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OPERATIONS DESIGN TO ENHANCE ARPA-E FUNDING FOR TRANSFORMATIONAL CLEAN TECHNOLOGY START-UPS

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Abstract

This paper analyzes the role of operations design in securing funding for highly risky projects. We use data from 36 transformational innovative clean technology projects, which have been selected and funded by the Advanced Research Projects Agency-Energy (ARPA-E), to examine to what extent the operational decisions can mitigate risk and enhance firm valuation during clean technology start-up stages. We find that firms with operations design that is targeted to reduce business risk receive more funding. Specifically, the start-up firms in highly risky projects receive more funding with operational hedging strategies. Nevertheless, operations design related to market competitiveness shows significant negative correlation to level of funding.

Introduction

The recent emphasis on increasing energy security and reducing carbon emissions has seen a heightened interest in the development of technologies in the U.S. that reduce reliance on foreign energy imports; cut energy-related greenhouse gas emissions; and improve efficiency across the energy spectrum (Science, 2010). In fact it has been stated that resolving these energy problems represents the opportunity of our times (Henderson & Newell, 2011). However, the innovations required are dependent on large assets and long development life cycles. It has been a challenge for cash-strived clean technology start-up managers to assess and verify their prospects and obtain resources to develop and grow (Erzurumlu, 2011). Major governments have recognized that in order to induce the necessary innovations to resolve the energy problem they need to seed transformational clean technology start-ups through development and growth (Fuchs, 2010). The US government has set up an Advanced Research Project Agency-Energy (ARPA-E) with a mandate to bridge the gaps between basic R&D and commercialization as shown in Figure 1. The agency has been charged with developing start-ups that will be "transformational" in the sense that they would be expected to bring in tenfold, or greater, improvements in performance of the underlying technologies. For example, Foro Energy, which has been funded over $9M by ARPA-E, has developed a unique thermal energy technology that breaks and weakens ultra-hard crystalline rock for efficient cutting that increases drilling rates up to "10-fold" relative to conventional technology.

In our view, this is a natural experiment in the making. The scope of innovations, amount of risk, needed scale of funding, and requirements to link emergent technologies into the existing energy infrastructure rule out conventional sources of funding such as banks or venture capitalists (VCs). Given the unique nature of promoting innovation in this high risk setting, the operations design choices made by the transformational start-ups such as scale, production, resources, etc. will play a distinct role. To the best of our knowledge, there have been no empirical studies that test the nexus between the ability to flexibly reconfigure resources in response to uncertainty and the valuation of transformational technology ventures in a high risk setting. Hence, we have set up an exploratory study of the 36 transformational start-ups funded by the ARPA-E to understand what specific operations design choices are used to mitigate risks and how these relate to the valuation of the technology. We argue that tenfold transformation can only come about if these firms excel at the operations design and proactively manage the risk associated with the underlying scientific potential.

Our results show that in this unique setting it is the product architecture and the fit with the application that relates to an increased valuation, but any competitive expertise in the market can be detrimental to valuation at this early stage. Counter intuitive to the traditional view that the start-up firms should obtain sustained competitive advantage, the disruptive power of transformational technologies eliminate the risks of market competition so long as the start-up could develop such technology and benefit from first mover advantages. This way, the government support should focus on the development and infrastructure for deployment.

Theory Base

Owing to the unique context for our exploratory study, and associated focus on the bundling and unbundling of resources in a highly uncertain setting, we ground our theory development within the resource-based view (RBV) of the firm, and draw upon two disparate subsets of this literature: dynamic RBV and operations strategy.

