A Theory of Entrepreneurial Opportunity Discovery, Knowledge Creation, and Decision-Making

Frederick A. Lins[1] & Robert Doktor[1]

[1] Shidler College of Business, University of Hawaii, Honolulu, Hawaii, USA

Correspondence: Frederick Lins, Shidler College of Business, University of Hawaii, 4410 Pahoa Ave., Honolulu, Hawaii 96816-5424, USA. E-mail: flins@hawaii.edu

Abstract

The philosophy and methodology of Bayesian statistics bring with it a "style of reasoning" which may inform organizational researchers as they seek to conceptualize and model managerial decision-making processes. The style of reasoning of the Bayesian approach, in which posterior probabilities of the hypothesis are rigorously and continuously updated given new data, appears to closely model the researched observed decision behavior of a very important subset of managers: innovative entrepreneurs. That is, Bayesian reasoning may serve as a model of the cognitive processes undertaken by innovative entrepreneurs as they engage in knowledge creation through a recombination of resources in response to new information from the environment (Schumpeter, 1934). Modeling disciplined intuitive implementation of Bayesian reasoning may assist researchers in building a cognitive theory of how and why innovative entrepreneurs are better at estimating the probabilities of success of newly recognized opportunities than the general public. Because innovative entrepreneurs are thought to play a very important role in the development of economic growth and productivity (Baumol, Sheshinski & Strom, 2007), a theory of their decision processes may assist organizational researchers devoted toward uncovering the here-to-fore poorly understood cognitive dynamics of the innovative entrepreneur, and may play a role in enhancing the efficacy of managerial decision behavior more generally.

Keywords: Entrepreneurial Decision-Making, Bayesian Cognition

This paper focuses upon how a Bayesian approach to reasoning might supplement theory development in entrepreneurial decision-making research. More specifically, the research herein presented seeks to examine how the ontological and epistemological tenets of Bayesian reasoning may inform theory development and knowledge creation in the sub-field of organizational research devoted to conceptualization of the decision-making behavior undertaken in innovative entrepreneurial endeavors. The inductive "style of reasoning" of the Bayesian approach, when applied to understanding and developing models of the decision-making behavior of the innovative entrepreneur, may benefit organizational research devoted toward uncovering these here-to-for poorly understood cognitive dynamics. This paper proposes a Bayesian model of innovative entrepreneurial decision-making, and to highlight how understanding Bayesian reasoning may lead to insight in understanding how and why innovative entrepreneurial decision-making differs from the dynamics of usual practice in general management decision-making.

Innovative Entrepreneurship requires decision making under uncertainty. In such circumstances, the entrepreneur must intuit the probability distribution which confronts his/her decisions. These probabilities, therefore, are born in the mind of the entrepreneur. They may be different for different people. They emerge out of a synthesis of differing cognitive attributes and differing environmental situations. Expert innovative entrepreneurs learn from their experiences, continuously revising their probability distributions based upon insights derived from past experiences and contemplated actions (Sarasvathy, Entrepreneurial Expertise, 2005). We propose that Bayes' reasoning closely models these same dynamics, and therefore may serve as a theoretical model for innovative entrepreneurial decision making. We explore the central role of uncertainty in both Bayesian reasoning and innovative entrepreneurial decision-making. Decision-making under uncertainty is defined and distinguished from decision-making under risk. This leads us to a more precise definition of innovative entrepreneurship, as differentiated from other types of

entrepreneurial activities. Thereafter, we explore the relationship between opportunity recognition and innovative entrepreneurship. This is followed by an illustration of Bayesian entrepreneurial reasoning that leads to a discussion of the causation vs. effectuation issue in entrepreneurship research. Thereafter, we explore the cognitive and decision-making entrepreneurial research literature relevant to the characteristics of Bayesian reasoning.

1. Bayesian Reasoning

We argue that Bayes' theorem may inform our understanding of entrepreneurial decision making. That is, it has the potential to be a hypothetical construct upon which a Theory of Entrepreneurial Decision Making may be modeled.

Bayer's theorem adjusts probabilities given new evidence in the following way:

Equation 1 $$P(H_0 \mid E) = \{P(E \mid H_0) \, P(H_0)\} / P(E)$$

Where

- H_0 represents a hypothesis that was inferred before new evidence, E, became available.

- $P(H_0)$ is called the *prior probability* of H_0

- $P(E \mid H_0)$ is called the *conditional probability* of seeing the evidence E given that the hypothesis H0 is true. It is also called the *likelihood function* when it is expressed as a function of E given H0.

- $P(E)$ is called the *marginal probability* of E: the probability of witnessing the new evidence E under all mutually exclusive hypotheses. It can be calculated as the sum of the product of all probabilities of mutually exclusive hypothesis and corresponding conditional probabilities: $\sum P(E \mid H_i) \, P(H_i)$

- $P(H_0 \mid E)$ is called the posterior probability of H_0 given E.

Bayesian analysis is all about updating our probabilities given experience. We set out in this paper to argue that good innovative entrepreneurial decision making is all about updating probabilities given experience, and we argue the keen ability to form accurate posterior probabilities is one of the key ingredients of successful innovative entrepreneurship.

2. Uncertainty and Entrepreneurship

Uncertainty is now and has always been ever present in the mind of mankind. It is a cruel reality of the complex nature of the turbulent world in which we find ourselves. Our earliest ancestors also lived in a world of unpredictable consequences. Acs and Audretsch in their Introduction to the Handbook of Entrepreneurship Research (2010) quote Bernstein (1996) pointing out "…The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than the whim of the gods and that men and women are not passive before nature…" One of the great challenges of mankind throughout the ages has been to learn to cope with risk and uncertainty. We try to understand our world; to model our world so as to be able to predict what will happen to us as a consequence of our actions or inactions. But it is extremely rare when we can be certain of what the outcomes will be of what we do and do not do. Most often we must intuit the likeliness as well as the value of the benefit or harm of one consequence over another. On the rarest of occasions we can know for certain that there will be five or seven or however many likely consequences of an action, and know as well that each of the consequences has a certain probability of occurrence, and further know for certain that these probabilities when summed will equal 1. When this most rare of circumstances does occur, we are indeed lucky, for what we are confronting risk rather than uncertainty. In the risky situation we can calculate an expected value for each of our possible actions and then choose the action with the most beneficial outcome for our needs. The world rarely gives us the benefit of such kindness as these situations of decisions under risk. Risky decision making is rare in the real world and rarer still in the world of the entrepreneur.

