Dynamic Relationships Management Journal

CONTENTS

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Aims & Scope

The Dynamic Relationships Management Journal is an international, double blind peer-reviewed bi-annual publication of academics' and practitioners' research analyses and perspectives on relationships management and organizational themes and topics. The focus of the journal is on management, organization, corporate governance and neighboring areas (including, but not limited to, organizational behavior, human resource management, sociology, organizational psychology, industrial economics etc.). Within these fields, the topical focus of the journal is above all on the establishment, development, maintenance and improvement of dynamic relationships, connections, interactions, patterns of behavior, structures and networks in social entities like firms, non-profit institutions and public administration units within and beyond individual entity boundaries. Thus, the main emphasis is on formal and informal relationships, structures and processes within and across individual, group and organizational levels.

DRMJ articles test, extend, or build theory and contribute to management and organizational practice using a variety of empirical methods (e.g., quantitative, qualitative, field, laboratory, meta-analytic, and combination). Articles format should include, but are not restricted to, traditional academic research articles, case studies, literature reviews, methodological advances, approaches to teaching, learning and management development, and interviews with prominent executives and scholars.

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The Dynamic Relationships Management Journal (DRMJ) is inviting contributions for upcoming issues. The manuscript can be submitted per e-mail to the editor (matej.cerne@ef.uni-lj.si). Before the submission, authors should consult Author Guidelines. There is no submission or publication fee.

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FROM THE PRESIDENT OF THE SLOVENIAN ACADEMY OF MANAGEMENT

Assis. Prof. Dr. Jože Kropivšek
University of Ljubljana
Biotechnical Faculty

Dear reader,

This spring, new members of the executive board of the Slovenian Academy of Management, who will provide the activities of the Academy in the future and guide its further development, were elected at the Electoral Assembly. Before introducing them (us) in more detail, I would like to express my special thanks to the previous President of the Academy, Professor Dr. Tomaž Čater, for his contribution to the operation and development of the Academy. During his mandate, a new website of the Academy was launched. It represents an important communication platform that presents all the main activities of the Academy transparently and attractively, including the online publication of journals and proceedings to ensure their wider reach and potential impact. This is undoubtedly very important for the authors of the articles in these publications. I am also grateful to all members of the former Board of the Academy, who each individually and collectively contributed to the recognition and development of the individual activities within the Academy. Special thanks go to the first President and founder of the Association, Professor Dr. Rudi Rozman, to whom the solid foundations and key program orientations of the Academy and its visibility in academia and business are attributed.

As already mentioned, the new Executive Committee took over the leadership functions in the Academy in Spring 2020, just during the first wave of the Covid-19 pandemic. Special circumstances considerably prolonged the appointment of functions and the transfer of activities from the former management. However, the new Executive Committee became operational in May 2020, while the formal recognition of the President took place in August 2020, when the transition was completed. The new Executive Committee consists of five members, two of whom were already members in the previous mandate. They are Associate Professor Dr. Matej Černe from the School of Economics and Business at the University of Ljubljana, who was appointed as Vice President of the Academy, and Assistant Professor Dr. Nina Tomaževič from the Faculty of Administration of the University of Ljubljana, who continues to work as the Secretary of the Academy. The new members of the Executive Committee are: Associate Professor Dr. Polona Šprajc from the Faculty of Organizational Sciences of the University of Maribor, who has been appointed to the new position of Public Relations of the Academy, Rebeka Žgalin Koncilja from the School of Economics and Business of the University of Ljubljana, who has taken over the position of Treasurer of the Academy, and myself, Assistant Professor Dr. Jože Kropivšek from Biotechnical Faculty of the University of Ljubljana as President of the Academy.

The Academy's Supervisory Board remained unchanged from the previous mandate, with Dr. Vojko Toman from Slovenian Intellectual Property Office as President and Professor Dr. Borut Rusjan from the School of Economics and Business at the University of Ljubljana and Assistant Professor Dr. Milena Alič from ALZIT d.o.o. as members.

There are no revolutionary changes planned in the key activities and main dedications of the Slovenian Academy of Management. The Academy continues with its dedication towards uniting academics, researchers, and experts from the field of management in the Republic of Slovenia and broader. The Academy will continue to act following its mission and thus organize conferences and other events, publish academic and professional literature in the field of management and organize other education, training, and research activities.

One of the first challenges we faced immediately after taking over the management of the Academy was the new situation dictated by the pandemic measures of Covid-19. Therefore, we had to cancel our academic conference entitled "Integrating organizational research: individual, team, organizational and multilevel perspectives", for which the Organizing Committee, led by Dr. Aleša Saša Sitar with strong support from colleagues from the University of Zagreb, has already received a sufficient number of high-quality papers. The decision was to postpone it until the next year, and we are currently planning to hold it in Bled in June 24-25 2021.

This period is also very demanding for communication and maintaining contacts with members of the Academy and the wider community. We have decided to approach this more systematically, and the first step was the establishment of the Academy PR. Thus, we will use all the possibilities offered by the Academy's website, while at the same time look for other ways to make "virtual" contacts to exchange opinions and messages via social networks, especially on LinkedIn. One of the main priorities of the new management is to expand the membership and ensure closer cooperation among members, so we are planning several measures in this respect. One of them is enrolling young graduates immediately after graduation, which could bring fresh ideas and thus provide the development of the Academy. **I take this opportunity to invite all readers of the Dynamic Relationships Management Journal to become a member of the Academy. This invitation is extended to everyone - Slovenian and foreign researchers, as well as experts and practitioners in the field of management and related fields. The more of us, the more the Academy will be able to create as a community, which will multiply the benefits and new opportunities for everyone and enrich each of us.**

Let me briefly present the main activities of the Academy. Most of them are already well established and will just be continued, whereas some will be upgraded. One of the main activities of the Academy is the organization of scientific conferences, from which one is international, and the other more local. International scientific conferences are primarily focused on the presentation of the latest academic findings in a specific area of management, on the exchange of opinions, and on establishing links among the participants. The purpose of the Slovenian scientific conference is to connect the Slovenian professional public with researchers, i.e. to transfer knowledge into practice, which is the fundamental goal of the Academy. A similar role of knowledge transfer and exchange is played by the two journals, whose development is successfully managed by both editors. The international journal of the Academy, i.e. Dynamic Relationships Management Journal, is managed by Associate Professor Dr. Matej Černe as an editor-in-chief. The quality of the journal is proven by its inclusion in the Scopus database and a rising number of manuscripts that are being submitted from all over the world. We would like to receive even more high-quality articles and manuscripts that put the dynamic relationships at the centre of their interest to directly address the aim and scope of the journal, so we would again like to ask academics and professionals to submit the outcomes of their research. Manuscripts can include literature reviews, theoretical contributions as well as qualitative and/or quantitative research. Soon, the editorial process will be transitioned online, including on-line submission. The Academy will also continue with the publication of the Slovenian journal titled "Izzivi managementu" (Management Challenges). It is more practically oriented and dedicated mostly to helping managers at their everyday work. Besides managers, the journal's targeted readers are also academics who wish to learn more about the practical aspects of management and related areas. The journal's editor remains Assistant Professor Dr. Lidija Breznik.

For the future, we plan to organize more forms of socializing, with the emphasis on formal and less formal debates and/or the exchange of opinions, knowledge, and experience. I would like to mention our regular activity "debate evenings", which is organized by Assistant Professor Dr. Nina Tomaževič. The current situation and the circumstances caused by the pandemic force us to look for new, mainly virtual ways and media to ensure their execution. One of the possibilities is certainly the transition to the hybrid or full online form of debate evenings using any of the Virtual Meeting Platforms and/or the introduction of thematic socializing via social networks. All those interested in this way of socializing,

I am already inviting to join us and help to shape the first steps towards building this platform.

Although the main direction of the Academy and its activities will remain unchanged, we plan to grow and expand the activities in the (near) future, with a focus on quality, and on improving its accessibility. This is only possible by increasing the number of active members and membership in general, including through expansion abroad. We will be very pleased with all the initiatives we will receive from you, dear readers, and especially with your commitment and dedication to the activities of the Academy. We are also open to more constructive cooperation with related societies and associations in the search for synergy effects. The pandemic and with it associated measures of isolation cause many challenges to establish and maintain contacts, but I am convinced that in the Academy we will successfully continue to maintain our connections also through the rational and imaginative use of all modern technological possibilities. This will help us to survive as individuals and, above all, to move forward as a community that transcends physical boundaries. This opens up entirely new possibilities for the Academy in its further development.

Finally, I have the pleasant duty to present some highlights of the new issue and invite you to read it. I am confident that everyone will find something interesting and useful in this issue of the journal. It contains five articles covering a range of different topics, research approaches, and levels of analysis. The first article was written by Chulsoon Park and focuses on the management of inter-organizational relations, thus fitting directly into the narrow framework of the DRMJ. Based on an agent-based model and the theory of the organizational learning curve, the author has shown that the knowledge performance of organizations can be changed by the way the structural factors of an ego-network are managed. The second model was created by a team consisting of Avigdor Zonnenshain, Gilead Fortuna, Eithan Adres, and Ron S. Kenett, who focused on regional development in the Industry 4.0 era. The paper presents the theoretical foundations of an integrated approach that includes an assessment using the Industrial Maturity tool for Advanced Manufacturing (IMAM), applied to the case of the Galilee region. The third paper included in this issue was co-authored by Ardita Todri, Petraq Papajorgji, and Francesco Scalera who analyzed the close interaction between organizational networking and financial mechanisms of growth and sustainable growth of SMEs operating in Albania. The authors used multivariate regressions and multilayer artificial neural perceptron networks to assess the growth of SMEs and promote their sustainable growth process using the age of the firm, which is divided into the start-up, grown, and maturity phases. The fourth paper was written by Stephen Ndula Mbieke and presents a systematic literature review of the literature on Outbound Open Innovation in the academic world. The author analyzed the literature in 42 academic journals and 118 articles specifically dealing with this research topic. This review is the first to systematically analyze the literature in terms of the financial benefits that universities derive from technology transfer and how income can best be generated. Finally, the fifth paper included in this issue was co-authored by Tomislav Hernaus, Marija Konforta, and Aleša Saša Sitar and provides a multi-informal assessment of agility maturity from an organizational perspective. The authors used Organizational Agility Maturity Model within a case study of an oil company to determine whether and to what extent there was an agreement between management and employees (informants) on the assessment of agility across different hierarchical levels.

With the desire to cooperate within the Academy, and to create new content for the Dynamic Relationships Management Journal, I wish you many new scientific and professional insights. Stay healthy!

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Dynamic Relationships Management Journal

INTER-ORGANIZATIONAL RELATIONSHIPS MANAGEMENT AS A KNOWLEDGE STRATEGY: A SIMULATION APPROACH

Chulsoon Park
Department of Business Administration, Sookmyung Women's University, Seoul, Korea
cspark@sookmyung.ac.kr

Abstract

Firms absorb knowledge from their partners, make it their own, and use it for innovation. The knowledge performance of a firm embedded in an inter-organizational network can vary depending on how concentrated its ties are and the number of direct ties. This study used an agent-based model and the organizational learning curve theory as basis to show that the knowledge performance of firms can be modified by the way in which the structural factors of an ego network are managed. In particular, the concentration of tie strength decreases the average level of a firm's knowledge profile; that is, a firm's knowledge level decreases when it has strong ties with a particular firm and weak links with others. The number of direct ties, the so-called node degree, increases the diversity of knowledge in the long run. The cumulative knowledge reduction effect of the concentration of tie strength varies depending on the network type. In a random network, the average knowledge reduction effect is mitigated by a high absorptive capacity, whereas the reduction effect is strengthened in a scale-free network. A knowledge strategy is presented to assist firms in effectively accumulating knowledge toward sustainable growth.

Keywords*: inter-organizational network, concentration of tie strength, node degree, knowledge performance, agent-based model*

1. INTRODUCTION

Knowledge is a source of technological innovation. A firm obtains knowledge through its inter-organizational networks. Firms innovate not only by their own internal research and development but also by acquiring skills, knowledge, and information from other firms through partnerships (Choi, 2020). In particular, firms in rapidly developing industries, such as the biotechnology and information and communications industries, strive to secure resources and reduce uncertainty through a variety of cooperative relationships, such as strategic alliances, consortiums, and joint ventures (Hoffmann, 2007). Firms drive innovation through a distributed process based on knowledge flows across organizational boundaries, so-called open innovation (Chesbrough and Bogers, 2014). According to the relational view (Dyer & Singh, 1998), business-to-business relationships can be an important component of a firm's competitive advantage and can lead to better performance. To successfully implement a firm's strategy, it is not possible to rely solely on one relationship. Strategies for accessing a variety of external resources through partnerships in different ways with different partners can be useful. How a set of relationships, rather than one relationship, is created and managed determines a firm's knowledge performance (Hoffmann, 2007).

Identifying the relationship between network structure and innovation performance has been a major concern for management. A knowledge-sharing network that facilitates knowledge exchanges between a central firm and its allied partners can be a source of competitive advantage for a firm (Dyer & Hatch, 2004). The type of network relationship appropriate for a firm has been debated widely be-

cause maintaining relationships with multiple partners can be costly (Lavie, 2007). Following Ahuja (2000), this study defines an inter-organizational tie as a voluntary arrangement between independent organizations to share knowledge. The influence of tie strength on knowledge performance has been discussed mainly at a dyad level. If the trust and communication frequency between two firms is high, they are said to be connected by a strong tie. A strong tie facilitates the flow of sensitive and high-level information (Rowley, Behrens & Krackhardt, 2000), but a weak tie allows access to new and diverse information (Hansen, 1999). However, in the ego network of a firm composed of multiple ties, weak and strong connections exist together. If there are multiple ties together, how does the distribution of the relationships relate to knowledge performance? To our knowledge, few studies have revealed the relationship between tie strength distribution and knowledge performance in the presence of multiple ties. This study focuses on the concentration of a firm's tie strength when several ties exist and identifies the relationship between the concentration and knowledge performance.

This study investigates how the structural factors of an ego network affect knowledge performance. Specifically, it argues that knowledge performance can vary depending on tie-strength concentration and the number of direct ties. To this end, an organizational learning model, in which knowledge is exchanged through a network, was built as an agent-based model. Each firm is set to accumulate knowledge by developing knowledge internally and by absorbing knowledge externally in situations in which multiple knowledge domains exist. A simulation revealed that the higher (lower) the tie strength concentration, the lower (higher) is the average level of knowledge. If the number of direct ties is large, the diversity in knowledge domains increases. The average reduction effect of the tie-strength concentration and the increase effect of changes in the number of direct ties vary depending on the network topology or a firm's absorptive capacity.

The contributions of this study are as follows. First, we identified the relationship between structural factors and knowledge performance. We developed a dynamic model that comprehensively considers firm-, relationship-, and network-level factors to clarify the relationship between structural factors and performance in various environments. Second, we present an inter-organizational relationships management framework as a knowledge strategy. Based on the relationship between structural elements and knowledge performance, we provide practical implications by presenting a relationship management plan that fits the objective pursued by each firm.

This paper is organized as follows. Section 2 summarizes previous research related to this study, and Section 3 presents an agent-based model for knowledge diffusion in an inter-organizational network. Section 4 analyses the experimental results. Section 5 discusses the results and presents a knowledge strategy framework. Finally, Section 6 summarizes the findings and outlines the limitations and the direction of future research.

2. LITERATURE REVIEW

Phelps, Heidl, and Wadhwa (2012) defined knowledge networks as networks consisting of nodes, which is the repository of knowledge. The nodes can be either firms or individuals that create, search, assimilate, and exploit knowledge. The performance of the knowledge network varies according to various factors in the network (Al-Jabri & Al-Busaid, 2018). Phelps et al. (2012) classified structural, relational, nodal, and knowledge properties as the main elements. Structural elements relate to how the relationships are connected—where they are located in the network, how they are connected with directly connected partners, what kind of relations exist among the partners, and what form the whole network takes. These structural factors can affect knowledge performance. Node degree is the number of direct ties of an incident to a node (Borgatti, Everett & Johnson, 2013). In studying the relationship between node degree and performance, Ahuja (2000) argued that the higher the number of direct ties, the higher is the innovation performance. A large number of direct links can lead to higher innovation performance due to knowledge sharing, complementarity, and economies of scale. Burt (1992) proposed the concept of a structural hole and argued that if the focal firm's partners were not connected with each other, the informa-

tion power of the focal firm would be higher. Empirical studies have shown that structural holes improve knowledge performance (Baum, Calabrese & Silverman, 2000; McEvily & Zaheer, 1999), whereas other studies have found that without structural holes, innovation improves (Ahuja, 2000; Schilling & Phelps, 2007). Chen, Zhang, Zhu, and Mu (2020) suggested that the impact pattern of the network positions of organizations on their performance likely varies with the network structure and composition in different inter-organizational contexts. Specifically, they argued that the node degree and structural hole of the research institute respectively affect the performance in an inverted U-shaped manner and in a positive linear manner in the homogeneous university-researcher collaboration network, but have different relationships in the other types of collaboration networks. In addition, the whole network topology can affect the firm's knowledge performance. Network topology refers to a structure of how firms are connected. Typical network topologies include random (Erdős & Rényi, 1959), small-world (Watts & Strogatz, 1998), and scale-free (Barabási & Albert, 1999) networks. A random network refers to a network in which nodes are randomly connected. A regular network refers to a network that is regularly connected to its partners. A small-world network can be constructed by creating a regular network and randomly selecting a small number of links and connecting them to other nodes. A scale-free network is a network in which the degree distribution of nodes follows a power law. The diversity of information can be increased by becoming a "small world" because there is a shortcut between dense groups (Schilling & Phelps, 2007). Using an agent-based model, Kim and Park (2009) argued that small-world networks are more efficient in diffusing knowledge than are regular or random networks.

Relational elements refer to the type of relationship each node has. A representative example is tie strength. The relationship between two firms is classified as strong or weak based on the tie strength. In a relationship with a strong tie, firms frequently communicate with each other based on trust, intimacy, and reciprocity, whereas in a relationship with a weak tie, firms are remote from each other or occasionally communicate and exchange information (Capaldo, 2007; Granovetter, 1973). Based on the level of intimacy and reciprocity, two firms with a strong tie can share more sensitive information and tacit knowledge than those with weak ties (Granovetter, 1973; Marsden, 1984). Strong ties, as a medium for reliable information delivery, promote the flow of a stream of advanced information and refined knowledge (Rowley et al., 2000). However, an advantage of a weak tie is that it enables access to new and diverse information (Hansen, 1999). Franco and Esteves (2020) argued that weak ties between clusters—groups connected by strong ties—play an important role in knowledge transfer among inter-cluster networks. Studies conducted from a social capital perspective state that links with other firms positively affects a firm's knowledge performance (Carey, Lawson & Krause, 2011). Cousins, Handfield, Lawson, and Petersen (2006) argued that enhancing social relationships between suppliers and buyers contribute to the formation of relational capital, making communication between firms smoother. Dyer and Singh (1998) argued that ties between two firms lead to investments in idiosyncratic assets, which promotes the flow of knowledge. Furthermore, they emphasized that this increase in investment and the facilitation of knowledge flows develop into a self-enforcing structure that further strengthens the tie between the two. Idrees, Vasconcelos, and Ellis (2018) argued that a cooperative–competitive tension of dyadic relationships facilitated knowledge sharing between five-star hotels.

Nodal properties refer to a firm's own characteristics. For example, a firm's high absorptive capacity (Cohen & Levinthal, 1990) facilitates the easy absorption of knowledge from partners (Zhao & Anand, 2009). Xie, Wang, and Zeng (2018) found that absorptive capacity mediated the relationship between inter-organizational knowledge acquisition and firms' innovation performance. Lastly, knowledge performance can vary according to various properties of knowledge. Codified knowledge is more likely to diffuse (Simonin, 1999), and complex and tacit knowledge is difficult to absorb, which can be alleviated by frequent communication (McEvily & Marcus, 2005). According to Balle, Steffen, Curado, and Oliveira (2019), managerial knowledge can be transferred in more alternative ways than technical knowledge.

3. MODEL

The knowledge diffusion model sets a firm as one agent, and each agent corresponds to a node in the knowledge network. Nodes are connected to each other by ties. The diffusion of knowledge occurs between firms linked by a tie. One tie could be a purchase contract, joint research, or joint development. This knowledge diffusion model is based on the work of Kim and Park (2009), but is extended to various network topologies and modified in knowledge acquisition logic. The network topologies considered in this simulation are random, small-world, and scale-free networks. It is assumed that all firms are connected as one network, which means that there are no isolated firms. A scale-free network is made using a preferential attachment, as proposed by Barabási and Albert (1999). The preferential attachment method starts from one link and adds a node with a fixed number of links (PA-degree) to connect them. When a new node is added to an existing node, it is added probabilistically in proportion to how many links the existing node has.

