

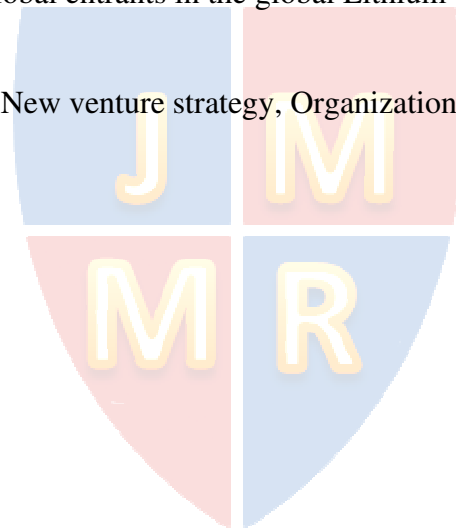
## The origin of depth search of entrepreneurs in the Lithium-Ion battery industry

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### ABSTRACT

Search is important for new ventures since it is a key for improving performance and survival chance. Yet, little is known about the origin of their search. Given the prevalence of depth search for new ventures due to new ventures' limitation of resources and short history, this study fills gap by examining how both founder pre-entry knowledge and firm post entry knowledge formulate new ventures' depth search. While new ventures with founders' core knowledge search deeply, those with founders with diverse industry experience do not search deeply. In addition, new ventures with broad product market knowledge do not search deeply. An empirical analysis of 84 global entrants in the global Lithium-Ion Battery cell manufacturing industry supports arguments.

Keywords: Entrepreneurship, New venture strategy, Organizational Search, High-tech Industry, Nascent Industry



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## INTRODUCTION

A key logic in innovation literature is that innovation is a function of firms' search (Cohen and Levinthal, 1990; Fleming, 2001; Katila and Ahuja, 2002). Recognizing the significance of search (Ahuja, 2000; Rosenkopf and Nerkar, 2001; Baum, Calabrese, and Silverman, 2000; Shan, Walker, and Kogut, 1994), organizational scholars have advanced the literature by investigating the determinants of firms' search. While one stream of literature focuses on individual characteristics (Audia and Goncalo, 2007; Tzabbar, Silverman, and Aharonson, 2015), other research highlights firm-level characteristics including organizational slack (Greve, 2007), alliances (Stuart and Podolny, 1996), absorptive capacity (Cohen and Levinthal, 1990), and organizational age and size (Kotha, Zheng, and George, 2011).

The manner through which firms solve problems by creating and recombining knowledge is especially important for new ventures since it is critical to their ability to gain financial independence and legitimacy, and thus critical to improving their chances of survival (Schoonhoven, Eisenhardt, and Lyman, 1990). While previous literature has investigated the role of search on performance in the context of entrepreneurial firms (Baum, Calabrese, and Silverman, 2000; Rosenkopf and Nerkar, 2001), limited attention has been paid to the origin of a venture's search. Moreover, extant literature has mostly highlighted the role of external factors on new ventures' breadth search from outside their organizational boundaries (Stuart, 2000; Zhang and Li, 2010). However, given the limitation of resources and short history, depth search is more prevalent for new ventures; the exploiting familiar knowledge inside organizations not only is less costly, but also provides more certainty than exploring knowledge beyond their organizational boundaries (March, 1991). Thus, this research focuses exclusively on the origin of depth search within organizational boundaries in the context of new ventures.

Building on the notion that a firm's search behavior is shaped by prior experience and current needs (Gupta et al, 2006), in this study, this study examines how founder pre-entry knowledge and firm post-entry knowledge, respectively and collectively, formulate a new venture's depth search. First, this study pays attention to individual-level characteristics, founders' different pre-entry experiences (Arrow, 1974), as their experience as a form of knowledge plays a critical role in determining search behavior at founding, when new ventures lack experiential knowledge within the focal industry. The study explores several forms of experience that founders can attain before entering the focal industry. Core industry experience is defined as experience gained before entry from industries that are closely technologically related to the focal industry (Helfat and Lieberman, 2002). In addition, diverse industry experience captures whether founders worked for a variety of industries before entry into the focal industry (Gruber, 2010). This study also examines firm-level knowledge – new ventures' post-entry knowledge regarding product market – since the accumulation of knowledge specific to the focal industry exerts influence on new ventures' subsequent search patterns by enabling them to configure strategies in tune with market needs (Sarangee and Echambadi, 2014).