So it is true for the entrepreneur. Innovative entrepreneurship is rarely about risk; it is all about dealing with uncertainty. The innovative entrepreneur faces uncertainty in all his/ her decisions and actions. Uncertainty impinges upon all stages of entrepreneurial action, and it is the response of the entrepreneur to that uncertainty which, more than other factors, determines the success or failure of the entrepreneurial venture. Because entrepreneurship is all about the implementation of a new and/or innovative business model, entrepreneurs actually face greater uncertainty than is generally common in more established business practices, which hold the benefit of learning from their longer experiences. There exists historic literature linking uncertainty to entrepreneurship: Cantillon (1755), as noted in the work of Herbert and Link (1988), speaks of the role uncertainty plays in initiating entrepreneurial acts. Austrian economists and their followers; in a most instructive insight; have argued that entrepreneurial acts are largely the consequence of less perceived uncertainty on the part of the entrepreneur (Hayak, 1945; Menger, 1950; Kirzner,

1973, 1985, 1989). Other non-Austrian economists have added to this line of thought. Knight (1921) posits that profit is the reward for bearing uncertainty because, unlike risk, uncertainty is inestimable and therefore uninsurable. Knight (1921) distinguished between risk and uncertainty:

> *"Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated… The essential fact is that 'risk' means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomena depending on which of the two is really present and operating… It will appear that a measurable uncertainty, or 'risk' proper, as we shall use the term, is so far different from an immeasurable one that it is not in effect an uncertainty at all."…*

Schumpeter (1934) added the key concept that entrepreneurs create new combinations, which become that heartbeat of the innovations that are the engine of the free market economy. Drawing on the wisdom of the Austrian economists and others cited above, these new Schumpeterian combinations may impart upon the entrepreneur a new insight, which leads to the perception of a new, and importantly, a more agreeable level of uncertainty (Galunic and Rodan 1998).

Proposition 1: Innovative Entrepreneurial Decision Making is often Decision Making under Uncertainty, not Risk.

3. Who Are the Entrepreneur Decision-Makers and Why Are They Important?

Almost everyone is an entrepreneur in one way or another. At one time or another; from lemonade stands to new software endeavors; just about everyone has had a turn launching a new business. While it is a virtue for society that we all are entrepreneurs, it is concomitantly a dilemma for the researchers of entrepreneurship. For lack of a consensus upon clear and operational definition of entrepreneurship leads to both validity and reliability trouble in research endeavors.

The definitional problem becomes quite apparent on the first pages of Entrepreneurship textbooks. If we randomly select a few texts on entrepreneurship from our own bookshelves or the bookshelves of a of a faculty colleague, we will likely find an array of definitions of entrepreneurship. For example, the fourth edition of "Entrepreneurship" by Lambing and Kuehl (2007) points out that there exists no consensus upon a definition of entrepreneurship. They note that Morris, Lewis and Sexton (1994) perhaps came close to a consensus when they proposed entrepreneurship to be:

> *"… a process activity. It generally involves the following input; an opportunity, one or more proactive individuals, an organizational context; risks, innovations and resources. It can produce the following outcomes; a new venture or enterprise; value; new products or processes; profit or personal benefit; and growth…"*

A second selected text, "Entrepreneurship: How to Start and Operate a Small Business" by Mariotti (2007) does not define entrepreneurship in its glossary, but does define the entrepreneur as

> *"… a person who organizes and manages a business, assuming the risk for the sake of potential return…"*

Both definitions above are valiant efforts. They attempt to be inclusive of all views of the entrepreneur and entrepreneurship. For researchers, the Morris et al. definition holds more promise than that of Mariotti, because Morris, et.al. are somewhat more meticulous, and therefore more readily operationalized.

The GEM project (Acs, Aremius, M., & Minniti, 2004) offers another insight into the definition of entrepreneur. While initially measuring entrepreneurial activity as the creation of a new venture or enterprise, the GEM project has refined its efforts by distinguishing two different types of entrepreneurship (Acs, 2006; McMullen, Plummer, & Acs, 2007).

1) Necessity entrepreneurship is having to become an entrepreneur because you have no better options

2) Opportunity entrepreneurship is an active choice to start a new enterprise based upon the perception that an unexploited or under-exploited business opportunity exists.

These two different forms of entrepreneurship are operationally distinguished by use of a questionnaire inquiring as to the motive for starting a new business. The more meticulous distinction of opportunity entrepreneurship is a major step forward. It begins to allow operationalization of the important dimension of "proactivity" and "innovation" along with and venture creation. Professor Acs and his colleagues in the GEM consortium (Acs, Aremius, M., &

Minniti, 2004) make a significant contribution to entrepreneurship research by the enhanced focusing of the definition.

Research on entrepreneurship, using the definition of opportunity entrepreneurship yield some interesting finding. Acs and Varga (2005), musing GEM data for 11 countries, found that opportunity entrepreneurship had a positive and significant effect on economic growth and development. Also, using GEM data, they found the propensity to exhibit opportunity entrepreneurship is negatively correlated to national measures of a culture's propensity to be uncomfortable with uncertainty.

Nevertheless, the definition of opportunity entrepreneurship may be enhanced by additional refinements. For example, implicit, but as yet not operationalized, in the definition of opportunity entrepreneurship is the notion of a new business model. All business have a business model. Most are made explicit; some are not. Many times these business models are imitations of the business models elsewhere observed. Such replications in new locations or environments are indeed new businesses, but they are not using new business models. We believe the founders of the concept of opportunity entrepreneurship had in mind not only new ventures, but new ventures with new business models. Thus, the emphasis on innovation and new combinations. However, the current measurement methodology used in GEM, while differentiating between entrepreneurship undertaken as a necessity, as opposed to entrepreneurship undertaken in recognition of an unexploited or under-exploited business opportunity, does not discriminate between using a new business model or imitating an on-going business model. That is, an individual who may be employed or self-employed in country A, while visiting country B, may notice a new successful business venture in country B, such as a Starbucks coffee store. The individual may decide to bring a similar coffee store to his home country, as none currently exists in country A. Under GEM methodology, this example will be measured as opportunity entrepreneurship. However, since it is more an imitation than the development of a new business model, we offer for consideration that it not be so classified, but rather put into a third category. We propose two categories of opportunity entrepreneurship: replica entrepreneurship and innovative entrepreneurship.