The organizational learning theory was developed by Argote and colleagues, and many empirical studies have been conducted based on it (Argote, 2013; Argote, Beckman & Epple, 1990; Epple, Argote & Devadas, 1991; Epple & Argote, 1996; Epple, Argote & Murphy, 1996). Based on those previous studies, this study models the way in which a firm accumulates knowledge assets based on the organizational learning curve equation suggested by Epple et al. (1991). A firm's knowledge assets are represented by a single knowledge profile (KP), and a knowledge profile consists of multiple knowledge domains. It is assumed that all companies build knowledge in a knowledge profile consisting of the same D knowledge domains. Each firm accumulates knowledge in two ways. One is through research and development inside the firm itself, and the other is by absorbing the knowledge of partners tied with the firm. Based on Epple et al.'s (1991) organizational learning curve equation, the equation for accumulating knowledge is as follows:

$$k_{id,t} = \alpha_i K_{id,t}^{\lambda_i} + \beta_i \max\left[K_{jd,t} - K_{id,t}, 0\right] \quad (1)$$

where $k_{id,t}$ is the increment of knowledge accumulated in knowledge domain d at time t by firm i, and $K_{id,t}$ is the cumulative level of knowledge accumulated in knowledge domain d at time t by firm i. The first term on the right-hand side is the knowledge gained through research and development inside the firm; α_i denotes a firm's internal innovation capability, which is the capability obtained through internal research based on the firm's accumulated knowledge. The larger α_i is, the greater is the internal research capability that firm i can create by using existing accumulated knowledge. In Equation (1), λ_i is the coefficient of the effect of the learning curve of firm i. The larger λ_i is, the greater is the learning ability that can be generated through existing knowledge. The second term on the right-hand side is the other source from which firms can build their knowledge and absorb knowledge of partners connected to them for their own knowledge enhancement; β_i is firm i's absorptive capacity (Cohen & Levinthal, 1990). If the partner firm's knowledge concerning the knowledge domain is greater, the focal firm absorbs the knowledge gap multiplied by β_i. Among the partner firms that are connected to the firm, firm j is probabilistically selected to absorb such knowledge. The probability p_{ij} that firm i selects partner firm j as a source of knowledge is made proportional to the tie strength as follows:

$$p_{ij} = \frac{s_{ij}}{\sum_{j \in N(i)} s_{ij}} \quad (2)$$

where s_{ij} refers to the tie strength of firms i and j, and $N(i)$ is the set of partners directly connected to firm i. However, some of the knowledge of a firm disappears or becomes obsolete over time (Epple et al., 1996). Thus, the cumulative level of knowledge of firm i, considering the depreciation of this knowledge, is

$$K_{id,t+1} = (1-\delta)K_{id,t} + k_{id,t} = (1-\delta)K_{id,t} + \alpha_i K_{id,t}^{\lambda_i} + \beta_i \max\left[K_{jd,t} - K_{id,t}, 0\right] \quad (3)$$

where δ denotes the depreciation rate of knowledge, which is the rate at which knowledge becomes obsolete from the cumulative knowledge in the previous period. In industries with rapid innovation and change, the value of δ is relatively large, and in industries in which technology has reached maturity, the value is relatively small. Equation (3) states that the knowledge of firm i at time t + 1 decreases at the depreciation rate of the cumulative knowledge at

the previous time, increases in proportion to the internal capability of the company, and finally increases by absorption of knowledge outside the firm. The equation encompasses the entire life cycle of knowledge by including two sources of knowledge growth and the depreciation of knowledge.

The explanatory variable, tie-strength concentration, is measured by Herfindahl–Hirschman Index (HHI). The concentration of firm i's tie-strength is defined as follows:

$$\mathrm{HHI_i} = \sum_{j \in N(i)} s_{ij}^2 \quad (4)$$

The HHI has a maximum value of 1, and the larger the value, the more concentrated is the tie-strength. Another explanatory variable—node degree—is defined as the number of direct ties connected to each node (Newman, 2010).

The dependent variables are KPMean and KPStdev. KPMean is the arithmetic mean of all knowledge domains in a knowledge profile, and KPStdev is the standard deviation, as shown in the following equations:

$$\mathrm{KPMean_{i,t}} = \frac{1}{D}\sum_{d=1}^{D} \mathrm{K_{id,t}} \quad (5)$$

$$\mathrm{KPStdev_{i,t}} = \sqrt{\frac{1}{D-1}\sum_{d=1}^{D}\left(\mathrm{K_{id,t}} - \mathrm{KPMean_{i,t}}\right)^2} \quad (6)$$

The network used in this model consists of 100 nodes. The parameters used in the model are designated as random variables, as summarized in Table 1, with reference to Kim & Park (2009), to allow for the heterogeneity of firms. Fifty repetition experiments were performed on one network topology. Simulations were performed up to 10,000 ticks, at which the cumulative knowledge of all nodes was stable. Short-term (100 ticks) and long-term (10,000 ticks) data were collected. The agent-based model presented in this study was implemented using NetLogo 6.1.1 (Wilensky, 1999), and the simulation experiment used the BehaviorSpace tool built into NetLogo.

4. RESULTS

A hierarchical regression analysis was performed, estimated by the following equations:

$$\widehat{KPMean_i} = \widehat{\beta_0} + \widehat{\beta_1}\alpha_i + \widehat{\beta_2}\beta_i + \widehat{\beta_3}\lambda_i + \widehat{\beta_4}HHI_i + \widehat{\beta_5}HHI_i{\times}\alpha_i + \widehat{\beta_6}HHI_i{\times}\beta_i + \widehat{\beta_7}HHI_i{\times}\lambda_i \quad (7)$$

$$\widehat{KPStdev_i} = \widehat{\beta_0} + \widehat{\beta_1}\alpha_i + \widehat{\beta_2}\beta_i + \widehat{\beta_3}\lambda_i + \widehat{\beta_4}Degree_i + \widehat{\beta_5}Degree_i{\times}\alpha_i + \widehat{\beta_6}Degree_i{\times}\beta_i + \widehat{\beta_7}Degree_i{\times}\lambda_i \quad (8)$$

The standardized coefficients and significance level of each variable obtained as a result of the regression analysis are summarized in Tables 2 and 3.

Table 1: Parameters for simulation.

Parameter	Description	Value or Distribution
α_i	Knowledge development capability of firm i	$\sim U[0, \alpha_{max}]$
α_{max}	Maximum value of α_i	0.002
β_i	Absorptive capacity of firm i	$\sim U[0, \beta_{max}]$
β_{max}	Maximum value of β_i	0.2
$K_{id,0}$	Initial value of knowledge domain d of firm i	$\sim U[0, K_{max}]$
K_{max}	Maximum value of $K_{id,0}$	0.1
λ_i	Learning rate of firm i	$\sim U[0, \lambda_{max}]$
λ_{max}	Maximum value of λ_i	0.05
δ	Depreciation rate of knowledge	0.001
s_{ij}	Tie strength of firm i and j	$\sim U[0,1]$
KDnum	Number of knowledge domains	10
PA-degree	Number of links created by one node in preferential attachment	3

Table 2: Results of the hierarchical regression analysis for KPMean

Ticks = 100	Dependent Variable = KPMean											
Topology	Random				Small-World				Scale-Free			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Alpha	0.590	***	0.591	***	0.636	***	0.636	***	0.584	***	0.584	***
Beta	0.564	***	0.564	***	0.495	***	0.496	***	0.529	***	0.530	***
Learning	−0.028	***	−0.029	***	−0.051	***	−0.052	***	−0.019	*	−0.019	*
HHI	−0.050	***	−0.051	***	−0.034	***	−0.035	***	−0.048	***	−0.050	***
HHI×Alpha			0.004				0.011				−0.036	***
HHI×Beta			−0.010				−0.021	*			−0.038	***
HHI×Learning			−0.031	***			0.005				0.012	
Adj. R^2	0.677		0.678		0.635		0.635		0.636		0.639	
F	2619.323	***	1503.098	***	2172.542	***	1243.896	***	2187.799	***	1265.444	***
F change			5.454	***			2.716	*			13.586	***
Ticks = 10,000	Dependent Variable = KPMean											
Topology	Random				Small-World				Scale-Free			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Alpha	0.311	***	0.312	***	0.321	***	0.321	***	0.301	***	0.301	***
Beta	0.410	***	0.410	***	0.331	***	0.331	***	0.403	***	0.404	***
Learning	0.014		0.013		0.005		0.005		0.018		0.017	
HHI	−0.045	***	−0.047	***	−0.021	+	−0.021	+	−0.025	*	−0.027	*
HHI×Alpha			0.013				0.001				−0.043	***
HHI×Beta			0.025	*			−0.006				−0.035	**
HHI×Learning			−0.045	***			0.006				0.000	
Adj. R^2	0.270		0.272		0.205		0.205		0.258		0.261	
F	463.465	***	268.300	***	323.770	***	184.982	***	436.041	***	252.961	***
F change			6.164	***			.151				6.822	***

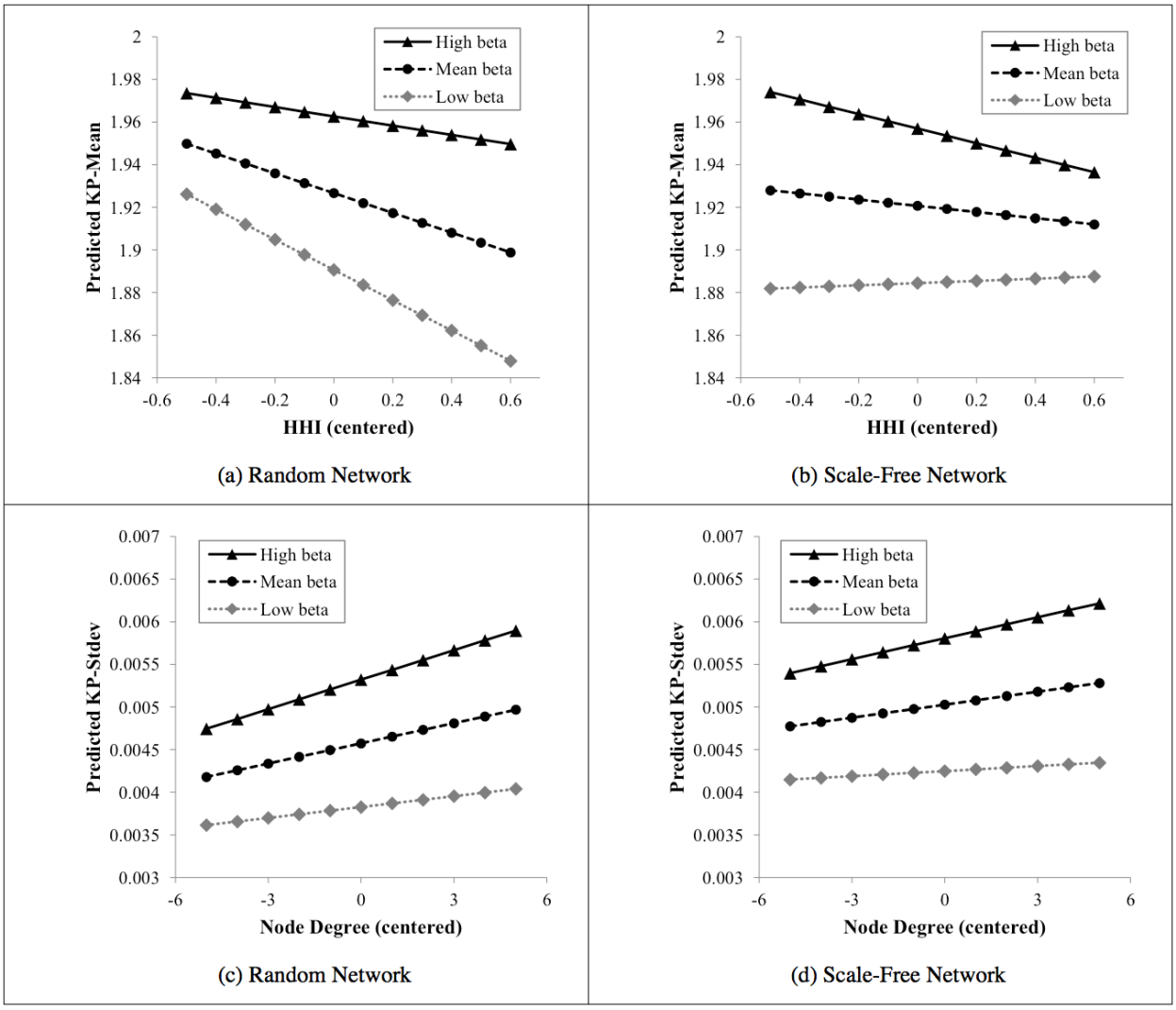
*Notes: Standardized coefficients are presented. ***, **, *, and + denote significance at the 0.1%, 1%, 5%, and 10% levels, respectively.*

For the dependent variable KPMean, Model 1 included only internal development capability (Alpha), absorptive capacity (Beta), learning curve effect (Learning), and HHI; Model 2 added interaction terms between HHI and other variables. In the short term (100 ticks), Model 1 had significant coefficients for all variables in all topologies. In particular, Alpha and Beta were positive, and Learning and HHI were negative. This confirms that HHI has the effect of decreasing the average of KP. Model 2, which added interaction terms, had different results depending on the network topology. In the random network, the coefficient of $HHI_i \times \lambda_i$ was significant and negative ($\widehat{\beta_7}$ = -0.031, p < 0.001). This means that HHI reduces the average of KP, but the higher the learning rate, the stronger is the effect. In the small-world network, the coefficient of $HHI_i \times \beta_i$ was significant and negative ($\widehat{\beta_6}$ = -0.021 , p < 0.05). This

means that the HHI's KP average reduction effect is enhanced as the absorptive capacity increases. In the scale-free network, the coefficients of $HHI_i \times \alpha_i$ and $HHI_i \times \beta_i$ were significant and negative ($\widehat{\beta_5}$ = -0.036, p < 0.001; $\widehat{\beta_6}$ = -0.038, p < 0.001). This confirms that HHI's KP average reduction effect can vary depending on the internal development and absorptive capacity. In short, the results indicate that the short-term KP average level decreases as the HHI increases, and that the moderating effect of the firm's capabilities differs depending on the topology.

The results for 10,000 ticks (long term) were as follows. First, the results differed from those in the short term in that the learning curve effect was not significant. The reduction effect of HHI still was significant in the long term, although marginally significant in small-world networks. Unlike the results in the short term, the moderation effect of absorptive capacity appeared in the random network, in which the coefficient of in the long term was positive and significant ($\widehat{\beta_6}$= 0.025, p < 0.05). This means that in the long term, HHI's KP average reduction effect can be mitigated by the absorptive capacity. Figure 1(a), drawn according to the guidelines of Cohen, Cohen, West, and Aiken (2002), shows how the KP reduction effect of HHI is affected by a high (average + standard deviation), average, and low (average − standard deviation) level of the moderating variable. If the absorptive capacity is large, the reduction effect is mitigated. In the scale-free net-

Figure 1: The moderation effect of absorptive capacity in the long term



work, the short- and long-term scenarios had almost similar effects. In particular, the coefficient for the moderating effect of absorptive capacity was significant and negative. This means that the higher the absorptive capacity, the stronger is the reduction effect of HHI. This is confirmed in Figure 1(b). In firms with low absorptive capacity, HHI's KP average reduction effect may lead to an increase effect on the KP average. This would mean that firms with low absorptive capacity are not significantly affected by the high concentration of relationships in the scale-free networks.

For KPStdev, in the short term (100 ticks) the coefficients of Alpha, Beta, and Degree were significant in Model 1, which considered only main effects. The coefficients of Alpha and Beta were positive,

Table 3: Results of the hierarchical regression analysis for KPStdev

Ticks = 100	Dependent Variable = KPStdev											
Topology	Random				Small-World				Scale-Free			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Alpha	0.390	***	0.390	***	0.243	***	0.243	***	0.371	***	0.371	***
Beta	0.306	***	0.307	***	0.386	***	0.386	***	0.244	***	0.245	***
Learning	−0.011		−0.011		−0.001		−0.001		−0.011		−0.011	
Degree	−0.119	***	−0.119	***	−0.032	*	−0.034	**	−0.131	***	−0.131	***
Degree×Alpha			0.000				0.014				−0.005	
Degree×Beta			0.029	*			−0.027	*			0.014	
Degree×Learning			0.019				0.009				0.008	
Adj. R^2	0.262		0.263		0.202		0.203		0.219		0.219	
F	445.677	***	256.142	***	317.686	***	182.663	***	351.386	***	200.992	***
F change			2.790	*			2.301	+			.584	
Ticks = 10,000	Dependent Variable = KPStdev											
Topology	Random				Small-World				Scale-Free			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Alpha	−0.433	***	−0.433	***	−0.445	***	−0.445	***	−0.392	***	−0.391	***
Beta	0.286	***	0.287	***	0.207	***	0.207	***	0.270	***	0.271	***
Learning	0.007		0.007		−0.001		−0.001		−0.001		−0.002	
Degree	0.051	***	0.052	***	0.038	**	0.038	**	0.083	***	0.084	***
Degree×Alpha			−0.047	***			−0.020	+			−0.014	
Degree×Beta			0.025	*			−0.003				0.050	***
Degree×Learning			0.024	*			−0.009				0.016	
Adj. R^2	0.267		0.270		0.248		0.248		0.227		0.230	
F	457.135	***	265.350	***	412.803	***	236.396	***	368.872	***	214.149	***
F change			7.322	***			1.141				6.288	***

*Notes: Standardized coefficients are presented. ***, **, *, and + denote significance at the 0.1%, 1%, 5%, and 10% levels, respectively.*

and the coefficient of node degree was negative and significant in all topologies. This confirms that various knowledge domains are learned evenly in the early stages, because the number of direct relationships is much higher. In the random network, the larger the absorptive capacity, the more the reduction effect on the KP standard deviation of the node degree was mitigated, whereas the reduction effect was strengthened in the small-world network.

As time passed, the reduction effect on the KP standard deviation of the node degree changed to an increase effect. The coefficients of the node degree all changed to positive and were significant. In other words, the more connected firms are, the more diverse their knowledge base becomes. In the random and scale-free networks, the increase effect was strengthened by the absorptive capacity. These results are confirmed by Figures 1(c) and 1(d).

5. DISCUSSION

5.1 Tie-strength concentration and node degree

Firms' decision-making and behavior are affected by how much they depend on their resources and their constraints (Pfeffer & Salancik, 2003). If only a small number of firms in a network have access to resources, their dependence on resources is intensified (Pfeffer & Salancik, 2003). The deeper the dependence on resources, the higher is the interdependence between firms (Burt, 1983). Interdependence between firms enhances the strength of ties. In ties that have been strengthened, knowledge can be effectively transferred with little effort. Especially in the case of tacit or complex knowledge, it is easy to communicate when there are strong ties (Uzzi, 1997). However, strong ties also can cause two firms to become stuck (Lechner, Frankenberger & Floyd, 2010), fall into collective blindness (Nahapiet & Ghoshal, 1998), or become complacent (Villena, Revilla & Choi, 2011), which may hinder the acquisition of knowledge. Moreover, when there is only a limited range of knowledge, knowledge that can be learned from a partner with whom a firm has a strong tie is quickly exhausted. In other words, if firms communicate frequently with each other, new knowledge that can be learned from partners inevitably will decrease, as knowledge is learned before it is accumulated internally and becomes part of the capabilities of the firm. Meanwhile, if the tie strength is not concentrated and is distributed evenly, the partner firms have time to accumulate knowledge by developing their internal capabilities. Therefore, the less concentrated the tie strength, the greater the cumulative knowledge of a firm becomes.

This finding is consistent among all network topologies. However, the moderating effect of absorptive capacity varies depending on the network topology. In a random network, the reduction effect of concentration is alleviated, but in a scale-free network, the reduction effect is strengthened further. This result occurs due to the characteristics of the network topology. Compared with random networks, scale-free networks have a hub-and-spoke structure, so one firm is likely to be connected to a hub. Firms with high absorptive capacity depend more on the knowledge profile of the hub than do firms with low absorptive capacity. As a result, the reduction effect of the tie-strength concentration is further enhanced.

