

Using Integrative Propositional Analysis for Evaluating Entrepreneurship Theories

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Abstract

Previous studies have noted a proliferation of disparate theories of entrepreneurship. This makes it difficult to find the best theory for application in teaching, practice, and research. Choosing the right entrepreneurship theories to teach and encourage is critical to providing entrepreneurs with the knowledge they need to succeed. Scholars have recommended integrating entrepreneurship theories across disciplines and across practice; however, rigorous methods to assess and integrate the best theories are lacking. Integrative propositional analysis is an emerging method to assess and improve theories using the theory structure as data, rather than relying on empirical data and opinion alone. This exploratory study pilot tested this approach with a sample of nine entrepreneurship theories. Several insights emerged that entrepreneurship researchers, educators, and practitioners can use to synthesize and improve theories for their specific needs and to collaboratively integrate the best theories from research and experience to create better theories.

Keywords

business management, theories, complexity, models, business administration, curriculum, entrepreneurship/small business, research methodology and design, research methods

Toward More Connected and Useful Entrepreneurship Theories

A U.S. Association for Small Business and Entrepreneurship (USASBE) white paper found a proliferation of disparate theories within studies and textbooks on entrepreneurship and small business, with little agreement about the cornerstones of entrepreneurship or what to teach (Solomon, 2006). Textbooks presented “divergent opinions and views as to who these entrepreneurs really are” (p. 27). Some sources presented entrepreneurs as those who start ventures, generally small businesses. Others portrayed entrepreneurship as about controlling one’s destiny, being creative and innovative, dealing with ambiguity, marshaling resources, creating teams and generating wealth, or being involved with growth ventures. More recently, a *Forbes* article (Furr, 2011) reported that business schools struggle to teach entrepreneurship in part because “large firm theories became theories of entrepreneurship.”

Similarly, business publications have noted the lack of agreement on what entrepreneurship means. A 2012 *Inc.com* article by Schurenberg argued for a definition conceived of 37 years ago¹: “Entrepreneurship is the pursuit of opportunity without regard to resources currently controlled.” A 2012 *Forbes* article by Nelson defined entrepreneurs as “those who identify a need—any need—and fill it.” The author contrasted this with a *Merriam-Webster Dictionary*

definition of “entrepreneur” as “one who organizes, manages and assumes the risks of a business or enterprise.”

For this article, we systematically analyzed and compared a sample of theories, or models, of entrepreneurship from the research literature. The terms *theory* and *model* can mean different things, generally referring to a “conceptual construct” or a “set of interrelated propositions . . . that is useful for engaging the world” (Wallis & Harris, 2013). Many other terms can also describe a theory or model, such as a *lens*, *assumptions*, *conceptual framework*, or *logic model* (Wallis, 2010b; Wallis & Harris, 2013).

The choice of which entrepreneurship theories to teach and encourage is important for many reasons. As the USASBE white paper (Solomon, 2006) discussed, the study and teaching of both small business management and entrepreneurship are vital to the nation’s economic growth and stability. Teaching should provide both small business managers and entrepreneurs with the knowledge they need to succeed. Problems such as the collapse of Enron have heightened

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questions about whether schools are teaching the right business theories.

Scholars have noted the need to integrate theories across disciplines, across the “supply” and “demand” sides of entrepreneurship, and across levels of analysis (e.g., individual, organizational, market, and environmental levels; Thornton, 1999, pp. 20-21). Studies have also recommended coordinating entrepreneurship theories across research, education, and practice.

Past studies have suggested several potential approaches to achieving this integration. The USASBE white paper (Solomon, 2006) recommended curriculum changes to make teaching more consistent with the literature, such as spending more time on marketing, creativity, and innovation and less time on creating business plans. The paper also argued for increased use of teaching methods that incorporate the realities in which entrepreneurs operate. Kearins, Luke, and Corner (2004) recommended changes to entrepreneur awards programs so that they would more equally emphasize elements of entrepreneurial success emerging from theories. A challenge to making these changes is that the fragmentation of theories makes it difficult to find relevant theories and choose the best ones to teach and apply.