The central argument of the paper is that while new ventures with founders who have core knowledge will search more deeply than those with founders who have non-core knowledge, and that those with founders who have diverse industry experience will search less deeply than those without. This study also argues that new ventures with broader product market expansion will search less deeply than those with narrower product market expansion. The study

tested these arguments using a unique longitudinal data set – global Lithium-Ion Battery (LIB) cell manufacturing ventures founded since the industry's inception in 1991.

## **THEORY AND HYPOTHESES**

### **Founders' Pre-Entry Industry Knowledge**

When new ventures create their own technological knowledge base through a search, what matters most is the pre-entry knowledge founders acquired and accumulated before founding their ventures in the focal industry. But not all types of founder experience are likely to affect the search equally. Different types of knowledge endowment enable/constrain the cognitive flexibility of new ventures conducting a search. One type of prior experience that has been of considerable interest to scholars studying entrepreneurship is founder pre-entry industry experience before entry into a focal industry (Delmar and Shane, 2006; Qian et al, 2012).

#### **i) Founders' Core Knowledge vs Complementary Knowledge**

Core industry experience is defined as experience gained before entry from industries that are closely related to the focal industry (Helfat and Lieberman, 2002). For example, if founders have working experience in the chemicals industry before entry into the Lithium Ion Battery (LIB) industry, this study categorizes that knowledge as core, since battery manufacture directly involves knowledge of chemicals. This implies that both the LIB industry and the chemicals industry are closely related technologically. Meanwhile, complementary industry experience is defined as experience acquired before entry from industries that are distant to the focal industry (Chatterji, 2009). For example, if founders have working experience in the VC industry before entry into the LIB industry, this study classifies that type of knowledge as complementary, as the LIB industry and the VC industry are not technologically linked.

Prior literature on cognitive constraint has examined how founder prior industry experience affects the strategic choices of new ventures (Ericsson and Charness, 1994; Edmonson, Bohmer, and Pisano, 2001). This stream of research posits that given the fact that founders' knowledge is formulated and accumulated around their pre-industry experience, founders with core industry experience can more easily obtain deep knowledge about the focal industry context. This benefit helps them perceive cues that environments and technologies are shifting (Ericsson, 2006). For example, in the empirical context, founders who came from chemical industries don't only understand that Lithium-Ion Battery (LIB) cells are composed of four elements – cathode, anode, separator, and electrolytes, but also that the chemical combination of cathode and anode materials generates electrical energy. This pre-existing knowledge can be a big benefit; however, core industry experience also tends to make new ventures cognitively inert and constrains their search range (Tripsas and Gavetti, 2000). As a result, new ventures with core industry experience intensively exploit existing knowledge over time.

Hypothesis 1a: New ventures with founders with core knowledge will search more deeply than those with founders with complementary knowledge.

## ii) Founders' Diverse Industry Knowledge vs Non-Diverse Industry Knowledge

Diverse industry experience captures whether founders worked for a variety of industries before entry into the focal industry (Gruber, 2010). For instance, if founders have broad work experience across the retail, manufacturing, and service industries before entry into the LIB industry, this study considers this founder's industry experience to be diverse.