A direct tie can have a positive effect on knowledge performance and a negative effect as well. The larger the number of direct ties, the more likely it is that knowledge will be exchanged with various firms, which would enable a firm to broaden its knowledge profile to various domains (Ahuja, 2000; Owen-Smith & Powell, 2004). However, maintaining too many relationships may cost more than the benefit generated from it (Rothaermel & Alexandre, 2009). With regard to achieving a knowledge profile that encompasses multiple domains, various sources exist for knowledge accumulation. In the short term, diversity in knowledge domains is low as a firm connects with multiple sources, but in the long term, the diversity of knowledge increases. In the setting of the experiment, all firms start with only one knowledge domain which is randomly chosen. In the short term, the more a firm is connected with multiple partners, the more it can accumulate knowledge stocks in diverse knowledge domains, so the deviation among knowledge domains decreases. As time passes, each firm can increase exponentially the knowledge level of some specific knowledge domains according to its internal innovation capability and learning curve effect (Epple et al., 1991). In firms which are more connected with these various partners in terms of knowledge profile, the deviation among knowledge domains increases. This

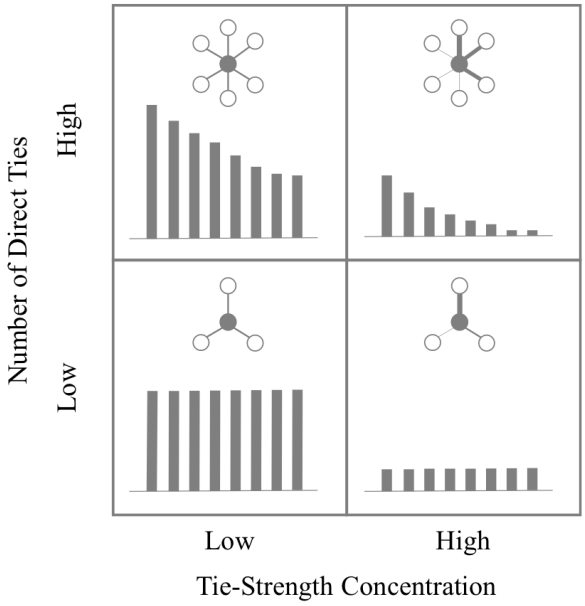
phenomenon has been confirmed by several empirical studies about strategic alliances in the biotechnology industry (e.g., Xu & Cavusgil, 2019; Zhang, Baden-Fuller & Mangematin, 2007).

These results help resolve the conflicting results regarding node degree and performance. Whereas some researchers (e.g., Ahuja, 2000) argued that the higher node degree made its innovation performance greater, others (e.g., Rothaermel & Alexandre, 2009) suggested that increasing reliance on partners has a negative effect on knowledge performance. The present finding suggests that the number of direct ties with suppliers has positive or negative effects, which can change depending on the period. This was revealed by comparing the short-term and long-term results in the regression analysis. The results indicate that in the beginning, the greater (lesser) the number of direct ties, the lesser (greater) is the knowledge diversity, and over time, this knowledge diversity increases (decreases).

5.2 Relationship management as a knowledge strategy

A firm can design and manage two structural elements to create its knowledge profile. The following knowledge strategy framework can be considered.

Figure 2: Relationship management as a knowledge strategy



In the long run, if a firm wants to increase its overall knowledge and focus on a specific field at the same time, it could benefit by maintaining evenly distributed ties with other firms and by expanding the number of its direct ties (Figure 2, top left). In the case of high-tech products, in which multiple knowledge fields are applied in a complex manner, such as electric vehicles, this strategy is suitable because it is important to focus on knowledge about a specific field while simultaneously developing related technologies. In the case of a mature industry, such as a gasoline-powered vehicle, a high level of knowledge must be accumulated evenly in various knowledge fields. Therefore, it is beneficial to manage relationships with fewer direct ties at low concentration (Figure 2, bottom left). In the case of a high-tech product, such as a personal mobility device, superiority in a specific technology is necessary. In the case of products that require a relatively low level of technology, it is necessary to maintain numerous direct ties and focus on major partners to manage relationships (Figure 2, top right). Lastly, if a product requires a relatively uniform skill, such as a bike, but do not need a very high level of skill, it is appropriate to manage relationships with fewer direct ties and focus on specific partners (Figure 2, bottom right).

6. DISCUSSION AND CONCLUSION

This study contributes theoretically to the knowledge management field as follows. First, it examined the knowledge performance of firms embedded in an inter-organizational network by considering various factors. In the context of inter-organizational network, knowledge transfer and inter-organizational learning is a recent topic that is expanding (Marchiori & Franco, 2020). Most previous studies of network structure and knowledge performance are empirical studies, because it is very difficult to measure the knowledge performance of a firm, especially the ego network, which is a combination of complex factors (Gulati, 1998). This study overcame the disadvantages of empirical analysis by establishing an agent-based model based on the organizational learning theory and by obtaining and analysing vast amounts of data through simulations using such a model. Second, the complex

mechanism concerning knowledge performance was exemplified using a dynamic model that includes network-, relationship-, and firm-level factors that affect knowledge performance. By using an agent-based model suitable for modeling emergent phenomena caused by the interactions among various factors, multiple factors were considered to identify the moderating effect.

The findings of this study provide insightful implications for practitioners. First, the findings provide implications for relationship management. This study helps firms design their own knowledge strategies for their targeted knowledge profiles by expounding on the implications of the number and strength of direct ties that firms can create and maintain. Second, we propose a strategic framework for firms to manage their knowledge profiles by identifying the number of direct ties that can be managed directly, the concentration of tie strength, and their relationship with knowledge performance. A firm has structural features that it can control and network characteristics that it cannot manage. This study helps knowledge managers to establish knowledge strategies by suggesting structural network factors—tie-strength concentration and node degree—that firms can directly manage for knowledge management. Third, this study revealed that the relationship between structural factors and performance can vary depending on the situation, such as the network topology, a firm's capability, and the length of time (Ahuja, 2000; Capaldo, 2007; Duysters & Lokshin, 2011; Rowley et al., 2000). By examining the moderation effect of absorptive capacity and network topology on the knowledge performance of a firm, knowledge managers can understand that the effectiveness of the knowledge strategy may differ depending on the firm's own situation and the structure of the industry.

To conclude, it can be said that a firm's knowledge performance can be a driving force for innovation. Firms produce knowledge internally, but they also absorb it from the outside. Firms are embedded in inter-organizational networks, and they absorb and utilize external knowledge. This study examined the relationship between the structural factors of a firm and knowledge performance by extending the organizational learning model into a network. We examined the relationship between two structural factors—tie-strength concentration and number of direct ties—and the average knowledge level and standard deviation of the knowledge profile. The results indicate that the more concentrated the tie strength, the lower is the average level of a firm's knowledge profile. The number of direct ties influences the standard deviation of the knowledge profile, resulting in a negative (positive) effect in the short (long) term. In the long term, the effect of increasing the KP standard deviation of the node degree is strengthened when the absorptive capacity is large.

This study has the following limitations and future research directions. First, the cost of maintaining and managing a relationship was not considered. As the results of this study suggest, exchanging knowledge with multiple partners inevitably is costly. By conducting a cost–benefit analysis of lowering the concentration of relationships and its utility, it is expected that an effective knowledge development strategy can be established. Second, among the factors that can affect the performance of knowledge, the characteristics of the knowledge being diffused were not considered. There may be differences in the transfer of tacit and explicit knowledge. This study did not include the forms of advanced knowledge that can be delivered only through strong ties. In future research, more sophisticated results can be expected if the type of knowledge transferred is considered.

EXTENDED SUMMARY/IZVLEČEK

Podjetja od svojih poslovnih partnerjev pridobivajo različna znanja, ki služijo kot izhodišče za različne inovacije. Ali bo podjetje pridobljeno znanje učinkovito in uspešno uporabilo je odvisno od števila, moči in neposrednosti povezav med podjetjem in različnimi poslovnimi partnerji. Raziskava temelji na modelu agenta ter teoriji organizacijske krivulje učenja. Slednja dokazuje, da je učinkovitost uporabe znanja v organizaciji možno uravnavati preko strukturnih dejavnikov prej omenjenih povezav med podjetji. Močne medorganizacijske povezave namreč znižujejo učinkovitost uporabe znanja; to pomeni, da se raven znanja v podjetju zmanjša v primeru močnih povezav z določenim podjetjem ter hkrati šibkimi povezavami s preostalimi podjetji. Nadalje, število neposrednih povezav dolgoročno povečuje raznolikost znanja v podjetju. Kumulativni učinek moči in neposrednost povezav na znanje se razlikuje glede na vrsto povezav med podjetji. Pri naključnih povezavah se povprečni učinek zmanjšanja znanja ublaži z visoko sposobnostjo vsrkanja znanja, medtem ko se učinek zmanjšanja okrepi v omrežju brez obsega. Avtorji v prispevku predstavijo strategijo, ki služi kot izhodišče za podjetja pri načrtovanju njihovega trajnostno učinkovitega kopičenja znanja.

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REGIONAL DEVELOPMENT IN THE ERA OF INDUSTRY 4.0

Avigdor Zonnenshain, Gilead Fortuna, Eithan Adres, and Ron S. Kenett
The Samuel Neaman Institute for National Policy Research, Center for Industrial Excellence, Technion, Haifa, Israel

Abstract

Regional development is a complex challenge for policymakers in government, business, and industrial leadership. The Fourth Industrial Revolution, labeled Industry 4.0, has created integrated opportunities for a circular economy involving actors from different society strata. This paper presents an integrated approach that combines conventional strategic planning methods with tools adapted to the Fourth Industrial Revolution. The regional development methods discussed here are demonstrated with a real-life case study from a major regional development project initiated by policymakers. The integrated approach presented here lists opportunities and challenges in regional development applications with interest to both researchers and policy makers. The case study is from the North of Israel, which also is called the Galilee. The Galilee is considered a geographical and social peripheral region in Israel, and, as such, it creates significant complexities and challenges for regional development policymakers. As a peripheral region, the Galilee suffers from major weaknesses such as low income, low productivity, poor services, and negative migration, especially of young populations. The paper presents the theoretical foundation of an integrated approach which includes an assessment using the Industrial Maturity for Advanced Manufacturing (IMAM) tool developed at the Samuel Neaman Institute, Technion, Israel. The IMAM scale assesses the maturity and ability of industrial companies to adapt and implement innovative and advanced manufacturing technologies and processes. We suggest that an integrated approach combining a strategic plan and an IMAM assessment can be replicated in other industrial zones.

Keywords*: fourth industrial revolution, strategic program, industrial maturity, regional development, SWOT analysis, innovation and productivity*

1. INTRODUCTION

As value and production chains become more trans-territorial in the era of globalization and Industry 4.0, the regional development level of analysis gains more salience. Regional development is a complex challenge that needs to address multiple interrelated goals. Traditionally, the main economic measures driving regional development, at both the national and the regional levels, are the GDP and GDP per capita. In contemporary developed societies characterized by growing income inequality, these measures may not provide an accurate assessment of the situation in which most people find themselves and of societal well-being (Stiglitz, Sen, and Fitoussi, 2010). This observation also applies to regional disparities which lead to the resurgence of regional economics, processes of development, growth, and sustainability. Consequently, careful attention should be given to long-term factors such as education, health services, welfare, and research and development (R&D) investments at the regional level. Advanced technologies also may play a major role in bridging the interregional well-being gap by advancing proximity – physical and virtual (Capello and Nijkamp, 2009). An essential vehicle for regional development is proper policy measures, such as moving jobs to region with high unemployment; indirect measures, including better infrastructure, stimulating R&D and innovations, improving education, and providing an attractive environment (housing, recreation, sport, culture); direct measures such as financial compensation, soft loans, low land prices, favorable energy con-

tracts, etc.; and strict direct measures such as relocation of governmental institutions (van Dijk, Folmer, and Oosterhaven, 2009).

Recent directions in theories of regional economics shed light on two main approaches: more realism, and more dynamics (Capello, 2008). We stress the following trajectories: understanding endogenous factors that support regional competitiveness (industrial specialization, infrastructure, location, entrepreneurship, realistic economic clusters, agglomeration economies, transportation costs, human resources, etc.); knowledge, which is embedded in human capital, as an endogenous driving force to development; and nonlinear trajectories of development (Krugman, 1991; Romer, 1986; Lucas, 1988; McCann and van Oort, 2009; Minerva and Ottaviano, 2009; Faggian and McCann, 2009).

Due to measurability difficulties, general modelling logic entails static assumptions. The focus on the "representative" firm and on pecuniary economies, while ignoring dynamic nature of externalities such as human capital and technological spillovers, underpins the critique of models (McCann, 2005; Fingleton and McCann, 2007; McCann and van Oort, 2009). Moreover, careful attention should be given to institutions and their relationships with knowledge. The role of institutions, and more specifically efficient institutions, in economic development is paramount (North, 1990; Aghion and Howitt, 1998, Helpman, 2004). Considering the dynamic environment of the 21st century and the Fourth Industrial Revolution, the breaking down of barriers between national economies make the region a fundamental basis of economic and social life (Fischer and Nijkamp, 2009). Therefore, the variance among regions should be considered, and for better assessment of potential regional development, it should be recommended to critically use generalizable predictions based on representative models. Hence, geographical thinking should be intertwined with economic analysis, and pinpointing the need for dynamic measuring tools is unquestionable. This dynamism gives central importance to entrepreneurship among processes affecting regional growth. Entrepreneurship encourages innovative activity and always involves economic risk taking, which nonlinearly leads to development and growth (Acs, 1994; Audretsch, 2004; de Groot et al., 2004).

To bridge gaps between theories and practice, we follow Cuadrado-Roura (2001), who identified seven attributes of succeeding regions in terms of development and growth:

1. The presence in a region of a group of medium-sized cities together with a large city.
2. The presence of medium- to high-educated labor, preferably with moderate wages.
3. Physical proximity to major markets and large urban centers together with access to new ideas.
4. Availability of business services such as consulting, advertising, financing, etc.
5. A facilitating local authority with well-developed strategies and leadership.
6. A positive social environment facilitating cooperation among institutions and organizations.
7. Many small and medium-sized industries easily enabling knowledge spillovers, as opposed to the dominance of a few large firms.

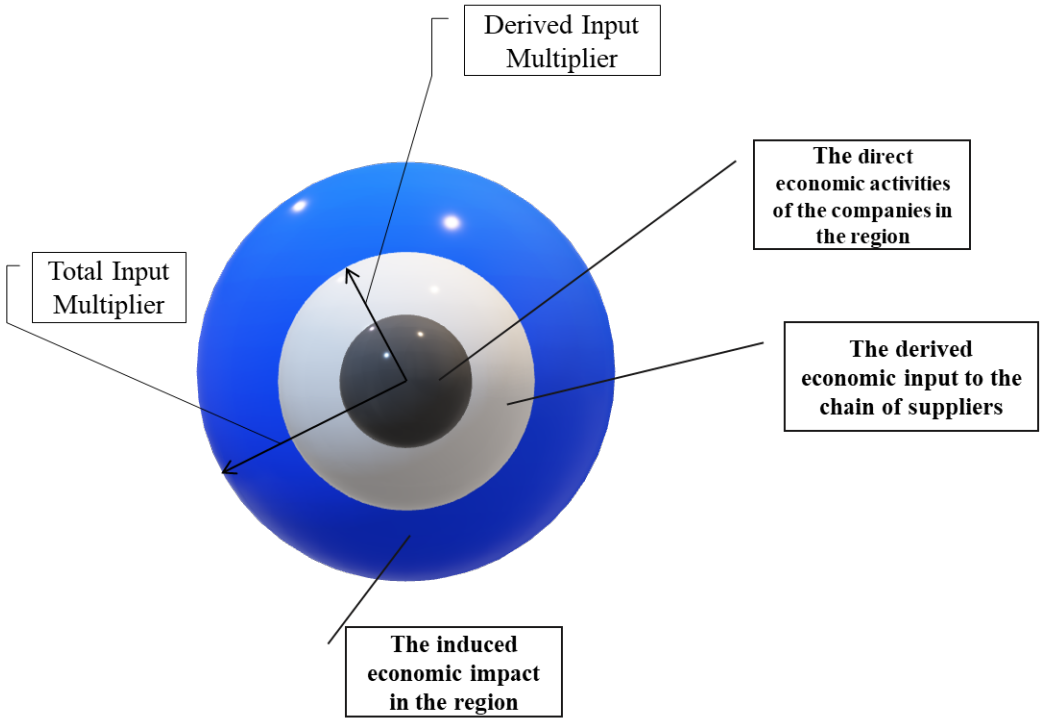
This article introduces a comprehensive integrated methodology for regional development and implements it in a case study. The article is structured as follows: Section 2 presents a survey of different models, the third section introduces the integrated methodology for regional development, Section 4 discusses the case study of Northern Israel, and the last section concludes with a discussion.

2. THEORETICAL BACKGROUND

2.1 Competitive advantage and the clusters approach

The importance of connections among branches of businesses and industries gained the interest of economists in the 1970s (Czamanski, 1974, 1976). These connections among manufactures are called "value chains" and the geographic concentration of manufactures which are creating and operating relationships among them are called "geographic clusters." Analysis of these networks among businesses and manufacturers is used to build and to calculate matrices which are the basis for conventional analysis methods such as "input–output," the gravity model (Haynes and Fotheringham, 1984), and the Diamond Model (Porter, 2000, 2003; Delegdo, Porter, and Stern, 2014).

Figure 1: The Input–Output Model

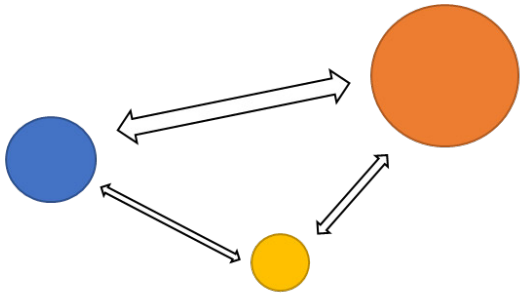


Adapted from Leontief and Strout, 1963

The "input–output" model (Figure 1) developed by Leontief and Strout (1963), represents the flow of money in an economy, primarily through connections between industries, i.e., the extent to which different industries are buying from and/or selling to one another in a geographic region. An "input–output" model also accounts for such factors as government spending, housing spending, investments, imports, and exports, all of which help provide a full picture of what is happening in an economy. This model was used to assess the economic impact of Teva and Intel on the economy of Israel (Fortuna, Neev, and Freeman, 2014; Fortuna et al, 2018).

The gravity model (Figure 2) demonstrates the general form of spatial interaction encompassing any movement over space that results from a human process. It includes journeys to work, migration, information and commodity flows, student enrolments and conference attendance, the utilization of public and private facilities, and even the transmission of knowledge. Gravity models are the most widely used types of interaction models. They consist of mathematical formulations used to analyze and forecast spatial interaction patterns. The gravity model as a concept is of fundamental importance to modern scientific geography because it makes explicit and operational the idea of relative as opposed to absolute location.

Figure 2: Illustration of the Gravity Model

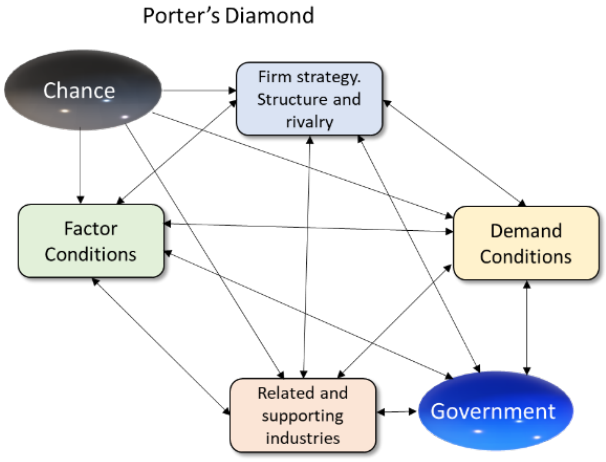


The shorter the distance between two locations, and the greater the mass of either or both locations (like size of population or attractive economy), the greater the economic pull and economic attraction between the locations

Adapted from Haynes and Fotheringham, 1984

The strategic analysis based on Porter's (1990) Diamond Model (also known as the Theory of National Competitive Advantage of Industries) is a diamond-shaped framework (Figure 3). It explains why certain industries are competitive internationally, whereas others are not, and why some companies perform consistent innovations, compared to others. Porter argues that any company's ability to compete in the international arena is based mainly on an interrelated set of location advantages that certain industries in different countries possess, namely firm strategy, structure and rivalry, factor conditions, demand conditions, and related and supporting industries.