Method

At the USASBE 2013 Conference in San Francisco, Wallis and Harris introduced an innovative method to rigorously evaluate and integrate entrepreneurship theories to create better theories, integrative propositional analysis (IPA). Building on their presentation, this analysis pilot tested the use of IPA to systematically evaluate nine sample entrepreneurship theories. A pilot test (or pilot case study) of a novel process can provide insights and lessons learned that researchers can use to plan research designs and procedures (Yin, 1994).

IPA

IPA is an emerging method to analyze and integrate sets of propositions (theories) stated in a study, strategic plan, or other document. IPA draws on a long research stream on integrative complexity, complexity theory, and systems thinking (Wallis, 2015). Research on integrative complexity dates back to the late 1950s and has focused on measuring the inter-connectedness of understanding of a topic, as found in text and other communications (Suedfeld & Tetlock, 1977). A list of related readings is provided at <http://project-fast.org/resources-for-researchers/reading-list/>. This scholarship indicates that we can develop more useful theories, mental models, and other conceptual systems by understanding their structure and making it more systemic (inter-connected). This reflects the idea that greater inter-connectedness among a theory’s concepts provides a more complete understanding of reality, because the real world is inter-connected.

For example, Curseu, Schalk, and Schruijer (2010) used integrative complexity to investigate how students understood the concepts presented in a course over the semester. Students with a better understanding of a systemic relationship between the concepts scored higher on their papers than students with less systemic understanding. In related conceptual work, Rogers (2008) drew on complexity theory to develop an approach to creating logic models for program evaluation that privileged complex causal structures and reinforcing loops. These more complex and inter-connected logic models were designed to support dialog within and among organizations.

IPA extends this research stream by applying a new approach to quantitatively and qualitatively measure the inter-connectedness among concepts found within theories. IPA also complements the usual approaches of assessing theories based on empirical data and stakeholder and expert consensus (Wallis, 2011). IPA adds rigorous understanding of the internal logics of the theory, using existing theories as data (Wallis, 2010a). One might think of IPA as an “x-ray view” into the structure of a theory. This reflects the view, drawing on the works of Popper, that scientifically validating and strengthening a theory involves three aspects: empirical data, meaning, and the internal logics of the theory structure (Wallis, 2008). Combining findings on a theory’s structure (e.g., IPA) with findings on its usefulness to experts and stakeholders (e.g., discussions, literature citations) and empirical data (e.g., evidence-based management, meta-analysis) provides a way to rigorously assess theories before they are carried out. This is especially important in some situations, such as when making decisions about large financial investments or actions that could significantly affect people’s lives (Wallis, 2011, pp. 94-95).

IPA involves six steps (Wallis, 2013):

1. Find the logical statements/propositions in a theory (found in a publication).
2. Diagram the propositions (a box for each concept/term, an arrow for each causal link).
3. Combine those smaller diagrams where they overlap to create a larger diagram.
4. Count the number of concepts with two or more causes (“concatenated” concepts).
5. Count the total number of concepts in the theory (“Complexity”).
6. Divide concatenated concepts by total concepts to assess “Systemicity.”

The systemicity score computed in the final step is a key measure of causal inter-relatedness in IPA. The greater the proportion of concepts in a theory that are concatenated, the more the theory’s concepts are causally interrelated (Wallis, 2013). On one end, a disconnected list of truth claims with no causal explanations would have zero systemicity, as the concepts would be disconnected from each other. A linear, deterministic

theory, such as “More A causes more B causes less C,” would also have a systemicity of zero, because each concept would have only one cause.