The literature on cognitive flexibility posits that individuals with greater cognitive flexibility can have a greater number and range of consideration sets in their decision-making process (Goodwin and Ziegler, 1998). If knowledge is obtained from diverse industry experience, that industry experience not only makes founders more cognitively unconstrained, but also provides founders with divergent perspectives (Eggers and Kaplan, 2009). Thus, when new ventures face strategic choices while setting their search strategy, diverse industry experience enables founders to come up with a wide variety of possibilities in technological areas. However, because founders with diverse industry experience tend to lack domain-specific knowledge about a focal industry, they do not have the capacity to materialize these options with any depth. Thus,

Hypothesis 1b: New ventures with founders with diverse industry knowledge will search less deeply than those with non-diverse industry knowledge.

### New Ventures' Post-Entry Knowledge

Following Li and Greenwood (2004), this study defines product market scope expansion as the decision to expand a firm's operation into more than one market within a focal industry. Thus, the study does not consider its product market scope expansion across industries (Hoskisson and Hitt, 1990).

Through expanding their product market scope inside the focal industry, firms can enjoy several benefits. First, rich knowledge about the focal industry context provides them with advantages when trying to understand the content of knowledge as well as the underlying links between knowledge components. This benefit helps them perceive cues in case environments and technologies are shifting (Ericsson, 2006). Second, post-entry market knowledge provides a clearer understanding of the products and technologies used in a focal industry, the industry's leading suppliers and distributors as well as competitors (Helfat and Lieberman, 2002). By engaging in less "trial and error" learning (Brüderl et al, 1992), they are more capable of recognizing potential new market opportunities in the industry. Third, one of key benefits of a broad market scope strategy is a venture's ability to hedge their bets about which of their products will meet consumer's preferences (Sorenson, 2000). Because of the lack of dominant designs in the early stages of the industry life cycle, this is particularly important in emerging industries. Taken together, with broader product market scope, new ventures are less likely to search deeply. Rather, they are more likely to search broadly. Thus,

Hypothesis 2: New ventures with broader market expansion will search less deeply than those with narrower market expansion.

## DATA AND METHODOLOGY

### Research Context: The Global Lithium-Ion Battery Cell Manufacturing Industry

The empirical setting for this study is the global lithium-ion battery (LIB) cell manufacturing industry during its period of emergence from 1991 to 2011. The empirical context of the LIB industry encapsulates the early phases in the industry's life cycle characterized by high uncertainty in both technology and market demand (Abernathy and Utterback, 1978), by a lack of accumulated industry-specific knowledge (Gort and Klepper, 1982), and by no consensus concerning the dominant technology (Suarez and Utterback, 1995). The LIB cell manufacturing industry is an ideal setting through which to examine the drivers of search pattern in an emerging industry because of the product's clear-cut market applications and founders' heterogeneous pre-entry experience.

### Data Sources

The study captures the population of global LIB cell manufacturing ventures founded between 1991 and 2010, including firms that exited (either by failure or acquisition). The data-gathering process began by refining research questions and hypotheses through interviews with representatives from 12 LIB manufacturing firms that attended the Advanced Automotive Batteries Conference held in Michigan in September 2014. First, the study identified all manufacturers in Thomson One, which lists all types of rechargeable battery cells (commonly classified by Standard Industrial Classification (SIC) code 3691 or 3692). Second, this study excluded the diversifying entrants whose founding years were prior to 1991, as it is possible that firms which enter the LIB industry via other industries are better able to manage broader market scope than those that are *de novo* entrants. Third, as it is not possible to distinguish between LIB and other types of rechargeable batteries (i.e. Lead-Acid and Nickel Cadmium Batteries) based on the two SIC codes above, this study identified the LIB firms that were listed in major international industry conferences (i.e. International Battery Seminar), industry trade journals (e.g. Batterypoweronline), or periodicals from research institutes (e.g. Navigant). Finally, this study used the Who Owns Whom directory to obtain owners' information. A total of 244 global LIB firms were eventually selected for the population.

