretical hypothesis. Caerteling's paper offered two possible explanations for this result (J. S. Caerteling et al., 2013). It will be analysed to answer whether and why these situations exist in Li-ion battery industry.

The six latent variables, i.e. government championship, government assistance, defensive behavior, pro-active behavior, project performance and benefits to customers, can be predicted by the loadings (Table 2) obtained in the CFA. Seemingly unrelated regression (SUR) will be used to examine the hypotheses, as this is a multiple-equation system which may have correlated error terms. In the regressions, the hypotheses will be examined; the two control variables' effect on R&D output will be examined as well.

The possible nonresponse bias and the common method bias need to be tested in following stage. The model fitness should be also analysed. The alternative models will be checked to see if the proposed model fits this case better than any other. In particular, analysis is necessary to be performed to see the relationship between government support and strategic behaviour, e.g. whether government assistance makes a positive effect on the defensive behavior.

APPENDIX A. STUDY MEASURES

Government roles								
Please indicate how much you disagree or agree with each statement. 1 = strongly disagree; 7 = strongly agree; the numbers between 1 and 7 represent the differing degree of your agreement.								
		Strongly disagree			Strongly agree			
Government championship								
In this selected project, . . .	ITEM							
. . . government officials enthusiastically promoted the technology's advantages.	CHAM1	1	2	3	4	5	6	7
. . . government officials got the key decision makers involved.	CHAM2	1	2	3	4	5	6	7
. . . government officials expressed strong conviction about the technology.	CHAM3	1	2	3	4	5	6	7
. . . government officials got problems in the hands of those who could solve them.	CHAM4	1	2	3	4	5	6	7
. . . government officials persisted their support in the face of adversity.	CHAM5	1	2	3	4	5	6	7
. . . government officials secured the top level support required.	CHAM6	1	2	3	4	5	6	7
. . . government officials showed optimism about the success of the technology.	CHAM7	1	2	3	4	5	6	7
. . . government officials knocked down barriers to the technology.	CHAM8	1	2	3	4	5	6	7
Government assistance								
In this selected project, . . .	ITEM	1	2	3	4	5	6	7
The technology was developed for a contract awarded through competitive bidding.	ASSIS1	1	2	3	4	5	6	7
The technology was developed on your company's own initiative.	ASSIS2[d]	1	2	3	4	5	6	7
The technology was developed with technical support of government.	ASSIS3	1	2	3	4	5	6	7
The technology was developed using performance specifications.	ASSIS4	1	2	3	4	5	6	7
The technology was developed with financial support of government.	ASSIS5	1	2	3	4	5	6	7
Strategic behavior								
Defensiveness dimension								
		Strongly disagree			Strongly agree			
In this selected project, . . .	ITEM							
. . . improving the operating efficiency of business was a top priority.	DEF1	1	2	3	4	5	6	7
. . . we had a continuing overriding concern for operating cost reduction.	DEF2	1	2	3	4	5	6	7
. . . we continuously sought to improve production processes so we could lower costs.	DEF3	1	2	3	4	5	6	7
. . . achievement of economies of scale or	DEF4	1	2	3	4	5	6	7

scope were important elements of our strategy.								
. . . we closely monitored the effectiveness of key business processes.	DEF5	1	2	3	4	5	6	7
Pro-activeness dimension								
In this selected project, . . .	ITEM							
. . . management actively sought innovative ideas.	PRO1[d]	1	2	3	4	5	6	7
. . . competitors recognized us as innovation leaders.	PRO2	1	2	3	4	5	6	7
. . . we were first to market with this technology.	PRO3	1	2	3	4	5	6	7
. . . we were recognized as being at the leading edge of technological innovation.	PRO4	1	2	3	4	5	6	7
. . . innovation was perceived as too risky and was resisted.	PRO5[d]	1	2	3	4	5	6	7
Performance								
Project performance								
Please indicate, with what you know today, how successful this selected project was or has been using the following criteria.								
Relative to your firm's stated objectives at the beginning of the project, how successful was this project in terms of:								
	ITEM	Far less than our stated objectives			Far exceeded our stated objectives			
Budget	BUD1	1	2	3	4	5	6	7
Quality	QUAL1	1	2	3	4	5	6	7
Development time	TIME1	1	2	3	4	5	6	7
Relative to your firm's other new technologies, how successful was this project in terms of:								
		Far less than our other technologies			Far exceeded our other technologies			
Budget	BUD2	1	2	3	4	5	6	7
Quality	QUAL2	1	2	3	4	5	6	7
Development time	TIME2	1	2	3	4	5	6	7
Relative to competing technologies, how successful was this project is terms of:								
		Far less than competing technologies			Far exceeded competing technologies			
Budget	BUD3	1	2	3	4	5	6	7
Quality	QUAL3	1	2	3	4	5	6	7
Development time	TIME3	1	2	3	4	5	6	7
Benefits to customers' performance								
Relative to the previous technology generation, this technology provides significantly higher benefits to the customer in terms of:								
		Strongly disagree			Strongly agree			
Increased reliability standard.	TPRF1[d]	1	2	3	4	5	6	7
Decreased production costs.	TPRF2	1	2	3	4	5	6	7
Shortened production time.	TPRF3	1	2	3	4	5	6	7

Increased safety standard.	TPRF4	1	2	3	4	5	6	7
Reduced environmental impact.	TPRF5	1	2	3	4	5	6	7
Reduced maintenance costs.	TPRF6	1	2	3	4	5	6	7
Broadened the applicability.	TPRF7[d]	1	2	3	4	5	6	7
Control variables								
Organization size								
Project team size	________							
Radicalness								
	ITEM	Strongly disagree			Strongly agree			
The technologies developed for project are clear departures from the state of current	RAD1	1	2	3	4	5	6	7
knowledge and embody high degrees of new knowledge.	RAD2	1	2	3	4	5	6	7
This project caused significant changes in the industry.	RAD3	1	2	3	4	5	6	7
[d] This item was removed due to factor analysis.								

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