In previous studies across diverse fields in the physical and social sciences, paradigm-changing scientific theories have shown greater systemicity (inter-connectedness among concepts) than earlier, less successful scientific theories (Wallis 2010a). Examples of revolutionary, high-systemicity theories include Coulomb’s theory of electrostatic attraction,² Newton’s theory of mechanical motion,³ Einstein’s theory of special relativity,⁴ and Ohm’s law.⁵ Each of these theories has the highest possible systemicity score of 1.0, because each theory has three concepts, where each concept is explained by the other two concepts in the theory (3 total concepts divided by 3 concatenated concepts = 1.0).

Compared with theory development in the physical sciences, in current management theories and in other social science research, progress in moving toward highly systemic theories that advance a field has been slower. IPA analyses of theories from these fields have found low systemicity scores. These studies used IPA to gain insights to help improve research and strategic decision making. For example, an analysis of three objectives of the USAID/PERU Country Development Cooperation Strategy used IPA to surface previously hidden strengths and weaknesses of the models and clarify directions for improving policy (Wallis, under submission). An analysis of two drug policy models showed how the model with greater systemicity could better support collaboration among stakeholders in identifying measurable results, because each indicator was linked to multiple other indicators (Wallis, 2010b). A bibliography of this IPA research is available at <http://projectfast.org/category/research/articles/>.

Searching and Selecting Sample Entrepreneurship Theories

For this pilot study, we selected nine sample theories from papers with a stated purpose of providing a new theory of entrepreneurship to serve as a framework for use in research, in the classroom, or both. We chose on a small number of theories to test this new process through in-depth analysis of each theory, drawing on a convenience sample of academic papers known to the authors. Convenience and access are generally acceptable as main criteria for selecting cases for a pilot study, to observe cases from many angles or trial test new approaches (Yin, 1994).

From this collection of studies, we purposefully selected the nine included studies to represent diverse disciplines, use of diverse methods develop and test the theories, and diverse definitions of entrepreneurship. This “maximum variation cases” approach let us explore the potential importance of theory variations (Flyvbjerg, 2006). Of the sample studies we reviewed, three described entrepreneurship as about self-employment or starting a new business (Acs, Braunerhjelm, Audretsch, & Carlsson, 2009; Holmes & Schmitz, 1990; Verheul, Wennekers,

Audretsch, & Thurik, 2001). For example, Acs et al. (2009) used percentage of the labor force who are self-employed as a measure of entrepreneurship in a country. Casson (2005), in contrast, stated that a “prevalent misconception” is that entrepreneurship is about self-employment. Casson identified “specialization in judgmental decision-making” as “the defining characteristic of the entrepreneur.” Similarly, Alvarez and Busenitz (2001) contended that entrepreneurs have a unique mind-set of “entrepreneurial cognition.” Zahra (1993) addressed “firm entrepreneurship,” defined in the study as proactive, risk taking, and innovative firm activity. Others focused on social entrepreneurship (Murphy & Coombes, 2009; Shockley & Frank, 2010).

Review of the Selected Studies’ Methods and Citations

We reviewed the selected studies for descriptions of the methods and data they used to develop and test their theories. In addition, as an indicator of how often an article had been read, we examined the number of citations for each study, using Google Scholar™, a widely used resource for citation statistics. Because more recent studies have had less time to be cited, we also calculated cites by year. Table 1 summarizes this information. Next, we applied IPA to each of the studies, as detailed below.

IPA Step 1: Identify Logical Statements (“Propositions”) Within Theories

The first step in applying IPA was to identify the logical statements (“propositions”) within each theory. The included studies varied in how concisely or ambiguously they presented the propositions inherent to their theories. At one end, two of the studies provided clear visual diagrams of their frameworks (Verheul et al., 2001, Figure 1, p. 8, and Figure 2, p. 10; Zahra, 1993, Figure 1, p. 13). In these situations, we used the propositions shown in the figures for our analysis. In other studies, we found propositions explicitly listed in a set of “predictions” (Acs et al., 2009, p. 17) or “theoretical propositions” (Murphy & Coombes, 2009, Table 2, p. 333). In the other studies, authors discussed their theories in narrative text, and the abstracts did not specify all the propositions of the theory. In these cases, we selected sections of text that detailed the theories. For example, for Holmes and Schmitz’s (1990) article, we used a section on “Brief Description of the Theory and Its Implications” (pp. 266-267).