Opportunity Entrepreneurship:

    A.   Replica Entrepreneurship:

> "…an active choice to start a new venture, often in a new geographic location, imitating a business model observed in another environment, thereby taking advantage of an unexploited or under-exploited business opportunity."

    B.   Innovative Entrepreneurship:

> "… an active choice to start a new enterprise with a new business model in recognition of an unexploited or under-exploited business opportunity."

Our main reason for offering this friendly amendment to the definition of opportunity entrepreneurship lies in our belief that the notions of innovation and re-combinations (new business model), first proscribed, need to be carefully discriminated, and operationalized in future entrepreneurship research.

The following 2 by 2 matrix is proposed to further clarify a more precise definition of entrepreneurship as a dependent variable in research:

Table 1. Entrepreneurship Definitions

	Old Business Model (Copied)	New Business Model (Recombination)
Necessity entrepreneurship	Replica Necessity Entrepreneurship (very common)	Innovative Necessity Entrepreneurship (very rare)
Opportunity entrepreneurship	Replica Entrepreneurship (very common)	Innovative Entrepreneurship (rare)

Note Table 1 distinguishes entrepreneurship with new business models at both the necessity entrepreneurship level and the opportunity entrepreneurship level. Also note, necessity entrepreneurship with a new business model

(innovative necessity entrepreneurship) is, indeed, a very rare event. Nevertheless, innovative necessity entrepreneurship is a very important concept, especially in emerging economies. However, innovative necessity entrepreneurship is also a very complex dynamic, whose discussion deserves more space than we can allocate in this current discussion, which focuses upon innovative opportunity entrepreneurship.

While we believe that both types of opportunity entrepreneurship defined immediately above are key in entrepreneurship's role as an engine of economic development and prosperity, we also believe innovative entrepreneurship serves a more significant role in developing enhanced economic growth and productivity (Baumol, 2002), while replica entrepreneurship serves its greatest role in job creation and widening of the distribution of economic prosperity.

William J. Baumol (2002) has long championed the role of the Innovative Entrepreneur in economic growth. In a recent volume which Baumol co-edits with Eytan Sheshinski and Robert J Strom (2007) entitled: "Entrepreneurship, Innovation, and the Growth Mechanism of the Free-Entrepreneurship", it is argued that independent entrepreneurs are the primary source of innovative breakthroughs in the marketplace. It is further argued that the phenomenally rapid economic growth of Free-Market economies is primarily attributable to these entrepreneurial innovations partnered with the resources of high tech corporations whose large R&D budgets steadily improve upon and bring to the wider market the innovative products and processes contributed by the innovative entrepreneurs.

Therefore, we seek to consider a theory of the decision making of innovative entrepreneurs. We do so because of their apparent contribution to economic growth. And we argue that Baumol's reasoning may serve to inform this theory.

Proposition 2: Innovative Entrepreneurship plays a Significant Role in the Development of Economic Growth and Productivity.

4. Innovative Entrepreneurship and Opportunity Identification

Innovative entrepreneurship is all about recognizing an unexploited or under-exploited opportunity and deciding to create a new business model within a new enterprise designed to profit from this identified opportunity.

Timmons (1989) pointed out "that the Chinese characters for crisis and problem, when combined, mean opportunity". While this is not correct, the characters actually mean "machine" and "meet" and together mean "opportunity," but as a completely new word and not meant to reflect their additive meanings. However, this well publicized translation error has been widely diffused and indicates that both entrepreneurs and scholars associate opportunities with difficulty and the problems associated with successfully exploiting them. Say (1826) saw opportunities in terms of arranging the means of production in a way that yield value, with the profit going to the entrepreneur. This is similar to Shane's view (2003) who defines "an entrepreneurial opportunity as a situation in which a person can create a new means ends framework for recombining resources that the entrepreneur "believes will yield a profit". While Shane recognizes that profit are not always earned when entrepreneurs attempt to exploit opportunities, Kirzner (1973) sees the pure entrepreneur as one "whose entire role arises out of his alertness to hitherto unnoticed opportunities." Kirzner (1979) recognized that individuals will not always notice all opportunities and that "at any given time people will, on the one hand, be blissfully ignorant of opportunities staring them in the face; on the other hand, they will be delightedly proceeding to exploit newly noticed opportunities of which they had been unaware yesterday." Kirzner's entrepreneurs always earn an entrepreneurial profit, but they do not see every opportunity. While Kirzner (1973) sees the entrepreneur noticing opportunities because of their alertness to new information, Schumpeter (1934) saw environmental change as providing new information, which provides entrepreneurs the opportunity for combing resources in new ways that results in the creation on new industries.

Thus, it is this recombination of resources which is the heart of a new business model. And the new business model is the main characteristic which distinguishes innovative entrepreneurship from other forms of opportunity entrepreneurship.

Proposition 3: Successful Innovative Entrepreneurs are better at estimating the probability of success of a newly recognized opportunity than is the general public.

5. Innovative Entrepreneurship and Bayesian Reasoning

The fundamental argument of this paper can now be more clearly stated:

Innovative Entrepreneurship is an active choice to start a new enterprise with a new business model in recognition of unexploited or under-exploited business opportunities. And, most fundamentally, Bayesian reasoning informs a theory of innovative entrepreneurial choice.

Bayesian probability defines the concept of probability as the degree to which a person believes that a proposition is true, and that Bayes' theorem (Equation 1) can be used as a rule to update the degree of certainty or uncertainty of that belief in light of new information. It is proposed that innovative entrepreneurs are more likely to behave consistently in a Bayesian fashion than the general population. It is further proposed that the decision-making behavior of innovative entrepreneurs will more closely model the results of the application of Bayes' Theorem than that of the general population.