Figure 3: The Porter Diamond Model for Cluster Development



Adapted from Porter, 2018

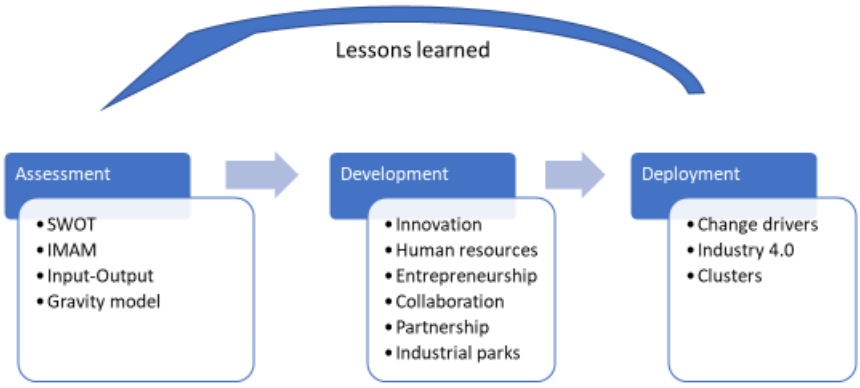
The Diamond Model of Porter describes the main benefits of the regional clusters to the competitiveness of the businesses in the clusters and to the economic growth of the region:

- Productivity can be improved through the availability of common resources such as an experienced workforce, shared knowledge, and information.
- Innovation can be nurtured through sharing ideas and innovative technologies.
- New businesses can be created through promoting the business environment and ecosystem.
- Positive spillovers across complementary economic activities can provide an impetus for agglomeration: the growth rate of an industry within a region may be increasing in the "strength" (i.e., relative presence) of related industries.
- Industries located in a strong cluster register higher employment and patenting growth. Regional industry growth also increases with the strength of related clusters in the region and with the strength of similar clusters in adjacent regions.
- There is evidence of complementarity between employment and innovation performance in regional clusters: both the initial employment and the patenting strength of a cluster have separate positive effects on the employment and patenting growth of the constituent industries.
- New regional industries emerge where there is a strong cluster. These findings are consistent with multiple types of externalities arising in clusters, including knowledge, skills, and input–output linkages.

3. AN INTEGRATED METHODOLOGY FOR REGIONAL DEVELOPMENT

The model described in the case studies is an integrated framework for policy making in regional development. The framework is depicted in Figure 4. This framework includes four stages: assessment, development, deployment, and lessons learned. The assessment stage can combine quantitative methods such as the gravity model, the input–output model, IMAM (see Section 4.4), and qualitative models such as SWOT (see Section 4.2). The development stage includes several elements of regional development like innovation and entrepreneurship, human resources development, collaboration and partnerships, and industrial parks. The deployment stage consists of several initiatives such as developing infrastructure change drivers and growth driver engines, deploying Industry 4.0, advanced manufacturing and engineering technologies, and supporting economic clusters. These initiatives are presented in the context of case studies.

Figure 4: Integrated Framework for Regional Development



3.1 The Role of Entrepreneurship in Regional Development

Entrepreneurship is a dynamic, ever-changing entity in constant interaction with its ecosystem. It begins with an idea sparked by the identification of an opportunity within the abilities of the business team. The main challenge lies in identifying an opportunity and approaching the matching market by materializing this idea into business success in which the outcome may be different from the initial idea. The essence lies in finding that opportunity, exciting the market and raising demand, planning the scenario, and delivering a winning solution, while managing the risk presented by uncertainty. This entity exists in a challenging ecosystem consisting of highly competitive market conditions and requirements, such as the need for faster development and delivery of new and differentiated products, services, value, and ever-growing customer expectations.

The ecosystem, and its regional cultural support and empathy for innovation, are key factors in the emergence of entrepreneurships. If it forms a sustainable local ecosystem, it can accept, absorb, and nourish exceptional and nonconservative concepts, approaches, and operations. This tendency, combined with the practice of appreciating calculated risk-taking and tolerance to failures, forms an encouraging incubator for various initiatives. These are only a handful of the issues to be considered. A mindset of dealing with a complex situation in a dynamic ecosystem is required, and often timing is of the essence. One should not disregard all relevant aspects of all factors involved, including human factors. Reasoning the main systemic components and carefully planning how to use a systemic concept may vastly increase the chances for the success of entrepreneurship initiatives in the region, which supports and advances entrepreneurship at the system level and the practical level. Entrepreneurship in system development was discussed in detail by Katz (2020).

3.2 The Role of Innovation and Creativity in Regional Development

Managing the innovation and creativity process also demands a holistic approach at the regional level. The idea generation lifecycle includes the following major milestones: focus selection, ideas generation, harvesting, assessing ideas, treatment, and ideas implementation. As indicated in Porter's model (Porter, 2000, 2003) innovation is nurtured through the sharing of ideas and innovative technologies in the cluster ecosystem. It happens on the micro level through personal connections and communications, and on the macro level through collaborations of companies and institutes. As mentioned subsequently, the theory of the strength of weak ties (Granovetter, 1973; Bakshy et al, 2011) explains the barriers to and the enablers of innovating and sharing ideas in regional periphery, through connections on the micro level.

3.3 The Role of Human Resources in Regional Development

The main source for successful regional development is the human resources who act and work in the region. There is a need for businesspeople, man-

agers, engineers, and workers who have the knowledge and expertise which fit the jobs of the businesses in the region. This may be called the regional intelligence. In addition, the regional institutes for training, such as academia and vocational programs, can fill the gaps of knowledge in the region through life-long training. The managers and workers not only should have knowledge for the jobs in the region, but also should have leadership and creativity skills. Creative workers have been shown to have a direct and an indirect impact on regional innovation (Sleuwaegen and Boiardi, 2014). Creative workers have an impact on innovation that is differentiated from the presence of regional intelligence, as measured by the availability of human capital. In addition, in peripheral regions it is important to create regional loyalty and identification with the regional vision and goals. Such regional human resources development programs may be created.

3.4 The Role of Collaboration, Partnership, and Industrial Parks in Regional Development

Collaboration and partnership among peoples, companies, and institutes in the region are essential drivers for successful regional development. This happens through the spreading and sharing of ideas and innovations. Industrial parks are excellent place for collaboration and partnership of the companies located in the park, through the leadership of the industrial park management.

4. CASE STUDY FOR REGIONAL DEVELOPMENT: DATA AND APPLICATION OF THE INTEGRATED METHODOLOGY

4.1 Background data

Following the proposed integrated methodology for regional development, a real case study of a strategic initiative to advance the geographical area of Northern Israel was conducted. The initiative involved a major strategic regional planning program followed by a focused assessment of organizational maturity in terms of Industry 4.0 implementation. The assessment was based on the IMAM scale described in Section 4.4 (Adres, Kenett and Zonnenshain, 2020). The methodologies and approaches described here can be adapted to other regions and industrial zones, and therefore provide a generic approach to the development of regions with industrial parks.

The first step was to collect and assess relevant data on Northern Israel, which is a heterogeneous area in terms of industrial activity, population structure, socioeconomic status, and educational aspects. Table 1 compares employment and salaries levels in this region to those of other regions in Israel.

Table 1 shows that 16.5% of Israel's population lives in the North, and 14.7% of the employees in Israel work in the North. The unemployment rate in the North region is the highest in Israel, 8%, compared to the average of 6.2%. In addition, salaries

Table 1: Employment and Salaries in the North Region Relative to Other Regions in Israel

Region	Percentage of population	Employment rate	Participation rate	Unemployment rate	Average compensation per job in the industry
Central District	24.2%	27.5%	70.2%	5.1%	115.6%
Tel Aviv District	16.4%	18.9%	67.3%	5.2%	94.1%
North District	16.5%	14.7%	58.0%	8.0%	79.7%

Adapted from Central Bureau of Standards, 2013

in the North are relatively low, only 79.7% of the national average.

The Northern region of Israel is home to a large portion of Israel's industry – about 34%. However, most of this industry is traditional, and its productivity and export rates are relatively low.

Industry in the North is strong in metals (38%), electronics (35%), and food (35%) (Figure 5).

There is migration from the North to the central regions of Israel, with high rates of migration among young people. The Israeli Ministry of Economy, in a joint program with the Samuel Neaman Institute, identified five strategic goals for improving the economic conditions in Northern Israel (Israeli Ministry of Economy, 2014). These goals are:

1. Growth of the economic system in the North;
2. Improvement of the socioeconomic status of the population in the North;
3. Advancing the joint economy of the Arab and Jewish populations in the North;
4. Exploiting the potential of the Arab population as a growth advantage; and
5. Reversing the negative migration from the North and attracting strong populations.

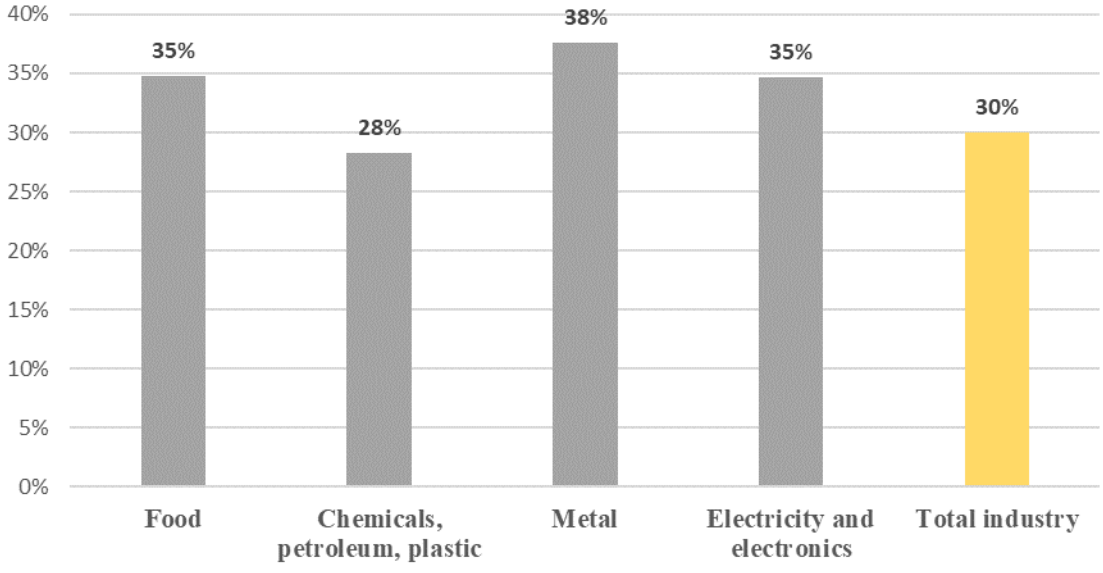
The first two goals relate to the entire population in the North of Israel. Goals 3 and 4 relate to the Arab population and its potential for the growth of the North. The fifth goal presents a challenge to achieve better employment figures, a better business environment, higher industrial productivity, and improved quality of life indicators. This aims at reversing the migration trends and attracting a stronger and younger population to the North.

4.2 SWOT Analysis and Assessment of the North

The SWOT (strengths, weaknesses, opportunities, threats) assessment and analysis of the Northern region was driven by the data collected and based on inputs solicited from 80 individuals with leadership positions in different areas, representing various positions within the government, industry, municipality, education, healthcare, academia, and NGOs. On-site visits were organized to several industrial plants and municipalities in order to receive first-hand impressions of and information about opportunities and barriers in the North.

This provided both quantitative and qualitative data that were combined with past programs and reports that discussed the economic and social con-

Figure 5: Percentage of Israel's Employees Who Work in the North and Haifa in Several Industrial Sectors



Adapted from Central Bureau of Standards, Industrial Review, Board 29, 2013

ditions in the North of Israel. All this information led to several discussions and roundtable brainstorming sessions that produced the SWOT of the North. The main findings of the SWOT were as follows.

Strengths:

- Large portions of the traditional industries are located in the North, and they have significant growth potential.
- The population in the North is diversified, with good qualities and historical connections to the North.
- The Arab population in the North is well educated.
- The basic relationships among the different cultures are good.
- The North of Israel is green, beautiful, and holy to Christians; hence it attracts both local and foreign tourism.

Weaknesses:

- The North lacks large vertically integrated companies with effective human resources growth.
- The North lacks sufficient professional work force.
- The North is a periphery far from the nation's decision makers.
- Many municipalities lack substantial cooperation.
- The city of Haifa is not perceived as and is not acting as the capital city of the North.
- The Jewish and Arab economies in the North lack integration.
- Investment in innovation in the North is relatively low.

Opportunities:

- There are many traditional and classical industries in the North with a potential for growth through innovation and productivity improvement.
- There is a good basis for life science clusters with many active companies (more than 290), eight hospitals with research capabilities, and several good research institutes in tes area.
- The Arab population in the North has a growing number of experts, workers, and students in the area of life sciences.
- There is a good basis for clusters that focus on water, with many active companies (more than 300) and several research institutes.
- The daily relationship between Arabs and Jews is good and offers an opportunity for joint development.
- Recent substantial government investments in public transportation and roads in the North, as well as roads connecting the North to the Center, may promote businesses development and housing opportunities.
- The new deep-water seaport in Haifa presents an opportunity to develop the economy of the North.
- There is potential for an international airport in the North, which may positively impact the economy of the North.
- The ultra-orthodox population in the North is growing as a community, with good qualities of work and study.
- The North is green and attracts ethnic and nature tourism.

Threats:

- The absence of substantial economic growth in the North in the next few years will encourage the young population's tendency to leave the region.

4.3 A Strategic Analysis of Northern Israel

A strategic analysis of the Northern region of Israel was conducted in "The North Project" (Zonnenshain, Fortuna and Dayan, 2015). The program studied the economic system of the North from various facets – industry, services, academia, municipalities, education, healthcare, transportation, large companies, small companies, different sectors of the population, etc. This also was based on the systemic approach of the Systems Engineering methodology (Zonnenshain and Shtauber, 2015) The program followed the integrated framework for regional development presented previously: assessment, development, and deployment. The assessment stage included the SWOT analysis and the IMAM scale (Adres, Kenett, and Zonnenshain, 2020). The development stage included identifying infrastructure change drivers and developing

growth drivers' engines. In the deployment stage, practical plans for deployment were prepared with the relevant partners and stakeholders.

4.3.1 Identifying infrastructure change drivers

This study proposes four change drivers designed to impact the infrastructure in the North in nonlinear paths:

1. Moving specified technological industries and plants of the Israeli Defense Forces (IDF) from the central part of Israel to the North. This move can add at least 2,000 job opportunities for technical and logistic staff. In addition, it will create 10,000 jobs for suppliers and subcontractors.
2. Deepening and upgrading the port in Haifa so that it can accommodate large modern containers ships. The government is investing about NIS 6 billion through 2021 to build this port. It is planned that this port will employ about 7,000 people in various positions in various industries.
3. Building an international airport in Ramat David. This move will create thousands of employment opportunities, both for the construction and the operation of this airport. This airport can change the status of the North region for international business and tourist communities.
4. Leveraging the transportation revolution in the North to develop new business and housing areas along the recently constructed railroads and along the new major routes in the North. Based on the transportation-oriented development (TOD) methodology, we propose several suggestions for developing businesses and housings centers.

4.3.2 Developing growth drivers' engines

The study also proposes several growth drivers that do not represent "business as usual." These growth drivers, aimed at creating employments opportunities, are:

1. Building and advancing an industrial scientific cluster in the area of life sciences. This cluster includes a full ecosystem of manufacturing plants, academic institutions, research institutes, start-ups, incubators, hospitals, and labs, all with advanced capabilities in life sciences. In the North region and in the Haifa area, there are impressive assets of manufacturing plants (representing more than 300 companies) and research institutes that use state-of-the-art technology in the life sciences. In addition, an impressive number of the Arab population have knowledge, experience, and expertise in this area. The North Project program proposes that there should be a national policy in Israel to advance the life sciences in the North of Israel. Furthermore, it is proposed that this policy should include support for international medical tourism in the North.
2. Building and advancing industrial-scientific water cluster. Similar to the life sciences cluster, it is proposed to build in the North an industrial-scientific ecosystem in the field of water. The North also has assets of manufacturing plants and research institutes. The Arab sector also can be integral in this cluster, with engineers, researchers, technicians, workers, and laboratory assistants.
3. Advancing innovation and productivity in the classical industry in the North. The North has a relatively large numbers of classical and traditional industries (34% of all classical industry sales, and about 115,000 employees), but the productivity, salaries, and export rates are relatively low. Innovation and excellence are recommended to improve productivity. The North Project program proposed specific tools for productivity and competitiveness improvements, such as investing in research and development, advancing automation, introducing advanced manufacturing, developing industrial parks that are oriented toward innovation and entrepreneurship, etc.
4. Better integrating the Arab sector in the Northern economy to create a common economy. Upgrading the economy of the Arab sector is one of the most important and crucial challenges in the North Project program. It is proposed to improve the Arab sector by creating a common economy with the Jewish population. This program includes specific steps for creating the common economy, such as improving the socioeconomic situations of Arabs in the North,

including initiating dialogue among the two populations to advance trust, create collaborative industrials parks, advance the employment of Arabs with academic degree in quality roles, encourage Arabs to join high tech organizations, and integrate Arabs into the life sciences and water cluster initiatives. This part of the program is prepared with representatives of the Authority for Economic Development of Minorities in the Prime Minister Office.

5. Advancing tourism in the North. Annual tourism revenue in the North is about NIS 10 billion. The tourism industry offers various employment and businesses opportunities to different populations. The North Project program explored several alternatives for developing tourism in the North and chose ethnic and cultural tourism, which demonstrates the highest possible revenue and future opportunities for sound investment. Furthermore, as mentioned previously, it is proposed to advance medical tourism as part of the life sciences cluster. As mentioned previously, it relates to building an international airport in the North to further advance tourism development.
6. Integrating the ultra-orthodox population in the North economy. Currently, 130,000 ultra-Orthodox Jews live in the North. This population may double in 15 years through natural growth and immigration. The North Project program proposed several tools and steps for developing a productive and quality ultra-Orthodox population in the North. These steps include, for example, academic and technical education, and integrating this community into the life sciences and water clusters.
7. Advancing innovation in the North. As mentioned previously, introducing innovation through industry and other enterprises in the North is a key factor for the success of the economy system. The Innovation Center in the Technion proposed, as part of this project, a holistic program to introduce innovation in the North. The program will include specific steps, such as education of leadership for innovation, teaching processes for innovation, creating collaboration between academia and industry, initiating pilot projects for innovation in the industries through advanced manufacturing, etc.
8. Advancing small and medium enterprises (SME) in the North. Small and medium enterprises are an important part of the North's economy. Through meetings with SME owners, and through national reviews, it was found that there are a significant number of barriers to the development and the success of SME in the periphery of the North. The theory of the strength of weak ties (Granovetter, 1973; Bakshy, Rossen, Marlow and Adamic) explains the barriers to innovating and sharing ideas in the periphery. It is very difficult for SMEs to survive in the economic and business environment of the Northern periphery. Therefore, special government and municipal help and support for the SMEs in the North are proposed, such as offering special loans, providing business-consulting services, lowering the burden of unnecessary regulations, and providing accessibility for purchase by government and public institutions.

4.3.3 Deployments plans

The aforementioned joint strategic program was developed during 2014–2015 and concluded with several practical deployment's plans (Israeli Ministry of Economy and Samuel Neaman Institute, 2015). These plans were the basis for several major decisions and actions of the Government of Israel for upgrading the North of Israel. Some of the actions were already initiated, such as building a new port in Haifa with deep water, improving the transportation system in the North of Israel, upgrading the economy of the Arab sector, and advancing innovation in the industries through advanced manufacturing (see Section 5).

4.4 Industry 4.0 – Maturity Assessment Model Development

During the last decade, industry in advanced economies has experienced significant changes in its engineering and manufacturing practices, processes, and technologies. These changes have the potential to create a resurgence in the engineering and manufacturing activities. This phenomenon is often referred to as the Fourth Industrial Revolution or Industry 4.0. It is based on advanced man-

ufacturing and engineering technologies, such as massive digitization, big data analytics, advanced robotics and adaptive automation, additive and precision manufacturing (e.g., 3D printing), modeling and simulation, artificial intelligence, and the nanoengineering of materials (Pai, 2014). This revolution presents challenges and opportunities for the systems, manufacturing, and process engineering disciplines. Several authors have discussed approaches to assess organizational readiness to advanced manufacturing challenges (McKinsey & Company, 2016; President's Council of Advisors on Science and Technology, 2014; PwC, 2016; Shuh et al., 2017). Under Industry 4.0, systems have access to large types and numbers of external devices, and to enormous quantities of data, which must be analyzed through advanced data analytics (Kenett and Shmueli, 2016; Kenett, Zonnenshain, and Fortuna, 2018).

To help companies make progress on the roadmap toward Industry 4.0, we developed a questionnaire-based tool that assesses the current maturity level of a specific or a group of industrial companies and highlights a set of focused areas for the companies to pursue in an effort to deploy Industry 4.0 methods. We call this the model of Industrial Maturity for Advanced Manufacturing (IMAM). The next section is an introduction to IMAM. More details were given by Adres, Kenett, and Zonnenshain (2020) and Zonnenshain et al. (2018).