This study drew on several sources of data including product market-, patent-, founder-, and firm-level data to construct key variables. After merging the data set, the final sample included 88 global LIB cell manufacturing ventures and 944 observations during the sample period. A key advantage of this data set is that it allows this study to track the entire history of founders' working trajectories and of new ventures' technology development paths, while also precisely tracking detailed market expansion paths. By merging data sets that are based on different theoretical underpinnings – entrepreneurship, technological management, and firm scope – this study uncovers how new ventures' strategic choices are influenced and determined by founder characteristics.

## Measures

### Dependent Variable.

The dependent variable, **Search Depth<sub>t</sub>** represents the degree to which firms acquire knowledge intensively from specific technological areas, measured using the Herfindahl index (Blau, 1977). This study uses the following formula to calculate the index:

$$D = \sum p_i^2$$

where  $P_i$  stands for the share of patents in class  $i$  during current year. The minimum value of 0 represents a situation where every patent filed by a focal firm is in a distinct patent class of its own, whereas the values approaching 1 represent the usage of one specific technological area, indicating depth search.

### Independent Variables.

To measure **Core Knowledge**, this study conducted 6 interviews with CTOs of the samples. The value ranges from 1 to 4. The value is 1 if founders' industry experience has no technological linkage with LIB industry, thus complementary knowledge, whereas it is 4 if founder industry experience has tight technological linkage with LIB industry. **Diverse Experience** captures the degree to which founders' prior industry experience was gathered from a variety of industries. This study calculated the sum of founders' industry experiences; thus it is a count variable. **Post-entry Knowledge<sub>t-1</sub>**, is a one-year time lagged count variable capturing post-entry market knowledge acquired through calculating a total number of new LIB ventures' product market application from their founding within LIB industry in year  $t-1$ . Ten distinct product market application sectors in LIB industry are identified: (1) consumer electronics, (2) military, (3) medical, (4) aerospace, (5) marine, (6) industrial, (7) UPS (Uninterruptible Power Supply), (8) RFID (Radio-Frequency Identification), (9) automotive, and (10) energy storage. This study collected yearly information on market scope since founding from various resources including industry trade journals (i.e. BatteryPowerOnline), Lexis-Nexis Academic press announcements, LIB technological specification documents (i.e. Shmuel de Lion), Lexis-Nexis Academic press announcements, and company websites.

### Control variables.

At the individual level, founder demography including **Age, and Educational Background** were controlled (Kalleberg and Leicht, 1991; Dencker and Gruber, 2015). To measure **Founding Experience**, this study coded the variable as 1 if founders were founders of other firms previously, and 0 otherwise. This study also controlled organizational-level factors including **Firm Size and Firm Age, Firms with any patent, and Integrator**. This study controlled for **Integrator** with a binary variable. The value of 1 indicates that the firm not only manufactures cells, but also packs and assembles cells into batteries within the firm, while that of 0 indicates the firm is only involved in cell manufacturing activity. At the environmental level, this study controlled for market scope of prior year by generating one-year time lagged variable – **Market Scope<sub>t-1</sub>**. This study also controlled time period effects using **Year Dummy** variables



pertaining to the different years in which firms operated. Lastly, this study created a binary variable – US to control for the country in which the firm was founded.

## Statistical Methods

This study estimated models using firm random effects for following reasons: (1) the independent and some control variables are constant over time, (2) Hausman specification tests were not significant, and (3) significant serial correlation was not detected. This study used a regression model with robust standard errors.

## RESULTS

Table 1 (Appendix) displays descriptive statistics and a correlation matrix for the variables in the analysis. While numerous variable pairs exhibit significant correlations, these correlations are generally moderate. Importantly, the models are not affected by multicollinearity problems, evidenced by the variance inflation factor (VIF) for Year Dummy, the highest at 3.02, which falls below the recommended threshold of 10 (Neter, Kutner, Nachtsheim, and Wasserman, 1996).