Please allow a simple example. This example is a fictional and over-simplified for illustration purposes. It is inspired by the innovative entrepreneurial behavior of a colleague, but is not an accurate reappraisal of all of the details and issues confronted by said colleague.

Our colleague was bedeviled by spelling when writing papers for his masters at MIT or his Ph.D. at Stanford. He often found himself sidetracked by the requirement of checking the correcting of his spelling.

Our colleague is a gifted computer software designer. In the 1970 he was aware that almost all written composition were being directly typed on PC's. Handwritten manuscripts were becoming a product of the iconoclast.

Our colleague in Schumpeterian style, associated the change in the environment with the resources available to him, and recombined those resources to produce a software application that checked the spelling of each word typed into the PC, and automatically advised the PC user of possible misspelling, conveniently offering the correct version of the word in question. This software allowed a poor speller to proceed without interruption and type out their idea, knowing that errors in spelling will later be identified and corrected.

Our colleague was pleased with his creation. It allowed him to write with the flow of his thoughts not interrupted by painstakingly consulting a dictionary each time a difficult to spell word was required by the text.

In addition to recombining resources to innovate a new product, our colleague was also proactive. He entertained the thought of resigning his professorship, moving to Silicon Valley and establishing a new venture to exploit a new opportunity he had recognized.

He recognized the opportunity to bring "spell-check" to all PC users, for a profit. But will this be a success? He reasoned in a Bayesian fashion as illustrated in the example to follow.

In this example; designed to illustrate an innovative entrepreneur using Bayesian reasoning, we follow an experiment our colleague undertook. Our colleague wished to acquire venture capital from Angel investors. He wondered how to best seek their participation. He decided that actually using the product, spell check, on their own PC, might be an important factor.

To test the idea, our colleagues asked his friends what they thought were the odds of his being able to attract an Angel investor, if the investor did or did not have an opportunity to first use spell-check. His friends estimated the following probabilities for our colleague:

$P(E \mid H_0)$ = the probability that the Angel used spell check and is willing to invest was estimated to be 0.9

$P(H_0)$ = the prior probability of an Angel to be willing to invest estimated to be 0.05

$P(\overline{H}_0)$ = the probability of an Angel not willing to invest 0.95

$P(E \mid \overline{H}_0)$ = the probability of the Angel having used spell check and is not willing to invest was estimated to be 0.5

Given these subjective probabilities from his friends our colleague intuitively estimated the probability an Angel investor will invest after he has had a chance to use spell check to be 0.1. However, most of our colleague's friends disagreed. They thought on average, that this probability was about 0.7.

What might Bayes' Theorem determine to be the probability that an Angel will invest after he has had a chance to use spell check?

From Equation 1:

$$P(H_0 \mid E) \quad = \{P(E \mid H_0)\,P(H_0)\} \,/\, P(E) \qquad\qquad (1)$$

$$= \frac{P(E \mid H_0)\,P(H_0)}{\{P(E \mid H_0)\,P(H_0) + P(E \mid \overline{H}_0)\,P(\overline{H}_0)\}} \qquad\qquad (2)$$

$$= \frac{(0.9)\,(0.05)}{(0.9)(0.05) + (0.5)(0.95)} \qquad\qquad (3)$$

$$= \frac{0.045}{(0.045) + (0.475)} \qquad\qquad (4)$$

$$= 0.0865 \qquad\qquad (5)$$

Thus, Bayes analysis predicts the posterior probability of an Angel being willing to invest after using spell check to be a little less than 1 in 10. Therefore, in this fictional illustration, we see that our colleague, the innovative entrepreneur, had assessed a posterior probability far closer to that which Bayes' Theorem yielded than did the friends of the entrepreneur:

Bayes Theorem: $p = 0.0865$

Innovative Entrepreneur: $p = 0.1$

General prediction of friends: $p = 0.7$

Our argument is not that innovative entrepreneurs are more conservative or more risky in their decision making. Rather, we argue that they are more Bayesian than the general population.

Proposition 4: Successful Innovative Entrepreneurial Decision-Making models Bayesian Reasoning.

We have proposed that successful innovative entrepreneurship 1) is decision-making under uncertainty, not risk, 2) plays a significant role in economic growth and productivity, 3) is performed by entrepreneurs who are better at estimating the probability of success of a newly recognized opportunity than is the general public and, 4) involves decision-making that models Bayesian reasoning. The following observations are offered to support these propositions.

6. Observational Studies of Angel Investors and Venture Capitalist Suggest Similarities between Bayesian Reasoning and the Reasoning of Innovative Entrepreneurs

Piaget (1971) contended that humans continually capture and maintain mental schemata of how life works through a process of acquiring, assimilating, accommodating, and adapting to experiences. Thus, decision makers, whether innovative and entrepreneurial or not, inherently rely on such schemata along with current, conscious interaction with others.

Innovation and entrepreneurship of the "opportunity" type as assessed by the Global Entrepreneurship Monitor organization (Xavier, Kelly et al. 2012) has been correlated with a diversity in mental schema, education, age (Block and Wagner 2010) and with an ability to associate and bisociate (Koestler 1964). Successful opportunity entrepreneurs may consciously surround themselves with experts to gather guidance to support, supplement, or compliment their internal schemata. Thus, the key to an entrepreneur's success appears to be 1) the scope and depth of mental schemata and 2) an ability to consciously recall and connect these past experiences. Bayesian reasoning rests on a process where schema are not only available but also ordered and prior-probability-weighted into a spatial-temporal hierarchy to support decision-making (Hawkins 2009).

It is difficult to prove that Bayesian reasoning is peculiar to individual innovative entrepreneurs without delving into physical neural processes more appropriately assessed by neural scientists. However, at the macro level of analysis, two recent behavioral changes, the use of Bayesian Network models by investors and the use of "lean start-up processes" by entrepreneurs have occurred in the world of start-up firm funding that may provide some evidence that Bayesian reasoning is operative.