According to RBV of the firm, the firm's ability to grow is driven by the firm's internal resources, which are distinguished between human, organizational and financial resources (Barney, 1991; Wernerfelt, 1984). The RBV suggests that a firm can generate competitive advantage from the resources and capabilities (such as management skills, processes, knowledge) that are rare, valuable, inimitable and not substitutable (Barney, 1991). This way, a firm's portfolio of tangible and intangible resources influences its rate of growth, e.g. Mishina et al. (2004). Entrepreneurship research is closely associated with the acquisition and configuration of resources to initiate and grow new business activities though concepts such as entrepreneurial orientation (Alvarez & Busenitz, 2001; Shane & Venkataraman, 2000). Recent research has advocated for a more dynamic examination of the black box of resources —how they are assembled and built over time (Lippman & Rumelt, 2003; Townsend & Busenitz, 2008). Wiklund and Shepherd (2003) also argue for this dynamic examination in the entrepreneurial setting. A *dynamic view of the RBV* of the firm requires an assessment of how resources are used while firms attempt to grow (McKelvie & Wiklund, 2010).

The conventional RBV of entrepreneurship does not specifically focus on the possibility that entrepreneurial success may be obtained from mitigating resource related risks through operations design (e.g. Barney et al. 2001). Likewise the operations design for hedging and gaining the capability to respond to uncertain future events (Kogut & Kulatilaka, 1994) has not been fully investigated in the entrepreneurial setting. However, the acquisition of resources from investors and the assurance of their effective and efficient use are critical to any firm's survival and growth (Schroeder, Bates, & Junttila, 2002). The resource demands of the entrepreneurial projects can be managed by financial resources (Bruno & Tyebjee, 1985), yet financial management tools may not be appropriate for firms that have high risk exposures resulting from firm operations, making it difficult to control through the use of financial contracts (Guay & Kothari, 2003). In addition, the operational decisions of entrepreneurs for acquisition and configuration of resources are often restricted by various types of risks, debt and other financial considerations (Berger & Udell, 2005; Bhide, 2000). In this paper, we argue that entrepreneurs – in particular, those of highly risky transformational projects such as the ones in clean technology – could use operations design to reduce risk and improve firm valuation by displaying proof of fit between the demands of a transformational project and the operational activities of the firm.

RESEARCH FRAMEWORK

Transformational Considerations

Transformational technology projects, like the clean technology projects funded by ARPA-E, require a long time horizon for return and large capital for what is highly unpredictable development, adoption and growth (Pernick & Wilder, 2010). Therefore, it can be hard for the transformational start-ups to find funding easily from VCs (Eckhardt et al., 2006). This is particularly the case as the operational and financial uncertainties exacerbate the informational gaps and asymmetries between the owners of start-up companies and resource providers (i.e., creditors) about the firm's prospects (Cassar, 2004). This gap forces many, if not most, clean technology firms to explore alternative funding strategies to overcome credit scrutiny (LaMonica, 2008) and rely on project financing from government and other institutions to fund their capital outlays (Cheung, 2009).

Although transformational projects may disrupt existing markets and create new markets, the timing of the cash flows and the risk profile of such projects make these start-ups unattractive investments to debt financing, venture capital funds, angel investors and corporate investors (Denis, 2004). In the clean technology context, long time scales, large financial outlays and technological uncertainty associated with scale up often lead to failures and hence, this phase of life cycle has been described as a "valley of death" (LaMonica, 2008). In consideration of the long-run performance of high technology firms governments have interest in offering subsidies to small high tech firms because social returns may not only exceed private returns, but also signal the value of the project to private investors (Lerner, 1999). Thus, the rate and direction of technological advance can be substantially influenced by various incentives from the government.

Within the context of clean technology transformation, it is instructive to compare the continuum of funding options being explored by the US government. They range from putting cap-and-trade policy that taxes consumption of carbon, to picking potential winners among more mature technologies (e.g. firms such as Abengoa Solar) and supporting them through a loan guarantee programs, to the creation of ARPA-E's portfolio of funded start-up firms. ARPA-E was created by Department of Energy to foster "out-of-the-box" transformational energy research by funding high-risk, high-reward R&D projects that address the technology gaps between basic science development and commercialized product (ARPA-E, 2012). ARPA-E's goal is to accelerate transformational start-ups in areas that industry by itself is not likely to undertake because of technical and financial uncertainty. In order to construct such a diverse portfolio ARPA-E has identified ten sub-sectors, including biomass energy, direct solar fuels, renewable power, and building efficiency, and funded multiple firms in each sub-sector to a value of $150 million. The portfolio approach is justified by the high level of risk of failure for a majority of firms, in order to engender a few highly successful technologies that achieve ten times or larger return. This is analogous to a venture capital firm, such as Rockport Capital, developing a portfolio of start-ups.