From Model 8 indicated at Table 2, the coefficient of Core Knowledge is positive and significant ( $\beta = 0.06$ ,  $p < 0.05$ ), supporting Hypothesis 1A. Consistent with Hypothesis 1B, the coefficient of Diverse Experience is negative and marginally significant ( $\beta = -0.06$ ,  $p < 0.1$ ). Lastly, the coefficient of Post-entry Knowledge<sub>t-1</sub> is also negative, and marginally significant ( $\beta = -0.02$ ,  $p < 0.1$ ), supporting Hypothesis 2.

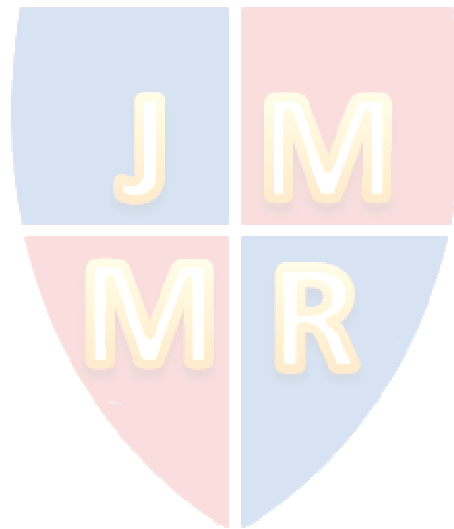
## Conclusion

By employing a rich longitudinal data set within a high-tech industry from the point of its emergence, this study advances literature investigating the determinants of depth search behavior by the simultaneous examination of 1) the founder pre-entry knowledge and 2) firm post-entry knowledge. This study complements both streams of literature, one reflecting micro-foundation of firm approach (Felin and Foss, 2005), and the other taking a macro approach focusing on firm-level attributes. Responding to calls for a systematic understanding of what drives new ventures to make different search strategy choices in a high-tech industry setting, this study also advances entrepreneurship literature by investigating how individual-level factors shape the way new ventures formulate their technology search paths.

## Discussion

The findings reveal several key insights for literature on entrepreneurship and search. First, this research has important implications for entrepreneurial decision-making research. The extant research on entrepreneurship has focused on firms during their early years of operation and, thus, overlooks the critical role founder prior experience plays in formulating the backbone of a new venture's evolution at its inception (Shane, 2000; Beckman, 2006). This study explores the significant influence founder pre-entry experience exerts on navigating the search trajectories of new ventures. This study also contributes to innovation literature, as it has begun to investigate the origin of firm heterogeneity in technology search strategies, which is an

unexplored area in the domain of innovation literature. Although it is paramount to examine the antecedents of firms' various search strategies in order to understand the whole processes of what determines firms' strategic choices and how such different choices will affect their innovative performance, the literature has thus far focused on the performance implications of search strategies (Katila, 2002; Laursen and Salter, 2006; Keupp, Palmie, and Gassmann, 2011; Terjesen and Patel, 2015). This study advances innovation literature fills this gap.





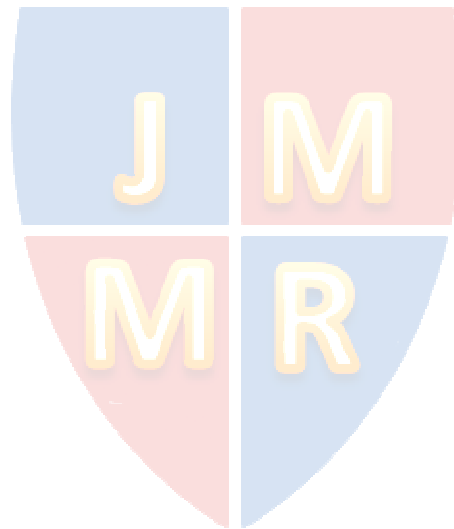
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## TABLES AND FIGURES