IPA Step 2: Diagram the Causal Relationships Among Concepts Within the Propositions

The next IPA step was to diagram the causal relationships among concepts within the propositions found in Step 1. This involved drawing one box for each concept and arrows to indicate directions of causal effects. A “concept” is a cause or

Table 1. Data, Citations, and IPA Results for Sample Entrepreneurship Theories.

Study	Data used to develop/test theory	No. of cites; cites/year	Complexity (C); systemicity (S) ^a
Verheul, Wennekers, Audretsch, and Thurik (2001)	Literature on country- and individual-level entrepreneurship from multiple fields; employment data for 23 OECD countries	218; 18	C = 15, S = 0.40
Casson (2005)	Economic and managerial literature on entrepreneurship	277; 35	C = 26, S = 0.38
Acs, Braunerhjelm, Audretsch, and Carlsson (2009)	Regression analysis, employment data from 19 OECD countries	440; 110	C = 4, S = 0.25
Holmes and Schmitz (1990)	Schultz and other theories; model using data on U.S. business transfers in 1940s and 1950s	325; 14	C = 13, S = 0.23
Alvarez and Busenitz (2001)	Resource-based theory, other literature	984; 82	C = 48, S = 0.25
Zahra (1993)	Covin and Slevin model, other literature	440; 22	C = 5, S = 0.20
Shockley and Frank (2010)	Schumpeter, Kirzner theories; epic poem	4; 1	C = 7, S = 0.14
Kearins, Luke, and Corner (2004)	Classic and recent literature; case study of an entrepreneur awards contest	4; 0.4	C = 10, S = 0.10
Murphy and Coombes (2009)	Literature on social responsibility and social entrepreneurship	65; 13	C = 9, S = 0

Note. IPA = integrative propositional analysis; OECD = Organisation for Economic Co-Operation and Development.

^aComplexity = total number of concepts. Systemicity = number of concepts that are concatenated (have more than one causal concept) divided by the total number of concepts.

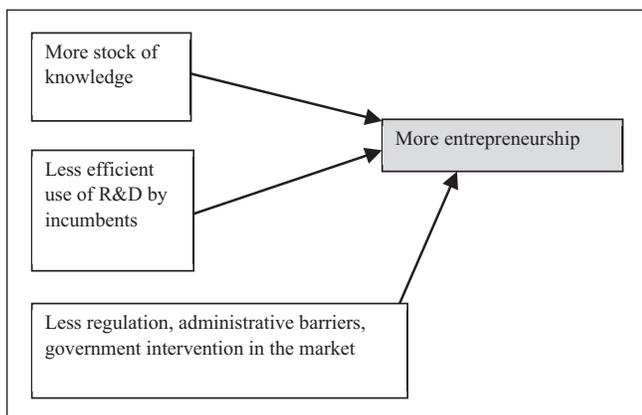


Figure 1. Diagram for Acs, Braunerhjelm, Audretsch, and Carlsson's (2009) "Knowledge Spillover Theory of Entrepreneurship."

Note. Complexity (total number of concepts) = 4, systemicity (number of concatenated concepts divided by total concepts) = 0.25 (concatenated concept shaded).

effect mentioned in the proposition. For example, Acs et al.'s (2009) "knowledge spillover theory of entrepreneurship" included the statement (proposition), "An increase in the stock of knowledge has a positive effect on the level of entrepreneurship" (p. 17). We diagrammed this as two concepts with an arrow to show causation: "More stock of knowledge → More entrepreneurship." We sometimes shortened text for space, but were careful to diagram what the writings explicitly stated. We avoided speculating on what we thought the authors "meant to say." Ritzer (1990) supported this approach, arguing that meta-theorizing should always strive to use the original authors' wording.