Despite academic research on the embedded government support in technology development beyond spending and regulations (Fuchs, 2010), understanding emerging themes and betting on the right projects have been a constant challenge (e.g. failures in solar industry, NY Times, 2010), and this is particularly difficult for ARPA-E due to the critical characteristics of the clean technology industry (Erzurumlu et al. 2012), such as the need for in-situ experimentation for scaling up production, long development times (5+ years), and even longer life cycles of the technology (30+ years). Thus, funding resources like ARPA-E differs from conventional venture funding in that it is seeking "transformational" breakthroughs that are not only highly risky, but will also have an impact over 30+ years life cycle. Therefore, risk minimization is essential to a firm's funding potential. To determine the extent to which operations design could influence the risk exposure of the transformational start-up projects and foster government support by displaying mitigation of risks, a closer examination of operations design and risk management is in order.

Operations Design Considerations

The conventional view of operations design comprises a consistent pattern of choices aimed at building capabilities key to the long-term success of the firm (Stalk et al. 1992). Hayes (1985) observed that many of the most successful companies tend to focus more on building internal capabilities than on achieving specific market or financial goals. But as market conditions changed, companies can exploit business opportunities that were particular to the specific capabilities created. Hayes and Wheelwright (1984) delineate these choices into structural and infrastructural investment categories. Structural decisions are considerations of capacity, facility size and location, vertical integration, and product and process technology. Infrastructural elements are production planning and control, human resource management, organizational design and quality management practices. This was later expanded into nine key performance areas (adaptive manufacturing, cost-effectiveness of labor, delivery performance, logistics, production, economies of scale, quality performance, throughput and lead time, and vertical integration) and tested empirically in six mature manufacturing firms (Cleveland et al. 1989).

The RBV of the firm suggests that the firm can generate competitive advantage with rare, valuable and inimitable resources and capabilities (Barney, 1991). Therefore, the RBV considers the acquisition and configuration of resources crucial to emerging of organizations (Katz & Gartner, 1988) and exploitation of opportunities (Alvarez & Busenitz, 2001). For a new venture to receive external funding investors consider the indicators of venture development such as the extent that organizational activities are completed or the initiation of marketing efforts (Eckhadrt et al. 2006). Similarly, operations management literature considers the structural investments as necessary for an organization to acquire and configure resources and design processes such that the resulting capabilities are aligned with the competitive position of the organization (Van Mieghem, 2008). Further, organizational capabilities are governed by trade-offs that are defined by the operational system of resources, processes and capabilities; and operations design manages trade-offs with decisions related to structural investments as well as investments in capability building in order to mitigate value degradation due to uncertainty (Van Mieghem, 2003).

Risk Management

Projects are exposed to various risks, some of which are technology-specific and organization-specific, whereas the rest are inherent and common to all firms in the economy such as market risks. The initial step in any risk management activity is the identification and assessment of risk exposure (Bodie & Merton, 1998), with later steps to manage and mitigate risks. Contrary to common perception, there may be types of risks that cannot be managed with financial tools such as futures, options, derivatives (Guay & Kothari, 2003) because a firm invests in multiple types of resources that have different financial and operational properties (Dixit & Pindyck, 1994). The utilization of operations to manage risks has recently attracted considerable attention and a growing interest in applying risk management concepts to manage the operations of firms (Van Mieghem, 2003; Boyabatli & Toktay, 2004). In the operations management field, operational hedging is defined as the firm's ability to anticipate and respond to changes in development and market conditions flexibly by means of the firm's operations design (Cohen & Huchzermeier, 1999). Specifically, operations design for hedging manages organizational resources with product, production and supply chain network options (Huchzermeier & Cohen, 1996).