The IMAM scale helps companies to assess their strengths and weaknesses and to prepare an improvement plan. It also provides companies with a tool for evaluating their actual improvements and achievements and serves as an effective benchmarking tool. The IMAM framework consists of an assessment tool based on the Software Engineering Institute's Capability Maturity Model Integration (CMMI) approach. It is specifically designed for assessing the maturity level of a company in the area of advanced manufacturing and engineering. The CMMI maturity level assessment in systems and software development was presented by Kenett and Baker (2010). The IMAM scale was established and validated using an accepted methodology (De Winter, Dodou, and Wiernga, 2009; De Vellis, 2012; Adres, Vashdi, and Zalmanovitch, 2016). The content of the IMAM was validated by an international experts' survey. The IMAM is a multidimensional latent construct constructed at the basic level with 14 identified application areas (subdimensions) which are relevant for advanced manufacturing and engineering. For each subdimension, we developed a self-report questionnaire, based on statements (items) measured on a five-point Likert-type scale. The 11th subdimension concerns information and knowledge management and builds on the information quality framework presented in Kenett and Shmueli (2016) and Reis and Kenett (2018). We added a concluding item stating, "It may be said that in general that the advanced manufacturing status of our company is in level…" (1–5 on a Likert scale). The dimensions are:

1. Strategy and long-term planning for advanced manufacturing
2. Human resources for advanced manufacturing
3. Communication with customers and the market
4. Processes in manufacturing
5. Processes in engineering
6. Business processes
7. Processes in maintenance
8. Logistics processes
9. Processes in the supply chain
10. Processes in product life cycle
11. Information and knowledge management
12. Processes in cyber assurance
13. Investment in infrastructure and equipment
14. Actual improvement outcomes and results

In each area, several possible actions and activities can be considered by companies aiming at the advanced maturity level. Statistical analysis of these 14 subdimensions showed that they converge into four higher-level dimensions: (1) value chain; (2) infrastructure; (3) monitoring and control processes; and (4) engineering processes. These four dimensions statistically converge to the IMAM scale, which is an individual-level characteristic that can be understood as a single industrial organizational construct, reflecting the competence and maturity for advanced manufacturing implementation. More details on the IMAM model are given in Chapter 22 of Kenett, Swarz, and Zonnenshain (2020).

4.4.1 Analysis of IMAM assessments from companies in Northern Israel

Self-assessment and IMAM scores of 15 industrial companies in Northern Israel are presented in Figure 6. We approached the industrial companies in the North of Israel based on our efforts and experience from the North Project.

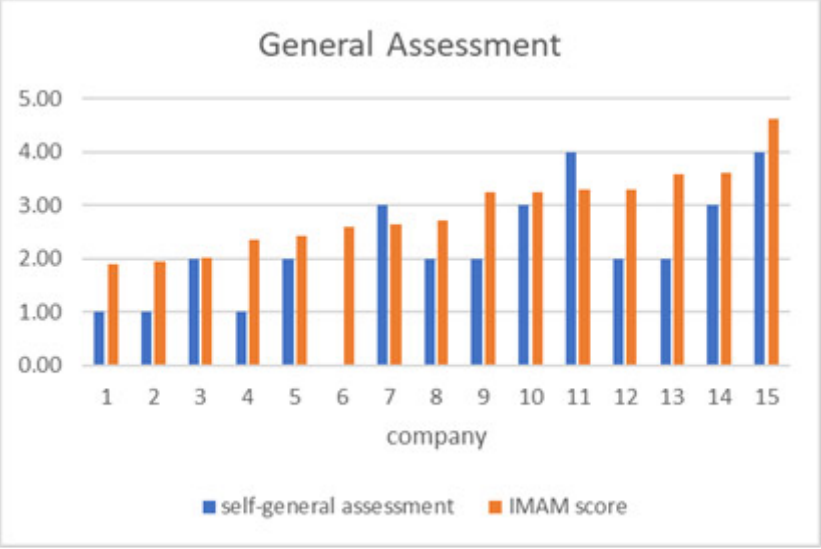
Figure 7 shows the subdimensions of the Infrastructure dimension.

Figure 8 shows the value chain subdimensions.

Figure 9 shows the subdimensions of monitoring and control processes.

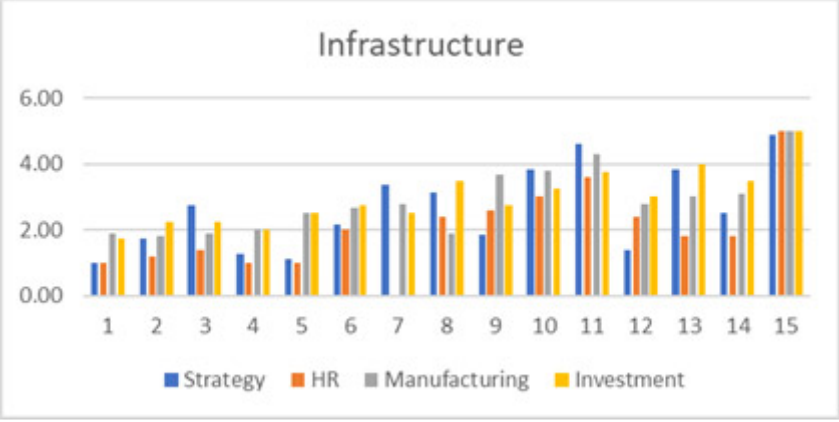
Figure 10 shows the engineering scores.

Figure 6: General Self-Assessment and IMAM Score



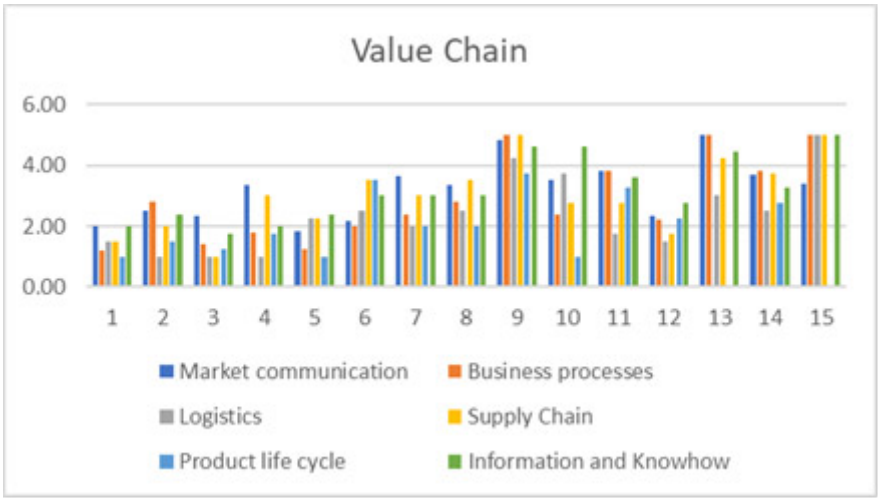
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 7 : Infrastructure Subdimension Scores



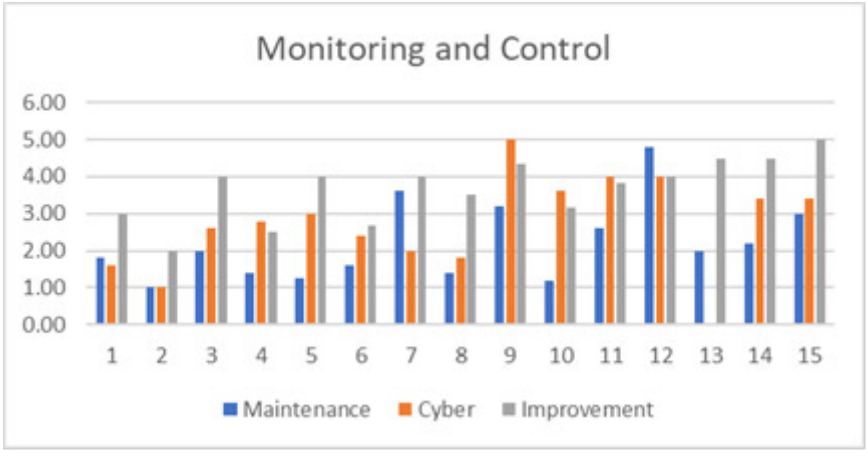
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 8 :Value Chain Subdimension Scores



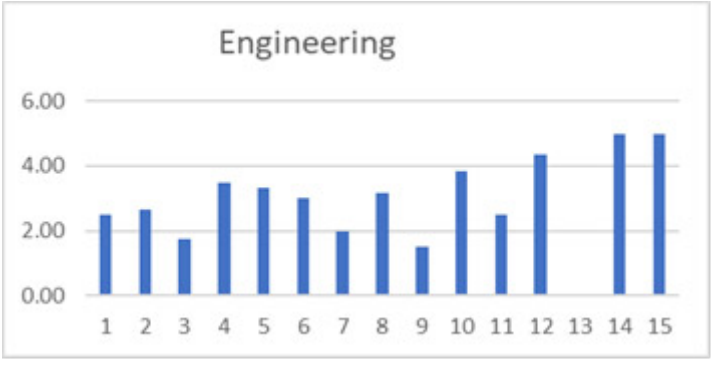
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 9: Monitoring and Control Subdimension Scores



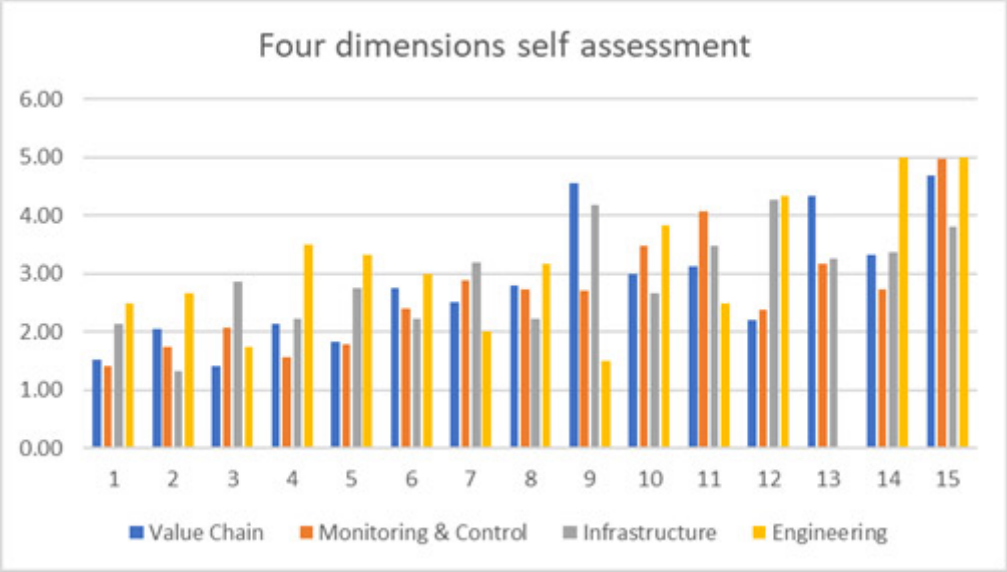
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 10: Engineering Scores



Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 11: Scores of the Four Dimensions of the Self-Assessment



Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 11 compares the four dimensions for the 15 companies.

The means, medians, and standard deviation for the general self-assessment; IMAM score; and the four dimensions are presented in Table 2. Self-assessment may be affected by overcriticism on the one hand, and by social desirability on the other hand.

However, all means, and medians were less than the mid-point, 3, except for engineering. This indicates a need for general improvement in the industry; hence, this finding calls for planning a national policy.

To analyze the data, we used a methodology and tools developed to highlight areas for improvement and areas of excellence (Kenett and Salini, 2011). A basic element in this analysis is the computation of the proportion of 1 and 2 ratings, labelled Bot1+2, and the proportion of 5 ratings, labelled Top5. The analysis shown subsequently builds on two standard statistical methods, control charts for proportions (p-charts) and analysis of variance (ANOVA) with Student's *t*-tests for paired comparisons, controlled for multiple comparisons. More details of this analysis were given by Kenett and Zacks (2014).

Table 2: Descriptive Statistics of IMAM Responses

		General self-assessment	IMAM score	Value Chain	Infra-structure	Monitoring and control	Engineering
N	Valid	14	15	15	15	15	14
Mean		2.29	2.8998	2.8174	2.6728	2.9311	3.1488
Median		2.00	2.7328	2.7500	2.7125	2.8667	3.0833
Std. Deviation		0.994	0.74718	1.04668	0.96802	0.82522	1.10852
Range		3	2.72	3.27	3.56	2.93	3.50
Minimum		1	1.89	1.41	1.41	1.33	1.50
Maximum		4	4.61	4.68	4.97	4.27	5.00

Based on this analysis of 15 respondents, representing industry in Northern Israel, overall strengths and weaknesses were identified for the companies which participated in the survey (Table 3).

Table 3:Strengths and Weaknesses of Industrial Group with Respect to Industry 4.0 Implementation

Strengths	Weaknesses
Communication with the customers and the market	Strategy and long-term planning for advanced manufacturing
Engineering processes	Human resources for advanced manufacturing
Processes in the supply chain	Processes in maintenance
Information and knowledge management	Processes in product life cycle

The IMAM maturity level assessment helps to achieve two major goals in efforts to implement advanced manufacturing.

Goal 1: Assessing the organizational maturity level of a specific company and positioning its level on a 1–5 maturity ladder. IMAM also helps companies design an advanced manufacturing program based on its strengths and weaknesses, and it helps the company assess progress along the maturity ladder.

Goal 2: Identification of regional strengths and weaknesses in the dimensions of advanced manufacturing. This can be done at the regional level, but also at the national level and for different industrial sectors.

Based on the findings of this survey, there is awareness in the industrial companies in North of the importance of advanced manufacturing for the success of these companies. However, previously this awareness did not drive most of the companies in the region to develop a strategy and long-term planning for advanced manufacturing. We claim that this conservative attitude may risk the survivability of traditional companies in the North of Israel. It is proposed that the integrated framework for regional development can support and promote the Industry 4.0 implementation in the industries in the region.

5. DISCUSSION AND CONCLUSION

This paper introduced an integrated framework for regional development. This framework includes four main components: assessment, development, deployment, and lessons learned.

As a case study for this framework, we presented a joint strategic program for the growth of the Northern region of Israel which was conducted for the Ministry of Economics during 2014–2015. This program proposes four change drivers, designed to change the infrastructure in the North in nonlinear paths. This study also proposes several growth drivers that do not present "business as usual" and that are aimed at creating employment opportunities. It led to several decisions and actions of the Government of Israel; some of these actions already have been initiated.

The additional component of the integrated methodology for regional development addresses the Industry 4.0 implementation efforts which were conducted in industrial companies in Northern Israel. It is based on the Industrial Maturity for Advanced Manufacturing scale, which assesses the maturity and ability of industrial companies to adapt and implement innovative and advanced manufacturing technologies and processes. The findings from 15 companies from the North of Israel are presented. These findings were used to validate the IMAM scale, and to reveal the strengths and weaknesses of the industries in the north of Israel.Both case studies demonstrated the framework for regional development in Northern Israel.

The combination of a strategic program, which gave a wide and long-term perspective, with the Industry 4.0 implementation based on IMAM assessment, which is focused on a mid-term perspective, represent the proposed integrative methodology approach. It helped to pool together stakeholders from government, business, industry and academia, including various associations and NGOs. The IMAM assessment gave individual managers of industrial organizations specific feedback that can impact their annual plan.

The combination of a strategic program and an Industry 4.0 implementation based on IMAM assessment can be replicated in other regions. It can

be combined with deployment planning initiatives and middle-of-the-road pulse-taking evaluations.

This paper demonstrated successful implementation of four theoretical approaches and practical tools: the input–output model, through the direct economic activities of the companies in the region, through the derived economic input in the chain of suppliers and the induced economic impact in the region; the gravity model, by journey-to-work, migration of families and peoples, and flows of information and commodity; Porter's Diamond Model for developing clusters in the areas of life sciences and water engineering by productivity improvement through the availability of common resources, nurturing innovation through sharing advanced ideas and technologies, and creating and supporting new businesses through promoting doing business environment and friendly ecosystem; and applying SWOT by advancing the strengths of the region like the traditional industries and the well-educated Arab population. These four approaches are integrated through four practical stages of an integrated framework for regional development: assessment, development, deployment. and lessons learned. These approaches were successfully applied for the case study of the Northern region of Israel. The implementation process includes elements such as innovation, creativity, and entrepreneurship, such as the Industry 4.0 initiative; infrastructure change drivers and growth engines; and promotion of the human resources. All are important for the development and execution of improvement program in the Northern region of Israel.

The program for developing the North of Israel presents initiatives which demonstrate the bridging of gaps between theories and practice for the benefits of this region, such as the presence of a large city (Haifa) with a group of medium sized cities; the presence of medium- to high-educated labor; positive social and economic environment facilitating collaboration among peoples, institutions, and organizations; etc.

EXTENDED SUMMARY/IZVLEČEK

Regionalni razvoj predstavlja kompleksen izziv za oblikovalce politik na vodilnih vladnih, poslovnih in industrijskih položajih. Četrta industrijska revolucija oziroma Industrija 4.0 je ustvarila integrirane priložnosti za razvoj krožnega gospodarstva, ki vključuje akterje iz različnih družbenih slojev. Raziskava predstavlja celostni pristop, ki združuje običajne metode strateškega načrtovanja z orodji četrte industrijske revolucije. Obravnavane metode regionalnega razvoja so prikazane s pomočjo študije resničnega primera razvojnega projekta, katerega namen je spodbuditi regionalni razvoj. V raziskavi predstavljeni integriran pristop navaja priložnosti in izzive regionalnega razvoja, zanimive tako za raziskovalce kot oblikovalce politik. Študija primera izhaja iz področja na severu Izraela, imenovanega Galileja. Galileja velja za geografsko in socialno obrobno regijo v Izraelu in kot taka predstavlja izziv za oblikovalce politik regionalnega razvoja. Kot obrobna regija Galileje trpi zaradi mnogih pomanjkljivosti kot so nizki dohodki, nizka produktivnost, slabe storitve in negativne migracije zlasti mladega prebivalstva. V raziskavi so predstavljena teoretična izhodišča celostnega pristopa ter ocena slednjega, pridobljena na podlagi orodja Industrial Mat mature for Advanced Manufacturing (IMAM), razvitega na Institutu Samuel Neaman, Technion, Izrael. Lestvica IMAM ocenjuje zrelost in zmožnost industrijskih podjetij za vključevanje in izvajanje inovativnih in naprednih proizvodnih tehnologij in procesov. Avtorji predlagajo, da se celostni pristop, ki združuje strateški načrt in oceno IMAM, uporabi tudi v drugih industrijskih conah.

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A MULTILAYER PERCEPTRON NETWORK–BASED ANALYSIS TO CONFIGURE SMES STRATEGIC ENTREPRENEURSHIP FOR SUSTAINABLE GROWTH

Ardita Todri
Faculty of Economics, University of Elbasan
ardita.todri@gmail.com.

Petraq Papajorgji
Faculty of Engineering, Canadian Institute of Technology
petraq@gmail.com

Francesco Scalera
Faculty of Economics, University of Bari
roby_sca@virgilio.it.

Abstract

This study analyzed the close interaction among organizational networking and financial mechanisms of growth and sustainable growth of SMEs operating in Albania. Data on 120 SMEs for 2017–2018 were analyzed using multivariate regressions and multilayer perceptron artificial neural networks. Initially, the data were analyzed using multivariate regression analyses to find the correlation between firms' growth measured by three different indicators: return on equity, return on assets and business size. In this approach, growth takes into consideration a firm's liquidity, its operational efficiency, and leverage indicators in addition to organizational characteristics. The results obtained during the initial phase were fed to the multilayer perceptron artificial neural networks model to evaluate SMEs growth and further their sustainable growth process by using the age of the firm, classified into start-up, grown, and matured stages. The model results showed that SMEs in the start-up stage assume a risk-taker approach toward sustainable growth. In the grown stage, they implement a market-timing strategy in selecting investments toward a sustainable growth perspective. Those in matured stage replicate the liberal managerial style of the SMEs in start-up stage, but employ a less aggressive strategy.

Keywords*: SMEs, strategic entrepreneurship, sustainable growth*

1. INTRODUCTION

This paper identified and evaluated the interaction among factors impacting small and medium-sized enterprise (SME) development toward a sustainable growth process. The existing literature shows that the growth process of SMEs is determined by the owner/manager personal and managerial approach (Baldwin, 1994; Frank & Goyal, 2009; Sarwoko & Frisdiantara, 2016; Neneh, 2020). In addition, the literature considers various approaches to SME development based on growth models, social psychology of business owners/managers, and financial performance issues, but no studies have considered the transition process from growth to a sustainable growth.