Some propositions contained multiple causal relationships. For example, Holmes and Schmitz's (1990) theory of entrepreneurship that they applied to business transfers included the statement, ". . . Numerous studies have shown that entrepreneurial ability can be enhanced through experience, training, schooling, and improvements in health (these studies are reviewed in Schultz [1975, 1980, 1989]) . . ." We diagrammed this as four propositions:

More experience → More entrepreneurial ability

More health → More entrepreneurial ability

More schooling → More entrepreneurial ability

More training → More entrepreneurial ability

Some propositions identified something as true or important, but did not specify any causal relationships. For example, Kearins et al. (2004, pp. 51, 52) stated, "Legal compliance and ethics, as the New Zealand case example demonstrates, warrant separate consideration as an important aspect of successful entrepreneurship. . . ." We diagrammed this concept as a stand-alone box (no arrows leading to or away from it) with the text, "More legal compliance and ethics."

Some theories included broader concepts overarching a set of specific concepts. For example, Verheul et al.'s (2001) theory included a broad concept of government policies, along with five specific types of government policies, namely, "G1" (regulation), "G2" (fiscal incentives), "G3" (labor, finance, and information policies), "G4" (government fostering of entrepreneurial culture), and "G5" (fiscal incentives). We drew G1 to G5 as five concepts (one box for each),