Empirical investigations show that firms manage their risks using operational hedges (e.g. Allayannis et al. 2001). Yet, operational hedging has mostly been studied with firms that are not necessarily encumbered by pressing financial constraints to tackle circumstances like demand drops, disruptions and supply shortages (Huchzermeier & Cohen, 1996; Ding & Kouvelis, 2001). Further, most operational hedging studies have primarily focused on the context of rather large and established firms (Boyabatli & Toktay, 2004), and only a few have been conducted on start-up firms to draw on operational tools to hedge risks (Tanrisever et al. 2012). Given that start-ups, endowed with unique characteristics, have to bear significant operational and financial uncertainties, which make it very hard to assess and verify their prospects (Bhide, 2000), to the best of our knowledge, there have been no empirical studies that test the nexus between such operations design and the sponsoring of transformational technology ventures in high risk settings.

Hypotheses

While prospective transformational technologies are attractive, they increase the degree of risk of technology development and deployment. Managing risk for highly risky products bears critical challenges, and has appropriately received considerable attention in the operations literature (Krishnan & Ulrich, 2001). Yet, the use of operations design to mitigate value degradation due to uncertainty for transformational technologies, like clean technology, has been scantly addressed in the operations management and entrepreneurship literature (e.g. Heirman & Clarysse, 2007). The operations management literature identifies a series of planning, organizational and project management decisions that can improve efficiency of the innovation effort, mainly in rather large and established firms (Krishnan & Ulrich, 2001). In this research we consider decisions made within the context of a single start-up project in actually developing a technology, and assess the impact of the operations design of the project. In light of the theory base discussed above we develop a framework that ties key constructs within the problem domain. For the case of transformational start-ups we propose that a lifecycle perspective is required to frame the choices of operations design, specifically when considering the risks involved in getting the product from design to market. Akin to Hayes and Wheelwright (1988) we consider not only the organization's ability to scale production and produce the technology efficiently and effectively, but also the earlier phases of constructing prototypes and laboratory testing.

We also use the scope of transformational projects as defined by ARPA-E in Figure 1 as an input for our framework development. We define four phases where risk mitigation levers need to be considered: “Design and Development” which incorporates basic and applied science, “Deployment” for the prototype, demos and laboratory testing phase, “Production Capability” to capture the production capabilities firms require to build a productive base for commercialization, and “Market Expertise” to reflect the needs of the market and asset investors. These risk mitigation levers will impact, and be impacted, by both operations design considerations and transformational considerations to achieve tenfold improvement in technology performance. We argue that the operational capabilities to transform and mitigate risk at each phase will ultimately influence the valuation of the project. The framework (as shown in Figure 2) is used to develop four hypotheses. To determine the extent that operations design would influence firm value, a closer examination of four categories of operations, design and development, deployment, production capability and competitive market expertise, is in order.

In the realm of operations a product design is represented as a bundle of attributes in *product architecture* to reflect customer needs and product specifications to technical performance (Griffin & Hauser, 1993). The product architecture such as parts commonality and modularity determines its functionality; therefore, it will have implications for operations and marketing issues (Ulrich, 1995), for organizational design (Sanchez & Mahoney, 1996), and for the evolution of entire industries (Baldwin & Clark, 1999). Further, the product architecture resulting in product complexity, technological requirements and difficulty, and the firm’s product and process development capability determines the application fit or lack thereof, and may result in higher risk of failure (Ahmadi & Wang, 1999; Meyer & Utterback, 1995). The entrepreneurs evidently face uncertainty over the costs and probability of technical development success (Dixit & Pindyck, 1994). However, the development process as a complex web of interactions ultimately determines the efficiency and predictability of the technology (Browning & Eppinger, 2002) and new firms with better access to resources will be more innovative in development than firms with less access (Casciaro & Piskorski, 2005). These entrepreneurs are more likely to proceed with exploitation when they believe to have enabling technologies for full scale (Choi & Shepherd, 2004). Therefore, we argue that the firm valuation can be improved by mitigating design and development risks. Hence,