The presented approach considers SMEs as a heterogeneous group, taking into account their size, age, equity origins, organizational philosophy, and

business strategies. This study does not consider them as closed and separate systems, and does not neglect the significance of networking and organizational mechanisms in their promotion and sustainable growth. There is a lack of studies that consider the strong relationships existing between organizational characteristics and financial aspects of SMEs during the transition process from growth to a sustainable growth.

SMEs are a very relevant part of the economic prosperity of a country and are considered as the backbone of the economy. Thus, it is very important from a theoretical and practical point of view to undertaking a deeper analysis that will help understand the factors influencing their wellbeing. Such an analysis should determine the factors impacting SME growth and indicate how to create a smooth transition versus a sustainable growth process. Thus, it is of high priority to select and use efficient tools that will determine SMEs' situation, and, based on these findings, to define the correct path for sustainable growth.

The presented approach is based on SMEs' financial aspects in close interaction with their organizational philosophy. This research study initially addressed the SME growth market measured through return on assets (ROA), return on equity (ROE), and business size (BoS) (Lee & Tsang, 2001; Naranjo, 2004; García-Teruel & Martínez-Solano, 2010; Czarnitzki & Hottenrott, 2011). Furthermore, in this approach the growth takes into consideration firm's liquidity, its operational efficiency, and leverage indicators in addition to organizational characteristics (Table 1) by using multivariate regression analyses. Next, based on the results of multivariate regression analyses, a multilayer perceptron artificial neural network (MLP-ANN) model is designed and used to specify and evaluate the factors influencing SMEs sustainable growth, measured by firms' age, classified as start-up, grown, and matured. To test our approach, we considered the Albanian market. The 2018 Statistical Register of SMEs (SRS) data show that SMEs account for 99% of total businesses, 81% of total employment, and approximately 67% of business turnover.

The potential contributions of this paper to the existing literature are as follows. First, this study addresses SME growth and sustainable growth issues considering the close interaction among organizational networking and financial mechanisms. This is a novelty of this study. Second, a multilayer perceptron artificial neural network analysis maps sets of input data onto a set of appropriate SMEs output classified in three different growth stages. In the current literature, these models are used to measure only SMEs' performance and creditworthiness. Thus, this study provides a novel utility of these models. Third, this paper presents a valuable model that can be used by SMEs to organize internal information to define their sustainable growth strategies.

The rest of the paper is presented as follows. A literature review reviews existing studies on the subject. Section Methods shows the research context, data used for the analyses, and the scientific approach; section Discussion presents the results obtained by this study; and the last section, Conclusions, presents the findings of this study.

2. LITERATURE REVIEW

Growth of small and medium enterprises is difficult to achieve because of the complexity of the phenomenon according to extensive studies (Czarnitzki & Hottenrott, 2011; Michna, 2007, Abdelaziz, Alaya & Dey, 2018). Sarwoko & Frisdiantara (2016) defined SMEs' growth philosophy as a set of owner's/manager`s personal characteristics, or as their personal approach. The definition also includes the way in which strategic decisions are made; this could be referred to as a managerial approach. The growth measurement process uses indicators such as sales, profit, assets, equity, and their derivatives (Lee & Tsang, 2001; Naranjo, 2004; García-Teruel & Martínez-Solano, 2010; Czarnitzki & Hottenrott, 2011).

In this context, many researches have shown that SMEs' liquidity management is their major challenge. This issue is complex because liquidity is managed day by day in order to meet business short-term obligations due to agency[1] and asymmetry[2] issues

[1] Agency problems in SMEs occur when managers are delegated by owners to act according their interests. This relation inherently creates conflicts of interest in respect of each individual benefit clue.

(Gopinath, 1995; Chittenden, Hall & Hutchinson, 1996; Chow & Fung, 2000; Berger & Udell, 2005; García-Teruel & Martínez-Solano, 2008; García-Teruel & Martínez-Solano, 2010). Good management of business short-term obligations may positively impact SMEs business growth. Nowadays, SMEs try to balance the liquidity management process with operational efficiency and leverage. Studies show a positive relationship between cash management, inventory (INV) turnover, trade credit practices, and profitability (Baños-Caballero, García-Teruel & Martínez-Solano, 2010; García-Teruel & Martínez-Solano, 2010). In addition, SMEs' efficiency and sustainability mainly depends on good working capital management (WCM) practices (Kubíčková & Souček, 2013; Hyz, Stavroulakis & Kalandonis, 2017; Abimbola & Kolawole, 2017). Studies have proven that there is a non-linear relationship between the variables examined by demonstrating that there is a non-monotonic relationship between working capital level and firm profitability (Czarnitzki & Hottenrott, 2011). The same studies make clear that the liquidity management strategy is a crucial element in the survival and further growth of SME businesses. Other studies (e.g., Michna, 2007; Marom, Lussier & Sonfield, 2019; Barwinski, Qiu, Aslam & Clauss, 2020) show that SME survival in a risky and competitive environment requires innovation, and that innovation requires new knowledge. Some studies (Chittenden, Hall & Hutchinson, 1996; Jordan, Lowe & Taylor, 1998; Hall, Hutchinson & Michaelas, 2000; Booth, Aivazian, Demirguc-Kunt & Maksimovic, 2001) used as performance measures the determinants of capital structure. Those studies explain that debt management practices serve as integral parts of financial strategies applied to SMEs. Financial strategies logically affect the ability of the SMEs to grow. Furthermore, small businesses carry different types of debt depending on the services or products delivered (Mazzarol, Reboud & Clark, 2015). Normally, to correctly manage business debts, it is crucial to appropriately estimate current debts, minimum payment schedules, and respective interest rates. The success or failure of a firm depends even on the ability to secure adequate funding, among other issues (Derelioğlu & Gürgen, 2011). Smith (2013) showed that the insolvency of many SMEs depends not only on the owner's underperformance, but also on the underperformance of other sectors of the business. Therefore, owners'/managers' poor debt management or lack of financial management is the main cause of financial problems in SMEs (Jindrichovska, 2013). Reasonably, a serious issue is the maintenance of an optimal capital structure ensuring guaranteed and sustainable growth. Many studies (e.g., Frank & Goyal, 2009; Salder, Gilman, Raby & Gkikas, 2020) have shown that some firm-specific factors that affect SMEs' capital structure and growth are firm size, profitability, tangibility, debt amount, growth, and volatility. Other factors that should be considered are industrial/environmental characteristics. The organizational characteristics and the managerial decision-making process also are known to have a decisive influence on SMEs growth. For example, managerial skill, the competence of leadership style, employee commitment, administrators' and owners' gender, and equity origin could affect SME growth (see Shrader, Mulford & Blackburn, 1989; Baldwin, 1994; Frank & Goyal, 2009; Neneh, 2020).

Kazanjian (1988) showed that sustainable SMEs growth occurs in different stages measured by life-cycle periods or the age of the firm (FA). The stages are (1) the business conception and development, (2) commercialization related to business start-up, (3) growth, and (4) stability.

In the growth stage, sales and market share are increased, and that requires that SMEs must consider organizational arrangements such as increasing human resources or equipment to deal with growth. The stability stage is characterized by profitability, internal control, and consolidation of a base for future growth.

In addition, an important aspect to consider is the integration of owners'/managers' behavioral, social, and psychological contexts in the firm growth philosophy. Studies such as Amit, MacCrimmon, and Oesch (1996) have found that both economic and psychological attributes are associated with businesses in the start-up stage to generate growth. How-

[2] An asymmetric information situation occurs when one of the parties involved in economic transaction possesses more information than the other (i.e., a buyer vs. a seller). Under these circumstances it can be deduced that almost all economic transactions involve information asymmetries.

ever, according to Blatt (1993), newly registered businesses do not seek immediate growth for their businesses. On the other hand, Orser, Hogarth-Scott, and Wright (1998a & 1998b) showed that the decisions to reach growth derive from a variety of motivations, including the owner's perception of growth and their values. The experience demonstrates that SMEs' growth it is impacted by business environment conditions. The business environment is a factor that also influences SMEs growth. Due to environmental conditions such as competitiveness and changing market dynamics, SMEs' growth is uncertain (Baum & Locke, 2001; Street & Cameron, 2007).

SMEs growth is a function not only of the financial performance of the businesses (Cragg & King, 1989; Belcourt, Burke & Lee-Gosselin, 1991; Covin & Slevin, 1991; Epstein, 1993, Sarwoko, Surachman & Armanu, 2013). Another important element of SMEs' growth performance is the interrelationship between planning, market timing–oriented strategies, characteristics of owners/managers, and growth philosophy.

However, past research, focused on the co-integration of SMEs' organizational characteristics and financial performance, toward sustainable growth in corresponding stages has not specifically addressed this issue in a holistic manner. The novelty of the present research is its insight into SME growth in a multidisciplinary context. This study explores various elements of business growth, such as the gender psychology of business owners/managers, entrepreneurship strategy, and relevant financial aspects to ensure business continuity and sustainable growth.

3. METHODOLOGY

3.1 Research context

SMEs were classified as micro, small, and medium enterprises, taking into account the number of employees and annual turnover. Micro businesses have fewer than nine employees and annual turnover of less than €81,600; small businesses have 10–49 employees and annual turnover of less than €408,160; and medium-sized businesses have 50–249 employees and annual turnover of less than €2,040,800. The 2018 statistics show that local businesses constitute 96%, joint ventures (foreign and local businesses) account for approximately 1%, and foreign businesses represent approximately 3% of SMEs operating in the country. During 2018, women owned 25.7% of total active enterprises.

3.2 Data

This research study used a sample containing 120 SMEs data pertaining to 2017–2018 from the National Registration Centre (NRC) and the Credit Registry of the Bank of Albania (CRBA) databases. The selected SMEs reported and documented in detail their financial data in both databases. Most of the SMEs' organizational characteristics were retrieved from the National Registration Centre, and only the borrowers' status records were retrieved from the Credit Registry of the Bank of Albania. In addition, all financial indicators used in this analysis refer to National Registration Centre data (Table 1).

The organizational characteristics analyzed (Table 1) emphasize the development philosophy of the SMEs operating in the Albanian business environment [i.e., Administrator Gender (AG), Business Ownership, Equity Origin (EO), Ownership Gender (OG), and Borrowers' Status (BS)]. The financial indicators analyzed pertaining to liquidity (current assets, inventory turnover ratio (ITR), inventory, and short-term assets/debts], operational efficiency [gross profit margin (GPM), net profit margin (NPM), asset turnover (AT), and return on equity), and leverage [long-term debt (LTD), long-term debt/equity ratio (LTDER), total leverage ratio, and interest coverage ratio] evaluate the business capabilities linked to organizational characteristics which ensure SMEs' growth and further their sustainable growth.

3.3 Variables and analytic techniques

To examine the SMEs' growth and their sustainable growth, this study considered their organizational characteristics and financial aspects at 95% confidence level. This study used various growth indicators, such as ROE, ROA, BoS and FA. Several models, such as multivariate regression models and the artificial neural network based on a multilayer perceptron classification also was used. Except for ROE, all the variables

(ROA, BoS, and FA) used to examine the SMEs' growth and sustainable growth pertained to growth area. ROE was used as a growth measure because it is the operational efficiency indicator most in line with growth referring to SMEs size (Naranjo, 2004).

In the first phase of this research study, a test was designed to determine a direct relationship between organizational characteristics and financial indicators of growth (measured in terms of ROE, ROA, and BoS). Three different multivariate regressions which use ROE, ROA, and BoS were developed:

1. $ROEit = \alpha + \beta \times organizational\ characteristicsit + \gamma \times financial\ indicators_{it} + \varepsilon\ it$ (1)
2. $ROAit = \alpha + \beta \times organizational\ characteristicsit + \gamma \times financial\ indicators_{it} + \varepsilon it$ (2)
3. $BoSit = \alpha + \beta \times organizational\ characteristicsit + \gamma \times financial\ indicators_{it} + \varepsilon it$ (3)

In these regressions ROE, ROA, and BoS were considered as the dependent variables. Other variables, organizational and financial (Table 1), were considered as the explanatory variables.

In the second phase of this study, an artificial neural network based on a multilayer perceptron classification was designed and implemented analyzing the results obtained during the first phase. The MLP neural network used the age of the firm as the SME sustainable growth indicator. SME sustainable growth was classified in three different stages: start-up, pertaining to businesses with 0–5 years of activity; grown businesses, with 6–15 years of activity; and matured, with more than 15 years of activity. The age variable was used with a dual purpose; it captured the effects of SME growth, and it measured the expansion into different business development stages.

The MLP model was used to map sets of input data onto a set of appropriate output:

$$FA(start\text{-}up;grown;matured)it = f(W\{organizational\ characteristics;\ financial\ indicators\}it) \quad (4)$$

Such an approach enables modeling the influence of beliefs, efforts and the implemented business strategies (their correlated effects not directly measured in the first phase of this research) on SMEs sustainable growth. Their impact on SMEs sustainable growth was analyzed using the multilayer perceptron network results.

4. RESULTS

4.1 Multivariate regression analyses

The first step of this analysis evaluated whether a direct relationship exists between SME growth measures and the independent variables examined (organizational characteristics and financial aspects) at 95% confidence level. The first model employed was a multivariate linear regression which used ROE as a SME growth measure. The same model was used for the second evaluation, which used ROA as the growth measure. The third model employed was a multivariate log-linear model in which the growth measure was a function of BoS (ln total assets).

The first model results (Table 2) confirm that the independent variables which influence ROE at the 95% confidence level are GPM, NPM, AT (operational efficiency area); LTDER (leverage area), and short-term debt (STD) (liquidity area). These variables can predict ROE volatility with approximately 99.6%. Note that the presence of multicollinearity issues are indicated by significant direct correlation between variables. Statistically this was confirmed from the variance inflation (VIF) value, which in every case was higher than 1. These results are the main reason why the organizational characteristics variables were excluded from examination in this multivariate linear regression analysis. In addition, results showed that the residuals of the model were negatively correlated. Thus, the model indicated heteroskedasticity issues, meaning that residuals were not normally distributed ($\pi = -2.12 \times 10^{-15}$; $\delta = 0.892$). Therefore, a different examination was performed to better explain ROE in terms of a SME growth measure.

The second multivariate linear regression model indicated that the variables that were statistically significant at 95% for ROA prediction are NPM (operational efficiency area), total leverage ratio (LEV) (leverage area), collateral value (CV) (growth area), OG mixed, and BS performing (organizational characteristics) (Table 2). These variables can predict only 57.1% of ROA volatility. The VIF value was higher than 1, which confirms the presence of multicollinearity issues between the examined variables. On the other hand, the residuals confirm a positive correlation (DW =1.781). Their distribution

was heteroskedastic ($\pi = -6.73 \times 10^{-16}$; $\delta = 0.893$). These numbers confirm that the relationship between the examined variables was not linear.

The third examination related to SMEs growth measure was performed using a multivariate log-linear model in which the dependent variable was BoS (ln total assets) (Table 2). In this case, the data showed that the variables that had a statistical significance at the 95% confidence level for BoS are AG mixed, EO foreign (organizational characteristics), INV (liquidity area), LTD (leverage area), and CV (growth area). However, they can predict only 56.7% of BoS volatility; thus the presence of multicollinearity issues in the model (VIF > 1) was confirmed. The residuals had a positive correlation (DW = 1.645), and their distribution was heteroskedastic ($\pi = -5.84 \times 10^{-16}$; $\delta = 0.763$), confirming that the relationship between the examined variables was not linear. The Pearson correlation also confirmed a weak correlation between the three variables examined as SMEs growth measures (ROE vs. ROA = 0.018; ROA vs. BoS = −0.116, and BoS vs. ROE = −0.143). There was a correlation between organizational characteristics, and a correlation between financial aspects of SMEs (Table 2). In addition, the data showed a correlation between organizational characteristics and financial aspects of SMEs. The multicollinearity, heteroskedasticity, and non-linearity issues between the variables and the model errors themselves from the multivariate regression models proved that these models are not adequate to measure SMEs' growth due to the complexity (Coenders & Saez, 2000). Thus, individual and correlated effects of the analyzed factors on the matter cannot be correctly evaluated. This means that this analysis should go deeper and use other tools to explain the complex relationships among elements of the study phase.

Thus, a more complex examination able to adequately evaluate all the variables' correlations and derived issues toward SME sustainable growth is needed. This study used the age of the firm as a variable to measure SMEs' sustainable growth during the three firm development stages (start-up, pertaining to businesses with 0–5 years of activity; grown businesses, with 6–15 years of activity, and matured, with more than 15 years of activity).

4.2 Multilayer perceptron networks analysis

Multilayer perceptron artificial neural networks are computational models able to model complex relationships between inputs/independent variables and outputs/dependent variables (Nabney, 2002). The multilayer perceptron classification used in this research classified the interaction between inputs (organizational characteristics and financial indicators) in three SME development stages: (1) start-up; (2) grown; and (3) matured. It calculated the ordinary and numerical variables outcomes and their observed nonlinearities easily by using a hidden layer with one unit and evaluated the direct relationship that existed between examined variables. The explanatory/input variables included in the MLP network analysis were ROE, ROA, and BoS (previously used as SME growth measures), in addition to all other variables previously mentioned pertaining to organizational characteristics and financial business areas.

In supervised learning, the MLP class of neural networks manages a set of training samples used to infer a classifier to predict a correct output value (Zhang, 2000). The MLP model confirmed that the overall percentage of incorrect predictions in the composition of testing and training sample was about 1.5%. This demonstrated that the model is statistically valid at the 95% confidence level.

The receiver operating characteristic (ROC) curve analysis (Figure 1) proves that the analysis fairly classified the output in the start-up stages (ROC area = 0.694). The classification of output in the grown and matured stages was very good (ROC areas = 0.803 and 0.788, respectively). The same results were obtained using a lift chart (Figure 2). In approximately 50% of cumulative cases, most businesses were in the grown stage, 30% were in the matured stage, and the remaining 20% were classified in turns as start-up, grown, and matured. The MLP hidden layer activation function was a hyperbolic tangent, whereas the final activation function was the softmax function. The MLP statistics show that the SME organizational characteristics which had a normalized impact over 30% on SME sustainable development phases were AG (male), OG (male), OG (female), and BS performing. In addition, in terms of SME financial aspects, the variables with

a normalized impact over 30% on SME sustainable development stages were GPM, AT, and ROE in the operational efficiency area); LTDER, LTD, and LEV (leverage area); CA, ITR, short-term assets (STA), and INV (liquidity area); and ROA, BoS, and CV (growth area). All the variables considered in the analysis had a statistically significant impact on SME sustainable growth classification, as measured by the age of firm (FA).

5. DISCUSSION AND CONCLUSION

Regression analyses of SME growth using as dependent variables ROE, ROA and BoS do not produce valid outcomes. This is attributed to the existence of multicollinearity, heteroskedasticity, and non-linearity issues between the variables and the model errors. This is why ROE (an operational efficiency indicator) used as a SME growth measure is not affected by the organizational characteristics. In this case, only the financial aspects influence SMEs' growth. When ROA and BoS (growth area indicators) are used as SME growth measures, the organizational characteristics significantly impact them in addition to financial aspects.

It is a novelty of this study to approach the evaluation of SMEs sustainable growth operating in Albania using an MLP. The literature recommends using MLPs for SME performance and creditworthiness evaluation (Derelioğlu & Gürgen, 2011; Abdelaziz, Alaya & Dey, 2018). This study makes a novel contribution by using an MLP to evaluate SME growth and sustainable growth.

The MLP was used to accurately identify the factors (organizational characteristics and financial indicators) influencing SME sustainable growth stages. The MLP helped to identify factors impacting SME growth in a complex business environment (Table 3).

The MLP classifier showed that the SME organizational characteristics with a greater influence on the business philosophy of SMEs in the start-up stage were the administration gender (female/male); the business ownership, in cases in which it is divided from administration issues; equity origin (foreign and joint ventures); ownership gender (male and mixed cases); and the business classification in non-performing status (see variables' correlation signs in Table 3). Furthermore, the financial indicators which impacted the SMEs' growth in this stage were ITR, INV, STA, and STD (liquidity area); GPM and NPM (operational efficiency area); ICR, LEV and LTD (leverage area); and CV and ROA (growth area). The maintenance of all the previously mentioned financial indicators at high levels represents value added for the SMEs for sustainable growth in the start–up stage. The opposite also can be confirmed: maintaining financial indicators at low levels negatively affects SMEs' sustainable growth (Table 3).