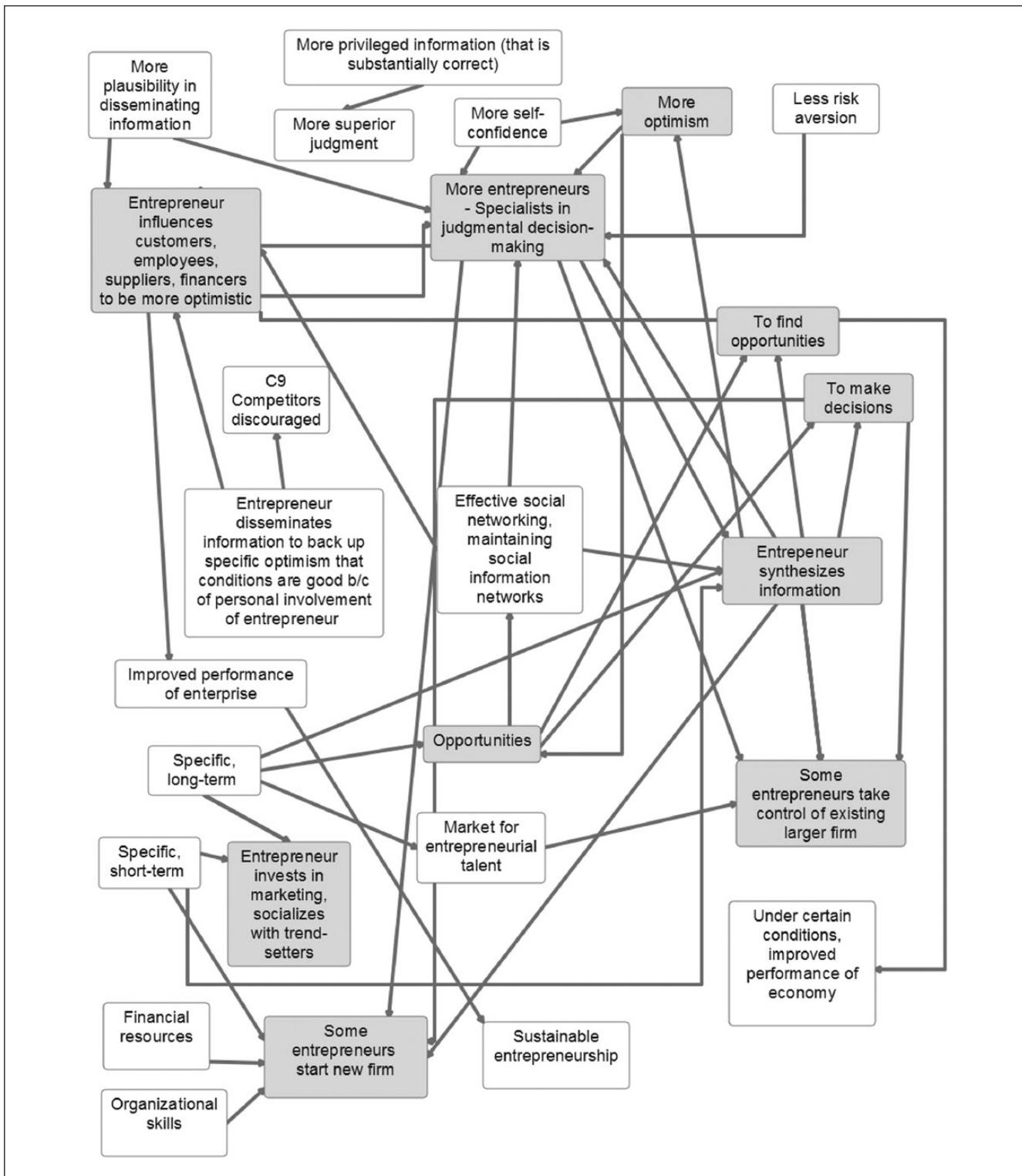


Figure 2. Diagram for Casson (2005), entrepreneurship of resource-based theory. Note. Complexity (total number of concepts) = 26, systemicity (number of concatenated concepts divided by total concepts) = 0.38 (concatenated concepts shaded).

then grouped these concepts together inside a larger box for the overarching concept of “Government Policy.” Thus, this diagram actually contained two diagrams: a larger diagram

showing the group concept and a more detailed diagram inside the larger diagram showing the specific concepts. This is similar to a regional map book that includes an overview

map of the major highways and cities in the region, along with detailed maps showing all the streets.

IPA Step 3: Combine Overlapping Small Diagrams Into a Large Diagram of Each Theory

Next, we linked the small diagrams created in Step 2 to create a larger, integrated diagram for each theory. We merged similar concepts from within each theory when authors used synonyms to refer to the same idea (e.g., “entrepreneurial activity” and “entrepreneurship”). Figures 1 and 2 show the complete diagrams for two theories. These diagrams serve as examples; diagrams for all of the theories are not shown due to space constraint.⁶

IPA Step 4: Count the Total Number of Concepts to Determine Theory Complexity

The next step was to count the total number of concepts (boxes) within each large diagram created in Step 3, to find the theory’s complexity (Wallis & Harris, 2013).

IPA Step 5: Identify and Count Concepts With 2+ Causes (“Concatenated” Concepts)

Next, we counted how many concepts were *concatenated*, an IPA term used to mean a concept that is explained by more than one other concept in the theory (Wallis, 2013). These concepts are more strongly explained than concepts with zero causes or with one cause. As an abstract example, if changes in A and changes in B will cause changes in C, then C is a concatenated concept. As a concrete example, in the Holmes and Schmitz (1990) study, the concept “entrepreneurial ability” is concatenated, because the theory specifies four things that can cause more entrepreneurial ability: (a) more experience, (b) more health, (c) more schooling, and (d) more training.

IPA Step 6: Calculate Theory Systemicity

The final IPA step was to calculate each theory’s systemicity, a measure of inter-connectedness of a theory derived by dividing the number of concatenated concepts from Step 5 by the total number of concepts determined in Step 4. This results in a number ranging from zero (least systemicity) to one (most systemicity). For example, Acs et al.’s 2009 theory (see Figure 1) contains four concepts, of which one is concatenated, resulting in a systemicity score of 0.25 (1 divided by 4).