> *H1: Valuation is positively associated with the effort to mitigate product design and development risks.*

The transformational start-ups must manage the invention and innovation (development) of a new technology product or process technology, and the adoption and use (deployment) of the technology over time for its success (Jaffe et al. 2004). Therefore, the *operational infrastructure*, which constitutes material and energy resources, production capacity, physical networks of procurement and distribution, and servicing, is a key complementary diffusion factor because the winners from the large array of technologies also require augmented and flexible use of systems and development of realistic mass-scale commercialization strategies (Erzurumlu et al. 2011). For example, the adoption rate of a clean technology relies on complementary technologies and industries like the simultaneous growth of the product or service offering (e.g. a hydrogen powered car) and its complementary infrastructure (e.g. a network of hydrogen refueling stations) (Struben & Sterman, 2008). Therefore, we argue that the deployment strategy that emphasizes operational infrastructure, scale and growth opportunities will be preferred by the start-up since it mitigates long-term business and market risks, and increases firm valuation. Hence,

H2: Valuation is positively associated with the effort to mitigate deployment risks.

Taking the RBV, Choi and Shepherd (2004: 381) define managerial capability as a firm's skills, knowledge, and experience to be able to handle difficult and complex tasks in management and production. Exploitation, thus, requires commitment of the entrepreneur's resources in building efficient production (Choi et al. 2008). Therefore, the entrepreneur has to manage complex tasks to implement high *volume production* and deliver a product to customers (Collis, 1994). Although the design and development stage manages the costs and benefits of the technology through prototyping different technologies (Thomke, 1999), the valuation of a transformational technology increases when it can deliver better performance to price ratio to consumers (Christensen et al. 2011). Hence, we argue that capability related to production and *cost improvements* will enhance firm valuation. Thus,

H3: Valuation is positively associated with the effort to mitigate production capability risks.

The RBV suggests that the role of resources and capabilities for a firm is to generate sustainable competitive advantage (Barney, 1991). New *entrants* to high technology industry are likely to develop a particular type of design innovation (Dowling & McGee, 1994). Their technological innovation could be used as a barrier for entry into industries facing a great deal of technological change (Weiss & Birnbaum, 1989). However, in high technology industries first movers with low technological capabilities suffer from poor survival rates when they cannot keep up with the changing technology (Franco et al. 2009). Hence, design and innovation capability of the firm determine its competitiveness in the market. Analogously, we argue that decisions associated with the firm's long term competitiveness will lead to a surge in firm valuation. Hence,

H4: Valuation is positively associated with firm's competitive market expertise.

Methods

Data Set

Our empirical work focuses on the funding of clean technology ventures by ARPA-E. In 2009 ARPA-E funded 36 proposals (from a pool of over 3600 applicants) to academia, research institutions, start-ups and public firms, ranging from $566,641 to $9,141,030, to a value of $149,112,541. These projects covered the spectrum of transformational technologies from biomass energy to waste heat capture. Despite the relatively small sample size, the ARPA-E projects provide a rich and robust dataset to a set of transformational technologies. Each start-up project is awarded a different amount of funding based on the level of risk and their potential to accelerate market adoption. Further, the projects accepted for funding were pre-screened by the expert team of ARPA-E on the basis of national economic and social value (ARPA-E, 2012); therefore, this allows us to work with a group of highly scrutinized projects. ARPA-E evidence therefore offers a natural experiment to understand the value of accelerators of transformational technology development by entrepreneurial start-ups.