Table 1 Descriptive Statistics and Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Depth Search	1									
Core Knowledge	0.1134*	1								
Diverse Experience	-0.1398*	-0.0635*	1							
Post-entry Knowledge	0.0769*	-0.0573*	0.0534	1						
Founding Experience	-0.002	-0.2179*	0.0163	0.0136	1					
Educational Background	-0.0169	0.6351*	-0.2297*	-0.0627*	-0.2327*	1				
Firm Age	0.0978*	-0.2746*	-0.0811*	-0.1404*	-0.0745*	0.0083	1			
Firm Size	-0.0464*	0.0334	0.0238	-0.3359*	-0.1319*	0.0862*	0.6344*	1		
US	0.2367*	-0.0468	-0.1377*	0.1204*	0.3291*	-0.1019*	-0.0449*	-0.2508*	1	
Integrator	0.0132	-0.2493*	0.0929*	-0.0858*	-0.0199	-0.0658*	0.2086*	0.3780*	-0.017	1
Anypatents	0.3334*	0.3484*	-0.2487*	0.1061*	-0.0807*	0.1299*	0.3780*	0.3476*	0.2911*	0.1755*

Note: N=944. Starred pairwise correlations are significant at least at 0.05 level.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Core Knowledge	Depthsearch	Depthsearch 0.0467* (0.0247)	Depthsearch	Depthsearch	Depthsearch 0.0557** (0.0245)	Depthsearch 0.0470* (0.0262)	Depthsearch	Depthsearch 0.0562** (0.0258)
Diverse Experience			-0.0432 (0.0294)		-0.0625** (0.0297)		-0.0440 (0.0327)	-0.0635* (0.0325)
Post-entry Knowledge				-0.0230* (0.0129)		-0.0220* (0.0128)	-0.0230* (0.0129)	-0.0219* (0.0129)
Founding Experience	0.00505 (0.0419)	0.0150 (0.0366)	0.00325 (0.0420)	0.0104 (0.0477)	0.0141 (0.0369)	0.0202 (0.0433)	0.00848 (0.0478)	0.0192 (0.0434)
Educational Background	-0.0202 (0.0346)	-0.0739 (0.0492)	-0.0305 (0.0359)	-0.0231 (0.0386)	-0.0992** (0.0487)	-0.0772 (0.0534)	-0.0335 (0.0392)	-0.103** (0.0516)
Firm age	0.00264 (0.00500)	0.00460 (0.00498)	0.00226 (0.00484)	0.00344 (0.00550)	0.00445 (0.00469)	0.00530 (0.00529)	0.00305 (0.00529)	0.00512 (0.00494)
Firm size	-0.00176 (0.0107)	-0.00443 (0.0105)	-0.000101 (0.0103)	-0.00561 (0.0123)	-0.00255 (0.00970)	-0.00820 (0.0121)	-0.00392 (0.0117)	-0.00627 (0.0111)
US	0.0806** (0.0407)	0.0731* (0.0379)	0.0815** (0.0400)	0.0710 (0.0448)	0.0733** (0.0368)	0.0640 (0.0422)	0.0719 (0.0441)	0.0641 (0.0410)
Integrator	0.0222 (0.0419)	0.0302 (0.0388)	0.0212 (0.0419)	0.0410 (0.0450)	0.0303 (0.0382)	0.0484 (0.0427)	0.0399 (0.0450)	0.0483 (0.0421)
Anypatents	0.255*** (0.0292)	0.237*** (0.0292)	0.245*** (0.0295)	0.268*** (0.0330)	0.220*** (0.0305)	0.250*** (0.0320)	0.258*** (0.0335)	0.233*** (0.0334)
Year Dummy	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Constant	-0.594*** (0.0718)	-0.692*** (0.0753)	-0.583*** (0.0724)	-0.602*** (0.0836)	-0.692*** (0.0735)	-0.697*** (0.0879)	-0.589*** (0.0842)	-0.696*** (0.0857)
Observations	1,028	1,028	1,028	944	1,028	944	944	944
Number of Firm	84	84	84	84	84	84	84	84

**Table 2 Panel Poisson regression results (Robust errors in parentheses) \*\*\*<0.01 \*\*<0.05 \*<0.1)**