From the organizational philosophy point of view, the analysis demonstrated that SMEs in the grown stage mainly were administrated by mixed genders, and the business owners were involved in the business administration process (Table 3). Data showed that female business ownership patterns in this stage are decisive. The correlation statistics were significantly negative in cases in which SMEs were in the grown stage and owned by females. Furthermore, the businesses in the grown stage repaid loans according to schedule. In terms of the financial aspects, grown businesses prefer to maintain low levels of CA (liquidity area), AT, and ROE (operational efficiency area), LTDER (leverage area), and BoS/assets growth (growth area). The increase of the remaining financial indicators, such as ITR, GPM, and NPM, is maintained to assure continuous progress.

This study found similarities between SMEs in the matured stage those in the start-up stage (Table 3). These businesses maintained lower levels of ITR, INV, STA, and STD (liquidity area); GPM and NPM (operational efficiency area); ICR, LEV, and LTD (leverage area); and CV and ROA (growth area) than did those in the start-up stage. Furthermore, in terms of organizational aspects, these businesses implemented strategies to expand their portfolio activity. Thus, their philosophy is open-minded toward administration issues, separation of each activity and the respective management duties, and foreign direct investments. Joint ventures bring additional experiences in the national market, even in the majority of cases in which the business owners are males. Another important element is that these businesses also may be classified as non-performing in terms of loan repayment schedules. This classifi-

cation is imposed by the banks, but nevertheless a business may perform well in its activities. The businesses borrowers' status from banks is evaluated considering their worst repayment schedule case. This means that as different loans are granted (pertaining to different activities undertaken from these businesses), bankers use the contamination evaluation rule to evaluate their entire loan performing status.

The business philosophy statistics showed that SMEs in the start-up stage face agency issues as the owners (male/mixed partnership cases) delegate to skilled managers (of female/male gender) the business management process. This is true mainly for foreign and joint ventures businesses. These businesses configure the daily activities as open organizations. Investing in a liberal management style and assuming a risk-taker approach vis-a-vis the financial aspects means that their business strategy for growth is aggressive. Furthermore, in this stage, SMEs explore as much as possible all the internal capabilities expressed in terms of knowledge toward innovation in order to survive in such a competitive business environment. Because of the competitive business environment, SMEs in the start-up stage try to maintain a balanced approach toward liquidity, operational efficiency, and leverage management, seeking a rapid growth process which can result in sustainable growth.

Another approach is that one pursued by the grown SMEs, which seem to adapt the business needs to specific organizational arrangements. In this stage, the owners mainly are females directly involved in the business management process. The administration process is facilitated by trusting some specific issues to skilled managers, although the decision-making process remains centralized. These businesses continuously invest in assets and profitability growth, supported by long-term funding. This behavior is present specifically in the most profitable business areas, which correspond to market timing strategy. In this way, they achieve growth and further progress.

Matured SMEs instead prefer to foster growth continuously; thus, they continuously increase liquidity, operational efficiency, and leverage indicators by diversifying portfolio activities and trying at the same time to benefit as much as possible from the situational market circumstances. In general, they pursue an aggressive managerial business style. They centralize the decision-making process in separate business areas, in which skilled managers are responsible for growth. Their progress at this stage is safe, but the owners control the benchmarks for future growth strategies.

The presented model is a good example of how SMEs define better financial and internal organizational policies to reach their growth and sustainable growth goals.

This study also affirmed that female ownership in each business development stage, independently of invested equity origin, represents added value. In particular, partially/fully female-owned initiatives should be supported with dedicated training and facilitated with specific fiscal instruments, especially when SMEs are in the start-up stage and deal with innovation issues. However, it is widely accepted that the business evolution dynamicity should be monitored continuously to initially help businesses pass the potentially delicate stages. Furthermore, there is a need to support the growth of the entire national economy.

This study examined factors influencing growth and sustainable growth of SMEs in Albania, which are considered to be the backbone of the national economy. It enriches the existing literature in three different ways. First, the study addressed SME growth and sustainable growth issues considering the close interaction among organizational networking and financial mechanisms. This is a novelty of this study. Second, a multilayer perceptron artificial neural network analysis mapped sets of input data onto a set of appropriate SME output classified in three different growth stages. In the current literature these models are used to measure only SME performance and creditworthiness. Thus, this study provides a novel utility of these models.

Third, this paper presents to SMEs a valuable model that can be used to organize internal information to define their sustainable growth strategies.

Using a sample of 120 SMEs operating in the Albanian market, growth was measured through return on assets, return on equity, and business size.

In this approach, growth took into consideration a firm's liquidity, its operational efficiency, and leverage indicators in addition to organizational characteristics by using multivariate regression analyses. Based on the results of multivariate regression analyses, a multilayer perceptron artificial neural network model was designed and used to specify the factors influencing SME development stages, measured by firms' age, classified as start-up, pertaining to businesses with 0–5 years of activity; grown businesses, with 6–15 years of activity; and matured, with more than 15 years of activity.

The MLP-ANN model easily calculated the ordinary and numerical variables' outcomes and their observed nonlinearities using a hidden layer with one unit and evaluated the direct relationship between the examined variables. The explanatory/input variables included in the MLP network analysis were ROE, ROA, and BoS, previously used as SME growth measures, in addition to organizational and financial variables. The MLP data confirmed that the overall percentage of correct predictions in the composition of testing and training sample was about 98.5%. This demonstrates that the model is statistically valid. The empirical findings of this research confirmed that SMEs in the start-up stage assume a risk-taker approach toward sustainable growth. In the grown stage, they implement a market-timing strategy in selecting investments with a sustainable growth perspective. Businesses in the matured stage replicate the liberal managerial style of SMEs in the start-up stage, but employ a less aggressive strategy.

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EXTENDED SUMMARY/IZVLEČEK

Avtorji so v prispevku analizirali tesno interakcijo med organizacijskim povezovanjem in finančnimi mehanizmi rasti ter trajnostne rasti malih do srednje velikih podjetji v Albaniji. Podatki o 120 malih in srednjih podjetjih za obdobje 2017–2018 so bili analizirani z uporabo multivariatnih regresij in modela nevronskih mrež, imenovanega večplastni perceptron. Sprva so bili podatki analizirani s pomočjo multivariatne regresijske analize. Namen slednje je bil potrditi korelacijo med rastjo podjetij, kar je bilo merjeno s tremi različnimi kazalniki: donosnost kapitala, donosnost sredstev in velikost podjetja. Pri oceni rasti podjetja se je v tem primeru poleg organizacijskih značilnosti upoštevala tudi likvidnost podjetja, njegova operativna učinkovitost in kazalniki vzvoda. Rezultati, pridobljeni v začetni fazi, so bili vključeni v model umetnih nevronskih mrež, s pomočjo katerega so avtorji želeli pridobiti oceno rasti malih do srednje velikih podjetji. Nadalje so avtorji želeli preveriti tudi njihovo trajnostno rast. Slednje je temelilo na starosti podjetja, ki je vključevala tri možnosti: zagonsko (start-up) obdobje, obdobje rasti in zrelo obdobje. Rezultati modela so pokazali, da mala in srednje velika podjetja v zagonskem obdobju sprejemanjo bolj tvegan pristop doseganja trajnostne rasti. Po drugi strani, podjetja v obdobju rasti vlagajo v trajnostno rast na podlagi trženske časovne strategije. Podjetja v fazi zrelosti uporabljajo bolj liberalni slog vodenja. Slednje je podobno strategiji malim in velikim podjetjem v začetni fazi vendar s to razliko, da je strategija podjetji v zreli fazi manj agresivna.

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APPENDICES

Appendix 1

Table 1: Summary of research variables

		Variable	Measurement	Abbrev
	Organizational charateristics	Administrator gGender	Administrator´s gender (female = 0, male = 1, and mixed genders = 2)	AG
		Business ownership	Business owner (administrator = 0, no administrator = 1)	BO
		Equity origin	Business equity origin (national = 0, foreign = 1, and joint ventures = 2)	EO
		Ownership gender	Ownership gender (female = 0, male = 1, and mixed gender ownership = 2)	OG
		Borrower status	Borrower status (non-performing + 30 due days = 0, performing 0–29 due days = 1)	BS
Financial Indicators	*Liquidity indicators*	Current assets	Short-term assets/Short-term debts	CA
		Inventory turnover ratio	Cost of goods sold/Average inventory	ITR
		Inventory	End of year inventory	INV
		Short-term assets	Cash + trade securities portfolio + receivable accounts + inventory	STA
		Short-term debts	Payable accounts, short-term loans	STD
	Operational efficiency indicators	Gross profit margin	Gross profit/Net sales	GPM
		Net profit margin	Net profit/Net sales	NPM
		Assets turnover	(Net profit + interest expenses)/Average equity	AT
		Return on equity	Net profit/Average equity	ROE
	Leverage indicators	Long-term debt/equity ratio	Long-term debt/equity ratio	LTDER
		Interest coverage ratio	Earnings before interest and taxes/Interest expenses	ICR
		Total leverage ratio	Total debts/Total assets	LEV
		Long-term debts	End-of-year long-term debts	LTD
	Growth indicators	Collateral value	End-of-year market collateral value	CV
		Age of firm	Analysis period/business registration period (start-up (0–5 years0 = 0; growth (6–15 years) =1; maturity (>15 years) = 2)	FA
		Return on assets	Net profit/Average assets	ROA
		Business size	ln(total assets)	BoS

Source: NRC and CRBA data

Appendix 2

Table 2: Summary of multivariate regressions models

Model no.	Significant variables at 95%	R^2	Residuals correlation (1 – DW/2)	Heteroskedasticity (π; δ)	Multicollinearity (VIF)
1. ROE	GPM, NPM, AT, LTDER, STD	0.996	2.719	(−2.12 × 10−15; 0.892)	VIF > 1
2. ROA	NPM, LEV, CV, OG mixed, BS performing	0.571	1.781	(−6.73 × 10−16; 0.893)	VIF > 1
3. BoS	AG mixed, EO foreign, INV, CV, LTD	0.567	1.645	(−5.84 × 10−16; 0.763)	VIF > 1

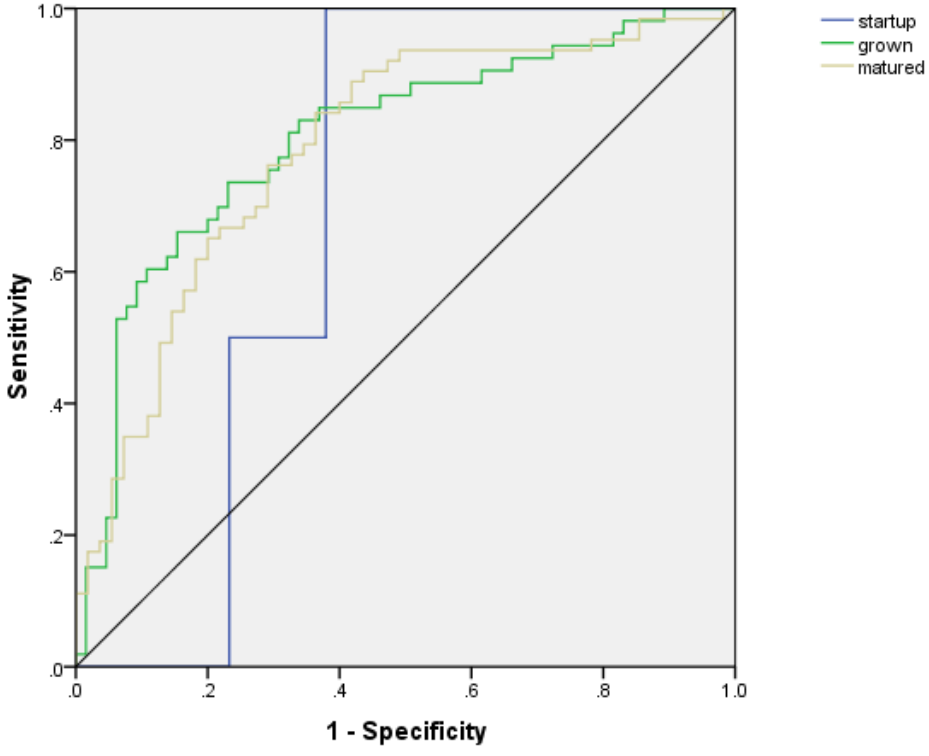
Appendix 3

Table 3: MLP model parameter estimates

	Input variables	Values	Input variables	Values	Input variables	Values
Input Layer	CA	−0.701	CV	0.741	EO foreign	0.162
	ITR	0.859	STA	0.375	EO mixed	0.262
	GPM	0.573	STD	0.065	OG female	−0.861
	NPM	0.113	LTD	0.645	OG male	1.027
	AT	−0.404	AG female	0.237	OG mixed	0.197
	LTDER	−0.539	AG male	0.683	BS non-perfoming	0.926
	ICR	0.232	AG mixed	−0.109	BS perfoming	−1.187
	LEV	0.318	BO administrator	−0.054	ROE	−0.157
	BoS	−0.415	BO non administrator	0.201	ROA	0.536
	INV	0.675	EO national	−0.693		
	Age of firm: start-up	Age of firm: grown	Age of firm: matured			
Output Layer	0.705	−1.236	0.108			

Appendix 4

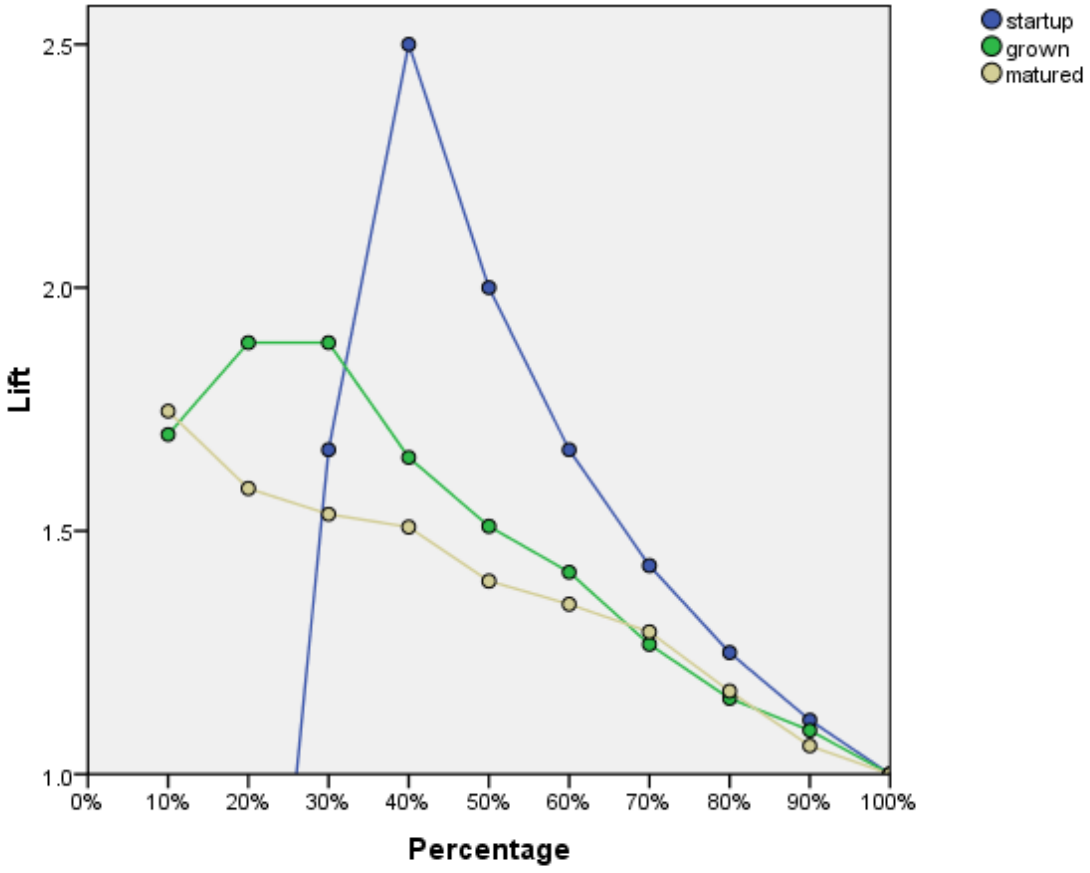
Figure 1: ROC analysis.



Dependent Variable: Firmage

Appendix 5

Figure 2: Lift chart results.



Dependent Variable: Firmage

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OUTBOUND OPEN INNOVATION IN ACADEMIA: A SYSTEMATIC REVIEW OF THE EXPLOITATION PRACTICES AND OUTCOMES IN UNIVERSITIES

Stephen Ndula Mbieke
Management and Actuarial Sciences, University of Udine, Italy
mbieke.stephenndula@spes.uniud.it

Abstract

In recent years, universities increasingly have been involved in the marketing and licensing of their intellectual property rights, mainly in the form of patent selling, technology licensing, and contract research. Although the reasons for this are clear, there are correlated research questions that deserve further attention. We examined how this happens and under which conditions universities carry out such activities to define outbound open innovation. This paper focuses on a specific part of the vast literature dealing with technology transfer from academia, and conducts a systematic review of the literature on the economic exploitation of the knowledge produced (in any form) and sold by universities. The results indicated that a greater part of such research analyzes commercialization modes, with licensing being the main channel of technology transfer, followed by analyses of the performance of the various research modes. In addition, some papers also mention the value network; fewer studies discuss strategies and the managerial perspectives. We analyzed the literature in 42 academic journals and 118 papers specifically dealing with this research topic. This review is the first to analyze literature systematically in terms of the financial benefit acquired by universities from technology transfer and to analyze the best means through which the income can be generated, e.g., licensing, commercializing, the creation of spin-offs, and transferring knowledge or technology to other institutions or establishments.

Keywords*: licensing, commercialization, intellectual property right, patent, university, spin-off*

1. INTRODUCTION

The pace of innovation processes is accelerating intensely in many sectors as new technologies—and especially enabling technologies such as cloud computing, artificial intelligence (AI) and the Internet of Things (IoT)—become more universal and embedded in a larger variety of products (Porter & Heppelman 2014; Macho-Stadler et al., 2007). In this context, innovating alone is less and less an option for firms because of the risks connected with rapid technological obsolescence and the continual discontinuities in technological development (Bianchi et al., 2011). Thus, a new approach to innovation, more open to collaboration with third parties, is needed by organizations aspiring to remain innovative (Chesbrough, 2007).

Such a scenario creates innumerable opportunities for universities because of their role as producers of base knowledge and new technologies (Phan and Siegel, 2006). However, great challenges come with these opportunities, such as exposure to competition, which might result in conflicting ideas among the various faculties (Baglieri et al., 2018), especially considering the inability of many universities and university researchers to transfer to the market the knowledge and the technology they produce (Mowery et al., 2002). This paper focuses on the business side of university technology transfer (UTT) which we call university outbound open innovation (UOOI).

The concept of "open innovation" first was mentioned by von Hippel in the 1990s and was emphasized in studies about open source software (von

Hippel 2003). It was highlighted by Chesbrough (2003), who subsequently defined it as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation" (Chesbrough 2006, 1). According to Chesbrough, open innovation has two sides: inbound and outbound. Inbound open innovation refers to the purposive involvement of third parties in the provision of new ideas and/or in the development of a new product or process, whereas outbound open innovation refers to the process of market valorization with third parties of knowledge, ideas, and other assets owned by an organization. The general aim of open innovation is to maximize the overall "return on innovation" of the organization or firm, which corresponds to the sum of efforts (financial and non-financial) put into innovation activities (Chesbrough 2003, 2006; Kutvonen, 2011).

Some authors, e.g., Lopes et al. (2018), have discovered in recent years that open innovation is a field of research that increasingly is being developed, as indicated by the increase in the number of publications in the field. This phenomenon has just begun, and therefore more attention is needed for better analysis. According to Bogers et al., (2017), it brings individual frameworks and a variety of levels of analysis to the research design, demanding more theory development. Furthermore, the term open innovation is a fundamentally dynamic process, which needs to be combined with some dynamic elements not only for better analysis, but also to achieve a good outcome (Appleyard and Chesbrough, 2017). UOOI refers to the strategies, the processes, and the organizational routines aimed at valorizing in the market, alone or in combination with other organizations, the knowledge, the resources, and the capabilities of universities and academics. Conventionally, the mechanisms through which universities have valorized their technologies include selling or licensing intellectual property rights (IPR) to already established companies (Penin, 2010).