Methodology

Understanding the value of the accelerators of transformational technologies and the role of operational resources in hedging motivates this research. Therefore, our methodology focuses on the documentation of a range of factors that affect clean technology valuation, and then produce an econometric model that explains the relationship between hedging using operations design and the amount of external funding awarded. In particular, we examine the specifications for 36 of the ARPA-E funded projects (one project had no valuation) using content analysis to identify which operations design factors are utilized in high risk, out-of-the-box technology development.

Content analysis is a technique for making inferences by objectively and systematically identifying specified characteristics of message (Holsti, 1969). Commonly used in political and socio-economic research, we have previously used this technique to assess the market valuation of publicly traded clean technology firms (Davies & Joglekar, 2010). We now draw upon this technique to identify the use of operations design and risk mitigating choices by clean technology start-ups. We apply STATA's content analysis for each project through the information available in the public filing of statements for the ARPA-E funded projects and the project web sites, and then employ factor analysis to understand the underlying structures and relationships that exist among these attributes. We subsequently use these latent factor variables within a regression model to link to the funding value.

RESULTS

Content Analysis

Through the information available in the public filing of statements for the ARPA-E funded projects and the project web sites, we examine the specifications for each funded project to identify references to design and development, deployment, capabilities for production and competitive market expertise for each technology. The complete list of terms identified and examined can be found in Table 1. For example, we seek references to product design choices such as modularity, standards, and customization (Baldwin & Clark, 1999) as exemplified in the following quotes:

> "it not only expands potential biomass for biofuels production; it also increases the spectrum of biomass acting as a *hedge* against disruption in any single biomass"
> EI du Pont

> "structural *flexibility* of the module will render it attractive for deployment in diverse settings such as automotive and data centers with minimal customization"
> University Of Illinois

> "the project will demonstrate a 5kW-10 kWh *modular* system (scalable to >10 MW power) and establish a viable manufacturing industry in the US"
> Eagle Picher Technologies, Inc.

Factor Analysis

The content analysis identified the frequency of the 51 terms used to describe aspects of design and development, deployment, and capabilities for production and competitive expertise for these transformational technologies. However, we wish to understand the underlying structures and relationships existing among these references in order to identify specific determinants of operations design and risk management. We used factor analysis to identify the latent variables. Using these 51 unique variables identified from the content analysis we found that they loaded onto the following ten different factors that explained 62.7% of the inherent variation. The logical grouping of these factors and the similarity to their discussion within the literature also provides face validity for the factor analysis. This grouping is shown in Table 1.

From the content analysis of the proposals for the 36 transformational start-ups, we observed that the projects identified a number of specific types of risk, including business risk, investor risk, financial risk, technical risk and market risk. It is of interest to note the alignment of these risks with the factors of operations design. For example, robust architecture is paired with business risk, whereas technical risk is related to cost improvement and safety, and investor risk is linked to the factors of integration for growth, again providing face validity for the factor analysis. We then marry the factors identified with the risks at the stages of transformation.

The factors of robust architecture and application fit explain the operations design choices and risks associated with product design and development; integration for growth, protected scale and proven infrastructure reflect risks and choices for deployment; cost impact, cost improvement, materials impact and productivity are all associated with production capability and reflect the traditional concepts of operations strategy; competitive expertise aligns with the competitive market risk choices (see Table 2).

Regression Analysis

We define these ten factors as our measures for operations design and use as inputs to an econometric model to test their relationship with the value of external funding awarded. We use an ordinary least squares (OLS) regression model with the value of funding awarded to the project as the dependent variable (see Table 3). We cluster on the clean technology sector to correct for potential correlations among different firms in the same sector and use White standard errors which are robust to heteroskedasticity (White, 1984). Despite the small sample size the OLS model is significant and indicates that three factors are significantly related to the level of funding provided by ARPA-E. *Application Fit* and *Robust Architecture* are positively related to the level of funding, whereas *Competitive Expertise* is negatively related, as seen in Table 3. Therefore, examining the results of the regression we show that Hypothesis 1 indicating valuation is positively associated with the effort to mitigate product design and development risks is supported by both Robust Architecture and Application Fit linked to higher funding values from ARPA-E ($p<.05$). Hypotheses 2 and 3 addressing the deployment and production capability risks are unsupported. However, Hypothesis 4 predicting that valuation is positively associated with the effort to mitigate market risks is opposed ($p<.10$).