Recording and Checking Data and Results

We created tables of propositions, in the form of Microsoft Excel workbooks, to record study information and IPA results, with one table for each theory.⁷ Each table captured the following data elements:

1. Theory propositions and the pages and sections or the figures where we found each proposition in the study (from IPA Step 1)
2. Small diagrams of each causal relationship stated in the proposition (from IPA Step 2)
3. Any notes or questions pertaining to the proposition or how to diagram it

This information guided our work to create the larger diagrams used in the rest of the IPA analysis and check the accuracy of our results. To test inter-reviewer reliability in identifying propositions, concepts, and causal relationships, both study authors reviewed results for the nine studies. We discussed and resolved questions and differences, leading to agreement.

Results

Table 1 synthesizes findings from the metatheory analysis (IPA), along with description of the empirical data the studies used to create and test their theories and citation data. This provides a way to assess how much each theory is supported by all three aspects of validity: data, meaning, and theory structure. As shown in Table 1, the number of concepts (complexity) in the nine theories in our data set ranged from 4 to 48. Systemicity ranged from 0 to 0.40. This range of systemicity is consistent with IPA results for other theories in the social sciences (Wallis, 2011).

Discussion and Ideas for Research and Practice

Results of this exploratory study highlight several insights for research and practice.

Ideas to Further Test and Improve the IPA Method With Entrepreneurship Theories

One interesting observation is that, of the theories in our sample, those scoring highest in systemicity were from studies that created integrated theories from broad sources. The two highest systemicity theories were Verheul et al.’s (2001) “eclectic theory of entrepreneurship” (systemicity = 0.40) and Casson’s (2005) “synthetic theory of the firm” (systemicity = 0.38). Verheul et al. developed their theory from disparate strands of the literature across the country level and individual level of analysis and across the disciplines of economics, psychology, and sociology. Similarly, Casson’s theory was developed by combining insights from managerial and economic perspectives. This suggests a potential benefit of synthesizing theories across disciplines, a process that IPA can facilitate. Another interesting observation is that theories scoring lower in systemicity appeared to be less frequently cited. The three lowest systemicity theories had the fewest cites and the fewest cites per year. This suggests that scholars might want to strive to create more inter-connected theories,

so that they will be more highly cited. Future studies could explore these possible trends with more publications.

As IPA is in its early stage of development and this is the first study to apply it to entrepreneurship theories, opportunities exist to build on this analysis and improve the method. Extending this study to include a larger sample of theories would improve its validity and usefulness by capturing a greater range of data from the published theories.

Other scholars might repeat this analysis to determine if they achieve substantially similar results. That kind of study would provide an indication of the extent to which different raters find the same concepts and causal relationships when reviewing the same theories. In cases where the phrasing of concepts was convoluted, sending a draft to the study authors might prove useful, asking “Is this what you meant?” An idea for theory authors is to provide diagrams or concise statements of their theories, to make them more amenable to rigorous meta-theoretical analysis.

Ideas for Using IPA to Evaluate, Select, and Improve Individual Theories

Looking at IPA results for an individual theory can stimulate insights for researchers and practitioners as they assess and improve the theories. The number of concepts (complexity) provides a measure of the theory’s breadth. Figure 1 shows a low complexity theory (four concepts). Figure 2 shows a more complex theory (26 concepts). A theory with more concepts shows a greater breadth of processes and steps that are likely to be important.

An approach to strengthen individual theories is to look at each concept and ask, what else might help make this happen. If researchers could show how new concepts are affected by changes in a concept that is already in the model, the overall explanatory power and usefulness of the theory would be improved. This is especially important for concepts that have fewer than two causal supporters (boxes with fewer than two arrows leading to them). One strategy is to look for potential feedback loops. For example, looking at Figure 1, the concept “More stock of knowledge” is unexplained (has no arrows leading to it). Researchers might ask whether a feedback loop exists in which a stock of knowledge causes an increase in entrepreneurship and that entrepreneurship then causes more stock of knowledge when the new firms generate new knowledge. Another strategy is to ask what other relationships might exist across concepts in the theory. Looking again at Figure 1, studies might ask whether “less regulation, administrative barriers, government intervention in the market” might affect the stock of knowledge, such as patent law changes or government incentives for innovation that might encourage development of new knowledge.