The first observation is of Angel and Venture investor groups that have traditionally used simple checklists and models to screen start-up ventures. The checklist and early models used subjective weights applied to 5-25 factors to derive a simple aggregate score that became the dependent variable selection score. More recently, these models have evolved to use dynamic Bayesian multilevel networks. The dynamic multilevel design appears to better fit the thinking of investors and real world entrepreneurs. For example, one two-level model (Subramanian 2009) uses the factors; business stage, competitive landscape, funding required, sales channels, size of opportunity, and strength of

the management team at the first level and one to four sub-factors at the second level (see Figure 1). The Bayesian priors are set subjectively at both levels by expert investors through a ranking of each factor's relative importance using dyad comparisons within the specified hierarchical level. Once this relative factor ranking super matrix is calculated, a screening team of selected investors is asked to answer specific questions (one to four items per secondary-level factor in the hierarchy). The Likert-score of each sub-factor item is multiplied by the chain of conditional probabilities on the path to the goal node. A computer generated probability for the goal is the Bayesian posterior probability for the subject firm. The highest ranking firms are then selected for further consideration. Investors thereby use the described Bayesian network of expert-determined prior probabilities to screen a start-up for eligibility to present to an investor group.
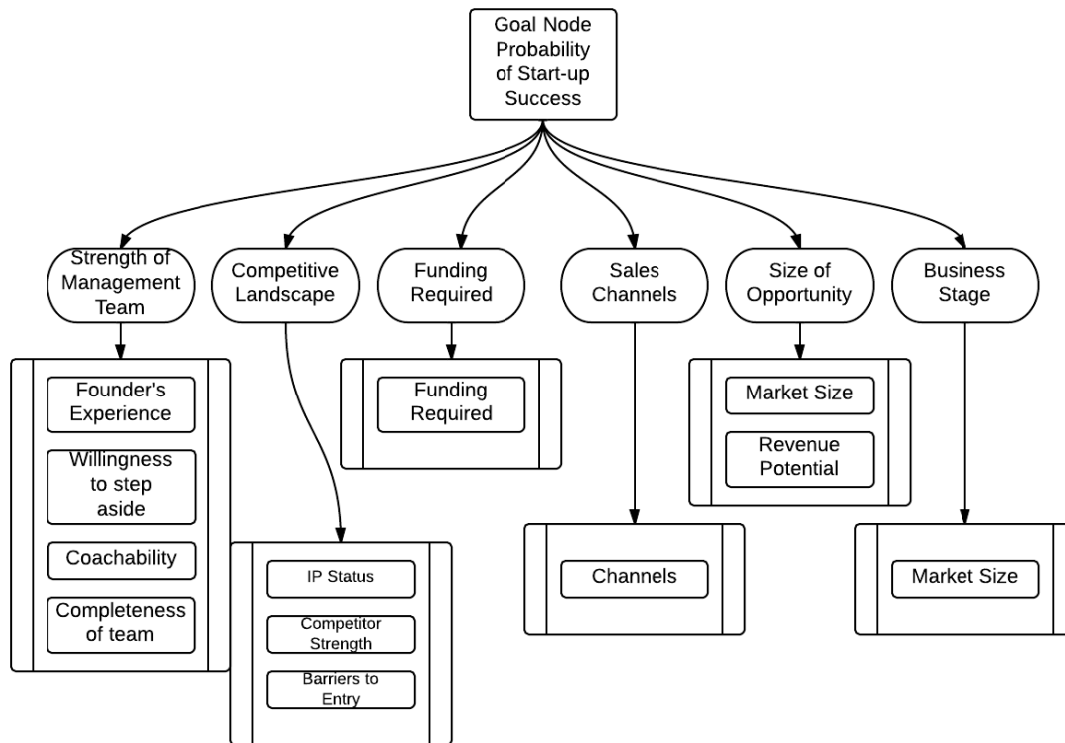

Figure 1. Structure of the Paine Bayesian Network Decision Model

Source: Derived from (Subramanian, 2009)

The statistical method utilized by investors for the first macro-observation shown in Figure 1 and described in the previous paragraph is similar to the use of a probabilistic weighted average (PWA) aggregation operator as suggested by Merigò (2012). Merigò contends that in multi-person decision-making situations the PWA operator "can unify decision-making problems under risk environment with subjective and objective information" (2012, p. 457).

A second macro observation suggests the applicability of an underlying dynamic Bayesian network process as a model for the behavior of entrepreneurs participating in the start-up funding industry. Recently, there has been a significant behavioral change by entrepreneurs that may attributed to Eric Reis's book, <u>The Lean Startup (2011)</u>. The lean start-up philosophy contrasts to the legacy "business plan" philosophy that has been traditionally taught in business schools and used by investors to evaluate entrepreneurial start-ups (Mintzberg 2007, Reis 2011, Blank 2013). The major difference between the two philosophies is in their respective planning time frames and behavioral assumptions. Whereas, the business plan philosophy assumes cause-effect determinism over a long period of development time, the lean philosophy, calls for the development of a short-term, minimally viable product with early and frequent hypotheses checks with respect to design, build, and market assumptions. The lean process resembles a Bayesian network in that early actions are tested to acquire probability of success priors that feed into determining the probability of success for later stage activities that are also communicated to and confirmed with prospects. The result of the lean, Bayesian-like process is to improve the posterior probability of success for the start-up.

The preceding two examples of Bayesian processes exercised consciously by entrepreneurs and start-up investors suggest the possible use of such mental reasoning by these individual in their tacit mental deliberations while decision-making. If one assumes that mental schema networks exist, and if a schema like that hypothesized in Figure 1 is reweighted with priors through the continuous Piaget-suggested acquire, assimilate, accommodate, and adaptation process (Piaget 1971), then the question of differentiation reduces to; How do successful, innovative entrepreneurs consciously reduce uncertainty by instantiating their subconsciously generated intuitive assessments to make better decisions. Perhaps the answer is that successful entrepreneurs (and investors) have mental schemata of such a large scope, wide diversity, and significant depth (relative to novice entrepreneurs and investors) that superior posterior probabilities are the result. Mero (2002) similarly concluded that scope, diversity, and depth of an individual's aggregate schemata in a specific domain of knowledge determined that individual's level of acknowledged expertise (2002, pp. 222-224).