DISCUSSION AND CONCLUSION

We summarize the implications of our findings as:

- The importance of the alignment of risk and operations design
- Pay explicit attention to product architecture and its fit with application
- Avoid early commitment to market, it will increase risk and reduce valuation

These implications are explained through post-hoc examination of FastCAP Systems, one of the firms within our dataset. FastCAP invented an improvement of an energy-storage device called the ultracapacitor (Science, 2010). Unlike batteries, capacitors store energy "in an electrical field," and unlike conventional batteries that are limited chemical reactions, they can be charged and discharged in fractions of a second, and they don't wear out like batteries do. Ultracapacitors have the potential to store energy, aka energy-storage capacity, that is much larger than standard capacitors, because they are made using activated carbon nano-technology coating. Activated carbon, because it's so porous, has a very high surface area, and that increases the amount of energy, thus providing a transformational (nearly tenfold) gain in performance. While applying for ARPA-E funding, FastCAP had focused on product architecture and application design, and patented its core technology. On the other hand, this firm's technology remained in search of the best suited application. With money now available for the next 2 years, CEO Signorelli's new challenge is to achieve the technology's practical and commercial promise (Science, 2010). Company website reported on a diverse set of target markets, ranging from automotive, to tidal energy, to geothermal solutions (www.fastcapsystems.com, accessed on April 11, 2012). It is worth noting that the technical performance requirements for each of these markets (in terms of amount of current and discharge time) are quite diverse. Such an unfocused marketing strategy is not likely to find favor with conventional start-ups. However, given the transformational potential for the underlying technology, our post-hoc work indicates that it's the ability to adapt and develop a market that is deemed valuable. Our regression analysis shows that the funding process values early lock-in into a specific target market negatively.

These results are quite revealing in terms of factors that drive valuation, while ARPA-E is steering important technologies from basic science, to applied science, to prototypes, to commercialization (as shown in Figure 1). It is clear that operations design issues (such as focus on the product architecture) are valued because they mitigate risk. However, these findings come from an exploratory study that comes with a number of limitations, both on the operationalization and on the theory fronts. The sample size is small. We have not accounted for fixed effect (in terms of lack of variation within sub-sectors) as well as selection bias issues. It would be ideal, if one examines both the projects that were funded as well as projected that were denied funding. It would also be illustrative to examine how these funded firms adapt to market realities while their technologies evolve, and when allied public policy (such as, introduction of carbon tax) is finalized. On the theory side, it would be illuminating to think through how the resource bundles associated with basic science, applied science and technology commercialization stages evolve. We identify these as assessments that ought to provide important findings for the field of entrepreneurship and public policy, especially in the energy domain.

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Figure 1: Scope of ARPA-E Funding (Source: ARPA-E Website)