Ideas for Using IPA to Integrate Theories

Research users can also look at a theory, notice what is not well explained (not concatenated), and see if it is explained

in another theory. Incorporating additional theories to explain these concepts would strengthen the theory. Following one potential path, researchers might “backtrack” to find the literature that theory authors cite to support their theories.

Some of the reviewed literature emphasized entrepreneurs gathering and synthesizing information to find opportunities and make strategic decisions as a key component of successful entrepreneurship (Alvarez & Busenitz, 2001; Casson, 2005). IPA can facilitate this synthesis process. Figures 1 and 2 show two sample diagrams that look at different things. Each study brings something valuable—a different piece of the big picture. Entrepreneurs can identify parts of each diagram that relate to their activities or research questions. Then, they can put all those pieces together to assemble a more complete diagram for their specific situation.

As scholars collaborate to identify and link the best theories of entrepreneurship and business management to develop a more integrated theory, they open a door to create more effective academic theories. A strength of using IPA to link research theories is that it easily shows where a study can improve the systemicity of the model and thereby provide a clear direction for advancing the field, not merely add to the storehouse of knowledge.

Another possible line of research could compare theories from scholarly journals with theories that are used in practice and integrate related theories from the academic and business worlds. Potential sources include entrepreneurship textbooks (Solomon, 2006), business plan contests (Kearins et al., 2004), venture magazines, conference proceedings, government reports, and learning from practicing entrepreneurs (Kuratko, 2005).

Researchers might extend this work to integrate the overlapping areas of entrepreneurship theories with theories behind how to meet the needs that entrepreneurs are seeking to address through their businesses. This type of integration would be useful for the growing number of entrepreneurs and affect investors who are seeking a “double bottom-line” (or “triple bottom line”) of growing a business and making a positive impact on social and/or environmental issues, such as public health (Novelli, 2013). This would reflect the view that to create a sustainable business model, one needs to create products and services that people want.

A rigorous meta-theoretical method like IPA can also support collaborative organizational development methods (Wallis & Harris, 2013). For example, in consortial benchmarking, participants in an industry–academic research consortium work together to refine a reference framework, select and visit best-practice firms, and share results (Schiele & Krummaker, 2011; Wallis & Harris, 2013). A similar approach could provide a way to bring together various constituencies of entrepreneurship scholars and practitioners, using IPA to integrate research and practice models (Wallis, 2014). This opens new methods for collaboration between academic and business worlds, to advance theories that combine insights from research and experience to increase relevance and effectiveness in practical application.

These steps provide a path forward for scholars and practitioners to rigorously assess entrepreneurship models and create better models to advance the field more quickly.

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Notes

1. The article noted, the original source of this definition was Harvard Business School professor Howard Stevenson, cited in Burgstone and Murphy's book *Breakthrough Entrepreneurship*.
2. $\text{Distance}^2 = \text{Force} \times \text{Charge}$; also, $\text{Charge} = \text{Distance}^2 / \text{Force}$.
3. $F = ma$ (the vector sum of the forces, F , on an object equals the mass, m , of that object multiplied by the acceleration vector, a , of the object; http://en.wikipedia.org/wiki/Newton%27s_laws_of_motion).
4. $E = mc^2$ (the increased relativistic mass, m , of a body comes from the energy of motion of the body—that is, its kinetic energy, E —divided by the speed of light squared, c^2 ; <http://www.britannica.com/EBchecked/topic/1666493/E-mc2>).
5. $I = V / R$ (Current in amperes = Voltage / Resistance in ohms).
6. Additional models developed for this study are available on request.
7. Data are available on request.

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