But, how do superior posterior probability estimates get selected and integrated into conscious deliberations? Damasio (1999) contends that "somatic markers" reflecting the emotional importance of a schema are attached to each schema. Then when an aggregate schemata is mentally associated, autopoietic processes prioritize such thoughts into consciousness. If so, the mere scope and depth of the schemata would achieve it a relatively high marker-score. Additionally, the diversity of the schemata might raise the score due to the emotional "surprise" of a diverse schema being included in the aggregated schemata.

This section has suggested that the innovative entrepreneur uses Bayesian reasoning to excel in decision-making based on uncertain evidence. The next section relates the entrepreneurial behavior described as the "lean start-up process" in this section, to research on "effectuation" (Read and Sarasvathy 2005) that further reinforces the argument that Bayesian reasoning is used by expert innovative entrepreneurs.

7. Innovative Entrepreneurs, Bayesian Reasoning, and the Causation vs. Effectuation Issue

It has been previously argued that successful innovative entrepreneurs may use Bayesian reasoning to achieve advantage in their decision-making. However, decision-making is only a part of a mental process that some researchers describe as having an "entrepreneurial orientation" (Lumpkin 1996, Kreiser 2002, Covin 2006). Kreiser (2002) confirmed a 3-factor model for entrepreneurial orientation (EO) that reflected specific mental beliefs related to proactivity, innovation, and uncertainty acceptance). These internal beliefs along with the depth, scope, and diversity of the domain expertise related schema may serve as a prior probability basis for Bayesian reasoning. If so, then this internal process when coupled with the filtering of advice from current expert sources to appropriately adjust priors or add new relevant schema with attached priors completes the Bayesian reasoning process. This suggested mental process has been legitimized to some extent through modeling based on a theory of the mind (Baker, 2006). Baker's partially observable Markov-process-based models incorporate prior-probability-based beliefs, and rewards along with agent and environmental states to generate the posterior probability of a specific action. Additionally, Baker (2009) addresses the inverse of the forward direction posterior probability prediction process in order to recalculate specific priors based on an assumed posterior action probability. This inverse process may also be an applicable analog to the process that a Bayesian-reasoning entrepreneur uses when experiencing a failure when testing a specific product assumption on a prospect. After experiencing a failure the Bayesian-reasoning entrepreneur lowers the prior probability of the tested hypothesis as a part of the thought process used in estimating the posterior probabilities of success of future untested hypothesized actions. The practice of frequently testing product assumptions is inherent to the lean startup methodology.

A reasoning process that incorporates beliefs in addition to knowledge and more specifically beliefs about innovation, proactivity, and decision-making under uncertainty introduces an action dimension to the cognitive decision-making process. Sarasvathy (2001) has bifurcated this action dimension into entrepreneurs who believe in causal action and entrepreneurs who tend to "effectuate" (intuition based action). She defines the causal action group as those who primarily rely on proven methods like business plans, discounted cash value methods, decision tree models, and even, static Bayesian network models. Whereas, she defines effectuators as those who act in a "…seat-of-the-pants and tentative…" manner. (2001, p. 246) Sarasvathy argues that causation rests on a logic of prediction, effectuation on the logic of control. She emphasizes this by saying that the use of causation rests on a belief that "...to the extent we can predict the future, we can control it." as contrasted with the effectuators belief that "…to the extent we can control the future, we do not need to predict it" (2001, p. 251).

Sarasvathy conducted an experiment to test her hypothesis that expert entrepreneurs performed more intuitively than non-experts (Sarasvathy, Dew, Read, & Wiltbank, 2007). A group of 37 MBA students (non-experts) and 27 successful entrepreneurs (experts) were given a task to startup a new firm and the subjects were interviewed. Their

thoughts on how they completed the task were subjected to a protocol analysis to determine their relative use of causal versus effectuation-oriented processes. The results showed that expert entrepreneurs were more inclined to use effectual methods. These results were somewhat moderated by the amount of resources available to the subject as novice subjects with more resource were found to be more effectual than novice subjects without such resources. Resources were defined means available as a result of who you are, what you know, and whom you know. Figure 2 depicts the proposed relationship between reasoning strategy and entrepreneurial experience (Read & Sarasvathy, 2005, p. 57).
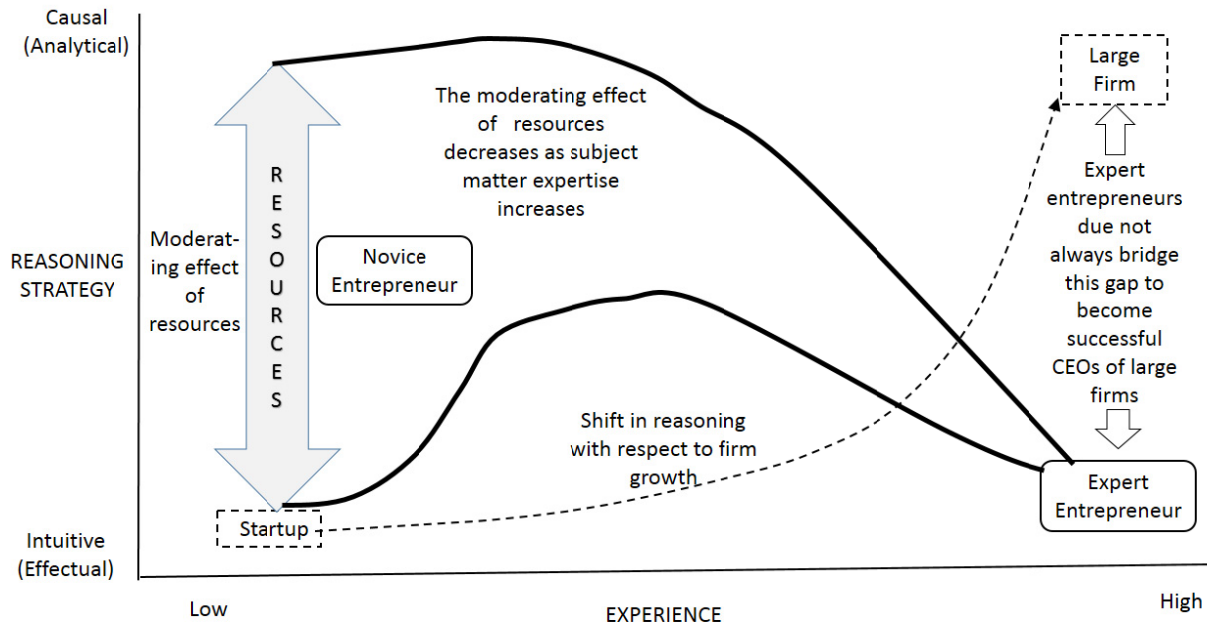