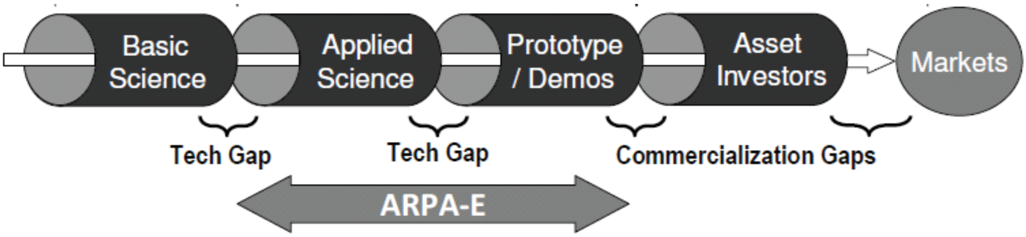

Figure 2: Research Framework

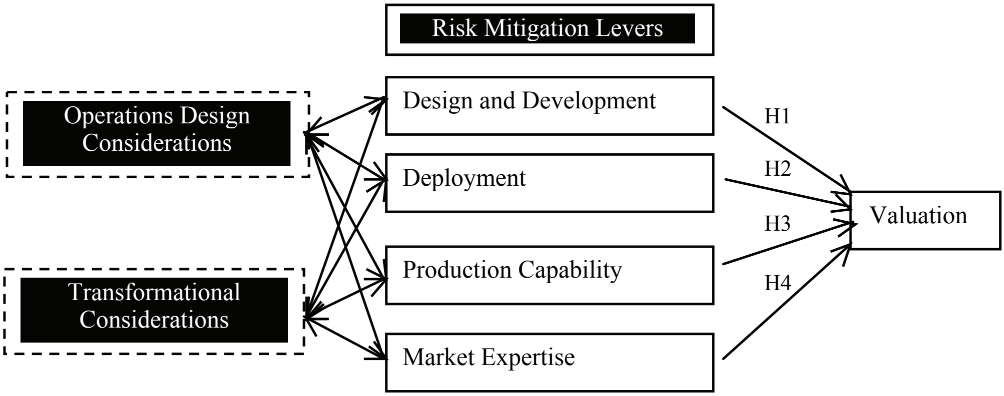

Table 1: Identified Factors

Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*
Integration for Growth	***Stage/ Infrastructure***	***Application Fit***	***Cost Impact***	***Protected Scale***
Flexible	Early Stage	Demonstrability	Low Cost Production	Test Scale
Integration	Laboratory Scale	Global Application	Higher Concentration	Intellectual Property
Speed	Proof of Concept	Sustainability	Complexity	Low Energy
Prototype	Infrastructure	Hedge	Oil Reduction	
Commercialization	Transformational			
Maturity	Financial Risk			
Market Growth				
Energy Security				
Greenhouse Gas Reduction				
Investor Risk				

Factor 6	*Factor 7*	*Factor 8*	*Factor 9*	*Factor 10*
Robust Architecture	***Materials Impact***	***Productivity***	***Cost Improvement***	***Competitive Expertise***
Modular	Yield Increase	Production Efficiency	Low Cost Improvement	Design
Robust	Material Inputs	Performance Effectiveness	Safety	Expertise
Business Risk	Carbon Impact	Manufacturing Capability	Technical Risk	Innovation
	Carbon Sequestration	Quality		Competition
				Market Risk

* Varimax Rotation. Displaying only those loadings >0.50

Table 2: Alignment of Start-up Risks Mitigation Levers with Identified Factors

Risks	**Design and Development Risks**	**Deployment Risks**	**Production Capability Risks**	**Market Risks**
Factors	Robust Architecture	Protected Scale	Productivity	Competitive Expertise
	Application Fit	Integration for Growth	Cost Impact	
		Stage-Infrastructure	Cost Improvement	
			Materials Impact	

Table 3: Regression Results. Dependent Variable: Funding Value

Independent variables	OLS Model		
Integration for Growth	27,152	(57,289)	
Proven Infrastructure	-172,748	(196,859)	
Application Fit	571,004	(204,099)	**
Cost Impact	66,551	(170,097)	
Protected Scale	25,060	(97,296)	
Robust Architecture	698,974	(306,883)	**
Materials Impact	-115,541	(353,972)	
Productivity	-46,050	(114,722)	
Cost Improvement	67,350	(139,865)	
Competitive Expertise	-170,712	(80,775)	*
Constant	4,198,000	(1288,000)	***
F statistic	6.38		
p value	0.00		
R-squared	0.311		
Observations	36		

Robust standard errors clustered on sector in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$