Figure 2. Reasoning Strategy versus Entrepreneurial Experience

Source: Adapted from (Read & Sarasvathy, 2005, p. 57)

Sarasvathy's finding that the degree of effectuation applied is moderated by an individual's available means is of special importance to the argument that expert, innovative entrepreneurs use Bayesian reasoning. It appears reasonable to assume that novice entrepreneurs with few means available (knowledge, network, financial resources) use their intuition and effectuative methods to overcome obstacles that entrepreneurs with greater means might resolve using causal tools and planning methods. However, why would expert entrepreneurs also use intuition and effectuation to build their businesses? The answer, as suggested from Sarasvathy's research and from observations of expert entrepreneurs by the authors of this paper, appears to arise from the confidence that an expert entrepreneur derives from serial attempts at starting a new firm. This confidence may be a result of the numerous and varied experience-provided and honed mental schema that underpin the expert entrepreneur's Bayesian reasoning processes.

Courtney (2013) recently touched on the issue of available means by proscribing five protocols for decision-making when faced with uncertainty in causative model design and outcomes. Specifically, Courtney noted that in cases where both the causative model and the outcomes were uncertain (in the Knightian sense), case-based decision analysis should be used. "Case-based decision making provides a structured framework for synthesizing information from multiple analogous experiences and examples" (p.68). This definition suggests a similarity between the causally oriented use of the Courtney suggested "case-based method of analysis" and the alternative use by innovative entrepreneurs of Bayesian reasoning using mental schemata followed by the effectuator-prone actions of expert innovative entrepreneurs suggested by Sarasvathy.

This section has added a belief dimension to the previously addressed knowledge dimension of entrepreneurial reasoning. An entrepreneur's unique orientation towards decision-making under uncertainty, proactivity, and innovation may have a significant impact on decisions made by the entrepreneur and the probability of success. Causal reasoning using deterministic tools with limited inputs and a limited number of functional variables may not be adequate to account for the success of decision-making in entrepreneurial growth ventures. Achieving such

successes would appear to require a more flexible, extensively mental capacity that could be hypothesized as Bayesian-based reasoning.

8. Conclusion

This paper seeks to demonstrate the important role that Bayes' reasoning may serve in informing the development of a theory of innovative entrepreneurial knowledge creation through recombination of resources in response to new information from the environment. The style of reasoning of the Bayesian approach, in which posterior probabilities are rigorously and continuously updated given new data, appears to model the observed decision behavior of innovative entrepreneurs. Disciplined intuitive implementation of Bayesian reasoning may help us understand how and why innovative entrepreneurs may be better at estimating the probabilities of success of newly recognized opportunity than the general public. Because innovative entrepreneurs play an important in the development of economic growth and productivity, it is worthwhile to explore the role the philosophy and methodology of Bayesian reasoning may play during the knowledge creation of innovative entrepreneurs in confirming their new recombination of ideas.

Organizational research through observational studies of entrepreneurial behavior appear to support the idea that Bayesian reasoning plays a significant role in successful innovative entrepreneurial knowledge creation through the recombination of ideas inspired by new data. Bayesian statistics and probability bring with it a style of reasoning and practices which appear to be an excellent model with which organizational researchers may come to better understand the dynamics of successful entrepreneurial knowledge creation, problem-solving, decision-making, and solution-implementation.

9. Limitations and Future Research

This paper has as its goal the initiation of a conversation among scholars of the field of Entrepreneurship Research. The basic tenet of this paper is that the concept of entrepreneurship is so broadly defined that it encompasses any and all initiations of any entrepreneur. As such, the broad concept of entrepreneurship defies scholarly convergence toward a model of problem-solving, decision-making, and implementation processes creating the act of entrepreneurial behavior. We have limited our focus to a narrow, albeit significant, sub-field of entrepreneurship: innovative opportunity entrepreneurship. In this focused area, we have argued that the ontological and epistemological tenets of Bayesian Reasoning may inform theory development and knowledge creation in entrepreneurial research in general and in innovative opportunity entrepreneurial research in particular.

In doing so, it is our hope that other scholars of entrepreneurship research consider these ideas; question them; and enhance the validity of these ideas through their own future research initiatives. Toward that end, we propose the following queries for future research:

1) How may we refine our measurements of necessity and opportunity entrepreneurship to be able to measure the concepts of innovative opportunity entrepreneurship and innovative necessity entrepreneurship?

2) Is it possible to further explore the "causation vs. effectuation" issue highlighted by the work of Sarasvathy, et.al. (ibid, 2001, 2007) through bifurcation of the innovative opportunity entrepreneurship process into a "creative problem-solving/ decision-making" phase and into a creative "implementation" phase? Always acknowledging that these two phases of innovative opportunity entrepreneurship are interactive and not necessarily sequential (What's Past is Prologue---Shakespeare).

We will be delighted to participate in future discussions with scholars of entrepreneurial research on these and related issues.

References

Acs, Z. J. (2006, Winter). How is Entrepreneurship Good for Economic Growth? *Innovations, 1*(1), 97-107. http://dx.doi.org/10.1162/itgg.2006.1.1.97

Acs, Z. J., & Audretsch, D. B. (2010). *Handbook of Entrepreneurship Research* (2nd ed.). New York: Springer. http://dx.doi.org/10.1007/978-1-4419-1191-9

Acs, Z. J., & Varga, A. (2005). Entreprenurship, Agglomeration and Technological Change. *Small Business Management, 24*(3), 323-334. http://dx.doi.org/10.1007/s11187-005-1998-4

Acs, Z. J., Aremius, P., M., H., & Minniti, M. (2004). *GEM: Executive Report.* London Business School, Babson College.

Baumol, Sheshinski, E., & Strom, R. J. (2007). *Entrepreneurship, Innovation, and the Growth Mechanism of the*

Free-Entrepreneurship.

Baumol, W. J. (2002). *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism.* Princeton, N.J.: Princeton University Press.

Bernstein, P. L. (1996). *Against the Gods: The Remarkable Story of Risk.* New York: John Wiley & Sons.

Blank, S. (2013). Why the lean startup changes everything. *Harvard Business Review*(May).

Block, J. H., & Wagner, M. (2010, June 1). Opportunity Recognition and Exploitation By Necessity and Opportunity Entrepreneurs: Empirical Evidence from Earnings Equations. *Schmalenbach Business Review* 62(4): 154-174.

Cantillion, R. (1775). *An Essay on Economic Theory* (2010 ed.). (M. Thornton, Trans.) Auburn, Alabama: Miser Institute.

Covin, J. G. (2006). Strategic process effects on the entrepreneurial orientation–sales growth rate relationship. *Entrepreneurship Theory & Practice (January)*, 57-81. http://dx.doi.org/10.1111/j.1540-6520.2006.00110.x

Damasio, A. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness.* San Diego, CA: Harcourt, Inc.

Doktor, R., et al. (2007). Cross-cultural aspects of entrepreneurship and uncertainty avoidance. Silicon Valley Global Entrepreneurship Research Conference, Nikko Hotel, San Francisco, University of San Francisco, School of Business and Management.

Galunic, C., & Rodan, S. (1997). *Resource Recombinations in the Firm: Knowledge Structures and the Potential for Schumpeter Innovation.* Fountainbleu: INSEAD.

Hawkins, J. (2009). *Hierarchical temporal memory: Concepts, theory, and terminology.* Redwood City, CA: Numenta, Inc.

Hayak, F. A. (1945). The Use of Knowledge in Society. *American Economic Review, 35*(September), 319-530.

Kirzner, I. M. (1973). *Competition and Entrepreneurship.* Chicago: University of Chicago Press.

Kirzner, I. M. (1979). *Perception, Opportunity, and Profit.* Chicago: University of Chicago Press.

Kirzner, I. M. (1985). *Discovery and the Capitalist Process.* Chicago: University of Chicago Press.

Kirzner, I. M. (1989). *Discovery, Capitalism, and Distributed Justice.* Oxford: Basil Blackwell.

Knight. (1921). *Risk, Uncertainty, and Profit.* Boston, MA.: Houghton Mifflin.

Koestler, A. (1964). *The Act of Creation.* London, Atlanta: Penguin Group.

Kreiser, P. M. (2002). Assessing the psychometric properties of the entrepreneurial orientation scale: A multi-country analysis. *Entrepreneurship Theory & Practice (Summer)*, 71-94.

Lambing, P. A., & Kuehl, K. R. (2007). *Entrepreneurship* (4th ed.). Englewood Cliffs, New Jersey: Printice Hall.

Lumpkin, G. T. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *Academy of Management Review, 21*(1), 135-172.

Mariotti, S. (2007). *Entrepreneurship: How to Start and Operate a Small Business* (2nd ed.). Englewood Cliffs, New Jersey: Prentice Hall.

McMullen, J. S., Plummer, L. A., & Acs, Z. J. (2007). What is Entrepreneurial Opportunity? *Small Business Management, 28*(4), 273-283. http://dx.doi.org/10.1007/s11187-006-9040-z

Menger, C. (1950). *Principles of Economics.* New York: Free Press.

Merigò, J. M. (1012). "The Probabilistic Weighted Average and its Application in Multiperson Decision Making." *International Journal of Intelligent Systems* 27: 457-476. Available at wileyonlinelibrary.com, DOI 10.100/int.21531

Mero, L. (2002). *Die Grenzen der Vernuft: Kognition, Intuition, und kimplexes Denken.* Reinbech bei Hamburg: Rowohlt Taschenbuch Verlag Gmbh.

Mintzberg, H. (2007). *Managers, not MBAs.* San Francisco: Berret-Koehler Publishers, Inc.

Morris, M. H., Lewis, P. S., & Sexton, D. L. (1994). Reconceptualizing Entrepreneurship: An Input-Output Perspective. *Srtm Advanced Management Journal, Winter*, 29-30.

Piaget, J. (1971). *Biology and Knowledge: an essay on the relations between organic regulations and cognitive*

processes. Chicago: University of Chicago Press.

Read, S., & Sarasvathy, S. D. (2005). Knowing what to do and doing what you know: Effectuation as a form of entrepreneurial expertise. *Journal of Private Equity, 9*(1), 45-62. http://dx.doi.org/10.3905/jpe.2005.605370

Reis, E. (2011). *The Lean Startup.* New York: Crown Business.

Sarasvathy, S. D. (2001). Causation and Effectuation: Toward a Theoretical Shift from Economic Inevitability to Entrepreneurial Contingency. *Academy of Management Review*, 243-263.

Sarasvathy, S. D. (2005). Entrepreneurial Expertice. In M. A. Hitt, & R. D. Ireland (Eds.), *Blackwell Encyclopedia of Management.* Oxford: Blackwell Publishers Ltd.

Sarasvathy, S. D., Dew, N., Read, S., & Wiltbank, R. (2007). *Effectual Entrepreneurial Expertise: Existance and Bounds.* Marion Kauffman Foundation.

Say, J. B. (1826). *Truite d'Economie Politique* (5th ed.). Paris: Chez Rapilly.

Schumpeter. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle.* (R. Opie, Trans.) New Brunswick: Transaction Publishers.

Shane, S. A. (2003). *A General Theory of Entrepreneurship: The Individual-Opportunity Nexus.* Cheltenham Glos, UK: Edward Elgar Publishing. http://dx.doi.org/10.4337/9781781007990

Subramanian, A. (2009). *The Paine Investor Model: A dynamic Bayesian network process using SuperDecision software.* Atlanta: Angel Capital Association.

Timmons, J. A. (1989). *The Entrepreneurial Mind.* Baltimore: Brick House Publishing.

Xavier, S. R., Kelly, D., Kew, J., Herrington, M., & Vorderwulbeche, A. (2012). *Global Entrepreneurship Monitor 2012 Global Report.* Global Entrepreneurship Research Association.