Recent literature has discussed how universities have been changing, especially in the last decades, in relation to the valorization of their knowledge assets (Özel & Pénin, 2016; Ho et al., 2013). The literature has highlighted that many changes have occurred both internally—more-precise transfer strategies (Siegel et al., 2003); new modes of knowledge transfer (Mowery et al., 2001); and the creation of ad hoc structures, such as technology transfer (TT) offices (Thursby & Jensen, 2001; Chang et al., 2015; Baglieriet al., 2018)—and externally, for example, through the foundation of joint research laboratories with firms (Chatterjee & Sankaran, 2015) or the creation of university–industry incubators (Rothaermel et al., 2007). Empirical evidence of best practices is not missing from the literature, because the respective capabilities for technology transfer realization have a significant positive effect on technology transfer performance, whereas there is no significance in the capabilities of identifying technology transfer opportunities (Bauer et al., 2018).

What is missing, in our opinion, is more conceptual knowledge on the theme. We urge a comprehensive and updated framework aimed at systematizing the existing literature that can help researchers better position their research on this theme. The rest of this paper is organized as follows. First, we provide a brief background of the evolution of technology exploitation in general. A detail systematic analysis of the methodology used in this research is presented, and the literature is reviewed by categorizing it into research streams Then the main findings of the research are presented, followed by discussions and a conclusion.

2. THEORETICAL BACKGROUND

Technology transfer is the process of "transferring a technology-based innovation from the developer of the technology to an organization utilizing and applying the technology for marketable products" Kirchberger & Pohl, (2016: 5). The process originates with an invention, which subsequently is disclosed to the market through specific means and intermediaries, creating a certain impact on the society (Chang et al., 2015). It is presumed by some scholars that defining technology makes it less challenging to define technology transfer. Bozeman (2000: 629) defined technology transfer as "the movement of know-how, technical knowledge, or technology from one organizational setting to another."

Nevertheless, there are many uses of the term "technology transfer," mainly in describing and analyzing a wide range of organizational and institu-

tional interactions which involve some form of technology-related exchange. This includes sources such as private firms, government agencies, government laboratories, universities, non-profit research organizations, and even entire nations. Thus, technology transfer has been used to describe the processes though which ideas, proofs of concept, and prototypes move from research-related to production-related phases of product development.

Furthermore, based on the annual conference of the Technology Transfer Society in 2011, Technology Transfer in an International Economy was devoted to bringing together professionals from academia, research institutes, and business practitioners (Audretsch et al., 2014). Audretsch et al. further confirmed that the main objective is to promote movement of federally developed ideas, knowledge, and technologies created in public institutions to the marketplace for commercialization mindful of its numerous objectives, which depends on the resource, user, or mechanism. Abdul Razak and Murray (2017) similarly expressed the need for university research to be strengthened by relating it to industries to take full advantage of the commercial opportunities.

These definitions differ substantially depending on the discipline as well as the purpose of the research (Audretsch al., 2014). For instance, economists such as Dosi (1988) tend to define technology based on the properties of generic knowledge, focusing especially on variables that relate to production and design. Sociologists tend to link technology transfer to innovation and to view technology, including social technology, as "a design for instrumental action that reduces the uncertainty of cause - effect relationships involved in achieving a desired outcome" (Zhao and Reisman, 1992, 14). It further can be concluded that researchers from business disciplines concentrate mostly on the stages of technology transfer, particularly relating design and production stages and sales to transfer, whereas management researchers are more likely to focus on the intersectoral transfer and on the relation of technology transfer to strategy.

It was discovered that at the beginning, market exploitation opportunities of new discoveries are clear. This can be observed from the uncertainty of the activities of base research, which is conducted equally by universities, research centers, and private firms. However, inventions often fail to reach the market not because of technology-related reasons, but because of management-related reasons (Ismail et al., 2011). Some authors have argued that open innovation brings about the development of nations through innovation and constructive collaboration, through knowledge transfer. Developments in this area still are emerging, and some opportunities are presented (for instance, the open science, co-creation of knowledge, and open innovation triangle) as great opportunities to generate an original contribution from research to open educational theory and practices (Ramírez-Montoya & García-Peñalvo, 2018).

3. METHODOLOGY

We conducted a systematic review of the literature that focuses on the process of market exploitation of knowledge assets possessed by universities. Therefore, our interest, as mentioned in the Introduction, was limited to the process of market valorization (in any way possible) of the discoveries made by university researchers. In this case, a multi-step process was conducted, in which we began by combining some key terms which are related to the research topic, using Web of Science as the main search engine, as well as Google Scholar. The keywords Technology Transfer, Patent, Licensing, Exploitation, Open Innovation, Outbound Open Innovation, and Intellectual Property Right were combined with keywords such as Universities, Spin-Offs, Academia, and Science, which initially produced thousands of results.

Following this systematic review, some of the combined words generated a huge number of entries, which were difficult to import into Endnote before the elimination was done. For instance, Technology Transfer AND University generated 4,551 results, and Licensing AND University generated 4,651 entries. On the other hand, some of the combined words did not have many entries; for instance, Outbound Open Innovation AND University generated only three entries. Each combination was treated separately. To narrow down this search, it was refined by selecting only Journal Articles and Review and by restricting the category of search to only

Management Journals. At this point, only articles that contained at least one of the keywords were considered, resulting in 1,754 papers. Each entry was exported into Endnote by carefully considering only articles that centered on university invention, university technology transfer (UTT), commercialization, and patenting and licensing in university. This further reduced the number of articles to 340, which then were prepared for categorization.

In the next step, the papers were organized in a table in the order Authors, Title, Year, Journal Type, Volume, Issue, and Abstract. The column following Abstract categorized the papers using a Likert scale from 1 to 5 with respect to how close the paper was to the main keywords, in which 1 indicated that a paper related to the fewest keywords, and 5 indicated papers related to most of the keywords. My supervisor to categorized these papers using the same scale; we agreed and disagreed about some of the papers, and had to come to a consensus on the elimination criteria.

This categorization and elimination of papers was carried out not only by reading carefully the titles of the articles and their abstracts, but also by downloading (mostly through Google Scholar) and reading (not in detail) the full version of the papers. The first categories of papers that were eliminated were those that mentioned only patent diffusion and patent citation. These papers (78 articles) mostly discussed the cost that universities incur in carrying out research, and not the benefits, which was the focus of the present research.

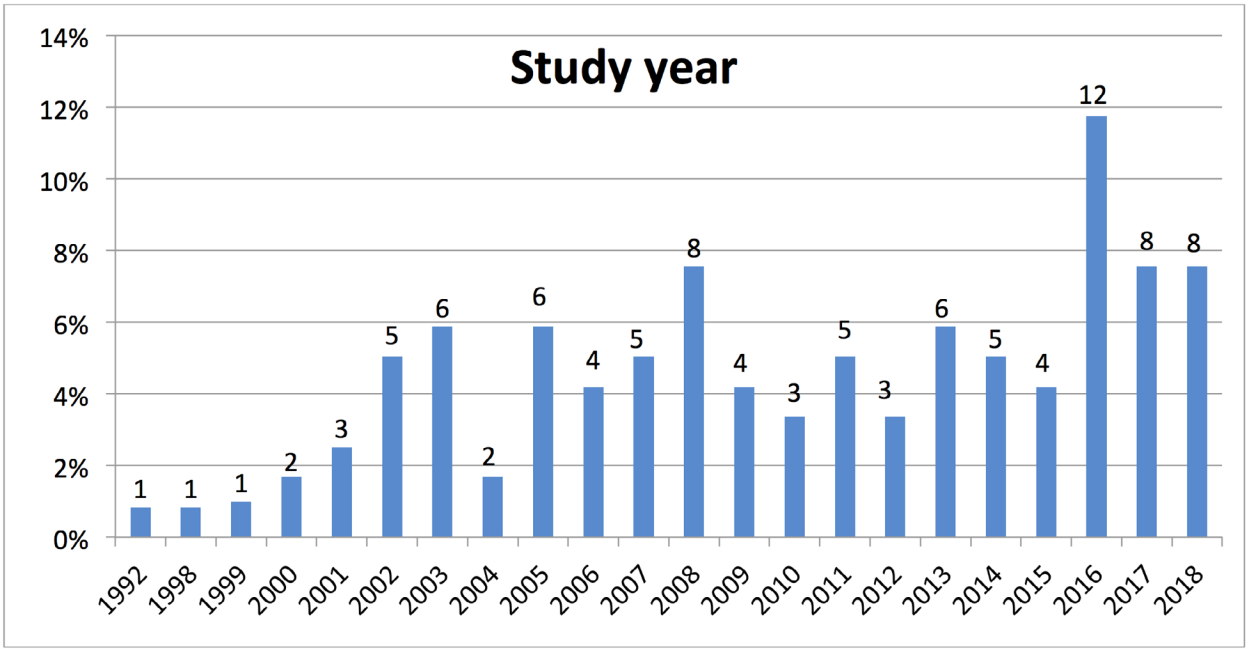
Following the second elimination criteria, 70 articles were identified which focused mostly on university–industry collaboration for purposes other than carrying out an income generating activity. In some of these papers, industries, enterprises, and firms were the beneficiaries, because most of these corporations used universities to achieve their respective goals. The next category of papers that were eliminated from the main review papers (74 articles) studied the theories that are involved in carrying out research in this area, and did not mention the financial obtained by the universities.

Only 100 articles satisfied the search results and were considered by the author to lay the foundation for this systematic review. In addition to these papers, 18 papers were selected carefully from Web of Science and Google Scholar, including some recent publications to update the research. As explained previously, no date range of research was included in the initial search criteria, because this field of study is not very old; 2003 is considered to be the year of breakthrough in this research area. Therefore the articles used in this research were published from 1998 onward (Fig. 1). Most of the articles used in this systematic review were published in 2016, which confirms the newness of this field.

After the 118 papers were obtained, the categorization was deepened by adding columns after the scale evaluation. These new columns were Paper Type, which included conceptual papers, empirical papers, and review papers; and Research Method, which included Quantitative, Qualitative, and Mixed Methods. Furthermore, we included the sources through which data were collected in these papers, such as Case Study, Survey, Investigation, Interview, Experiment Content Analysis, Ethnography, Data Mining, Statistical Analysis, and Annual Report. The next column categorized papers according to the methods of analysis, such as Disruptive Capacity, Regression, Comparative Cross-Case Analysis, Multidimensional Process, Multiple Methods, Descriptive Analysis, Data Envelopment Analysis (DEA), Cohort Analysis, Descriptive Statistics, Technology Transfer Model, Multiple Case Study, Content Analysis, Input-Output Model, Game-Theoretic Model, Practice-Based Analysis, Market Analysis, Multivariance Analysis, Multi-Stage Process, Revenue Maximization Model, Intermediate Input Model, Two-Stage Model, Multivariate Probit Model, Company Start-up Model, Conceptual Model, Cognitive Model, Licensing and Spin-off, Social Network Analysis, Systematic Literature Review, Semi-Structured Interview, Panel Analyses, Cross-Section Estimates, and Meta Data Analysis.

There was a slight increase in publications from 1992 to 2003, when many scholars started developing interest in this field of studies. Thereafter, publications fluctuated from 2004 to 2015, with 2008 having the highest percentage (8) of publications. The fewest publications in this field according to the data collected in this research were in 1992, 1998, and 1999, equivalent to 1% each. This fluctuation could be because researchers became interested in

Figure 1: Articles published from 1992 to 2018



this field of studies after the publications by Chesbrough in 2003 and 2006. From 2011, there was a continuous but slight increase of publications in this field of studies until 2016, when 12% of papers were published. Studies show that the number of researches carried out in this field will be greater in the future compared with previous years because this field of research has not been exploited fully by scholars. The years 2017 and 2018 show that there still is much research to be carried out in this field, because it now has been extended to companies and to society at large. The term OOI is not new; it has existed for many years, but with different meanings. This paper was updated by adding six papers which focus more on the relationship and benefits that universities obtain through their collaboration with some of the industries.

4. LITERATURE REVIEW

4.1 Introduction

This section reviews the literature on open innovation and discusses how some of these authors have approached the term technology transfer. We focused on the evolution of the literature on the transfer of knowledge in universities and the application of the open innovation perspective in university technology transfer. The literature subsequently was evaluated using details of the articles that were involved in carrying out this research. This classification helped to identify some streams of literature which then were classified further with respect to the author's main idea.

Friedman & Silberman (2003) highlighted that technology transfer has been cited by many university administrators as an indication of economic growth and as the main source through which universities derive their revenue, considering the reduction in university funding. According to these authors, the fact that the Patent and Trademark Law Amendments Act, P.L. 96-517 was established in the US and its content was later adopted elsewhere in Europe and Asia, rendered this concept uniform. This uniformity removed the restrictions on university licensing, allowing a rise in university patents resulting from federal research grants. Thus, the aim of this law was to permit universities to license their research to industry for commercial development in the public interest.

According to Roessner et al. (2013), there have been several efforts to improve technology transfer, including those of the National Science Foundation

and the Organisation for Economic Co-operation and Development. Thus, efforts by faculty and a firm's investment will determine the success of the technology transfer (Siegel et al., 2003). For example, there is a long history of technology transfer in the US university system, dating far back before the 1980s, and these activities have been rooted in the motivations created by the unusual scale and structure of the US higher education system compared with that of many Western European nations or Japan (Mowery & Sampat, 2005). However, this situation significantly changed in the early 2000s, beginning in the UK, France, and Spain and later spreading to most European countries, such that universities, rather than professors or scientists, retained the ownership of academic patents (Geuna & Rossi, 2011; Crespi, et al., 2011).

It is in academia that TT, in the form of university technology transfer, has been studied the most, because of the primary role played by universities as providers of base knowledge in many scientific and technological fields (Friedman & Silberman, 2003). However, concerns have been raised that this increased activity suggests that university scientists and engineers might be moving toward applied research and away from fundamental (basic) research in efforts to capture some of the gains from licensing (Thursby and& Thursby, 2007).

UTT has been studied abundantly in both the economic and managerial literature and from different angles (Friedman & Silberman, 2003). The definitions used by scholars reflect the differences in the perspectives used. For example, Vinig & Lips (2015) defined UTT as "the results of research from universities to the commercial sector," and Han and Kim (2016) considered this aspect as "the transfer of the research output from universities to the commercial sector." The similarity of these definitions arises from the fact that these authors mentioned that the product of research carries into the technology market, because results and output can be used interchangeably.

A different definition was provided by other scholars, such as Friedman & Silberman, (2003) who defined UTT as "the process whereby invention or intellectual property (IP) from academic research is licensed or conveyed through use rights to a for-profit entity and in the end commercialised." A similar viewpoint was shared by Mesny et al., (2016) and Kirchberger & Pohl, (2016) who referred to UTT mainly as a "process," specifically one through which technology is transferred or moved from the inventor to society and then is used to produce goods or services destined for the market. Similarly, Thursby and Thursby (2002) described technology transfer as a three-stage production process involving multiple inputs such as invention disclosures, intermediate inputs, and license and option agreements.

In contrast to the definition provided by previous authors, Siegel et al., (2003) referred to university industry technology transfer (UITT) as the movement or transfer of workers of a company from one division to another or from one country to another, either within the same company or between companies. This definition, however, does not actually precise the concept of technology as stipulated by other authors. For instance, Chen et al. (2016) referred to the case of China and some Western nations which have no standard definition of university technology transfer, so they compared it with patents, technology licenses, and university spin-offs.

4.2 Evolution of the literature on UTT

Over the centuries, the main responsibilities of academics have been to produce new discoveries for the benefit of the whole humanity and to instruct and tutor pupils to become future scholars (Litan et al., 2007). Only in the last few decades have academics been assisting with the market exploitation of the knowledge produced in universities (Breznitz et al., 2008; Schmitz et al., 2017). In recent years, this has provided modern universities with the opportunity to perform a wide range of activities in tandem, geared toward the development of economic and social aspects irrespective of their historical differences (Etzkowitz 2001, 2013).

Following the evolution of the transfer of university technology, Youtie and Shapira (2008) stated that universities have adopted the role of knowledge factories, which is manifested through the transformation of research inputs (mainly young researchers and funding) into output which comprises

Table 1: Summary of definitions of university technology transfer

Authors	Journal	Definition of TT
Chen, Patton & Kenney (2016: 892)	Journal of Technology Transfer, Vol. 41, N. 5.	It "equate(s) to patents, technology licenses, and university spin-offs."
Friedman & Silberman (2003: 18)	Journal of Technology Transfer, Vol. 28, N. 1.	"The process whereby invention or intellectual property from academic research is licensed or conveyed through use rights to a for-profit entity and in the end commercialised."
Vinig & Lips (2015: 1036)	Journal of Technology Transfer, Vol. 40, N. 6.	"The results of research from universities to the commercial sector."
Siegel, Waldman, Atwater & Link (2003: 3)	Journal of High Technology Management Research, Vol. 14, N. 1.	"The spreading of information through transfers of employees from one division or country to another referred to as intra-firm transfers of technology. University Industry Technology Transfer (UITT)."
Mesny, Pinget & Mailhot (2016: 2).	Canadian Journal of Administrative Sciences, Vol. 33, N. 4.	"The transformation of research results into technology whose intellectual property can be protected and transfer from university to existing company or a spin-off created purposely for commercializing this technology through granting IP rights in return for financial consideration."
Han & Kim (2016: 3)	International Journal of Innovation Management, Vol. 20, N. 8.	"The transfer of the research output from universities to the commercial sector."
Thursby & Thursby (2002: 1).	Management science, Vol. 48, N. 1.	"Technology transfer is a three-stage production process involving multiple inputs such as invention disclosures, patenting or intermediate inputs and licensing and option agreements".
Arvanitis, Kubli & Woerter (2008: 1866)	Research Policy Vol. 37, N. 10.	"Technology transfer is defined as any activity that aims at transferring knowledge or technology that may help whichever academic institution or company to further carry on with its activities."
Rasmussen & Rice (2012: 3)	International Journal of Technology Transfer and Commercialisation, Vol. 11 Ns. 1-2.	"Technology transfer is the process through which the outputs of academic research are conveyed to those who make use of the research results."
Kirchberger & Pohl (2016: 5)	The Journal of Technology Transfer, Vol. 41 N. 5.	"Technology commercialization/Transfer is defined as the process of transferring a technology-based innovation from the developer of the technology to an organization utilizing and applying the technology for marketable products."

is done outside the university as some academic researchers side-step their universities and pass technology directly to firms (Lee & Stuen, 2016).

Some studies have shown that when a company develops an innovative idea, it does not directly bring it to market. Instead, the company partners with or sells the idea to another party, which then commercializes it. Chesbrough (2007) explained this phenomenon as an open business model which permits an organization to be more effective not only in the creation of value, but also in capturing it. Chesbrough further explained why this model should be implemented, giving reasons such as value creation by leveraging many more ideas because of their inclusion of a variety of external concepts; or permitting greater value capture using the key asset of a firm, resource, or position in both the organization's operations and other companies' businesses. This permits knowledge to pass through a variety of means for its enhancement.

Knowledge exploitation activity passes through many channels: technology transfer offices (TTO)—technical know-how, market insights, research evidence, consulting firms—or joint research ventures

that are opened by universities with the aim of facilitating the process of technology transfer from university to the market (Siegel et al., 2007; Thursby et al. 2002; Mesny et al. 2016; Slavtchev & Göktepe-Hultén, 2016). Hall et al. (2014) stated that the transfer of knowledge from the universities to the commercial market has been possible due to the availability of technology transfer offices. For instance, in 2005, US universities' economic activity totalled $40 billion, generating 628 start-ups and 4,932 licenses, whereas in 2012, the number increased to 705 start-up companies and 5,130 licenses as recorded by the Association of University Technology Managers (AUTM) Licensing Activity Survey (AUTM, 2006; Lee & Stuen, 2016).

Chang et al., (2015) stated that technology transfer offices of universities have drawn the most attention from researchers in the last two decades. Leitch & Harrison (2005) found that the efficacy and appropriateness of these TTOs can be involved in second-order spin-out activity and potentially determine the contribution to regional development mainly in the UK. Weckowska (2015) partially shared this view, but pointed out that TTOs can constitute a barrier to efficient and actual technology transfer due to bureaucracy (Siegel et al., 2003) or bottlenecks (Litan et al., 2008).

4.3 Applying an open innovation perspective to UTT

As mentioned previously, universities are less and less passive in managing their knowledge assets. According to Cardozo et al., (2011), it was only after the 1980s that most universities had the right to own and obtain revenues from inventions that were either entirely or partially developed with public funds. This evolution of the ownership of research by universities is termed open innovation because universities now can license their IP or valorize this knowledge through the transfer of technology to non-academic institutions such as firms and companies.

Chesbrough, (2003; 2006: 1) defined the concept of open innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation." Consequently, according to Chesbrough, open innovation creates more-extensive collaboration and engagement in a wider scope of participants, including suppliers, customers, partners, third parties, and the community in general, with universities becoming friendlier through this trend.

The idea was shared by Lichtenthaler (2005), who describes external exploitation (in other words, external commercialization) as the deliberate commercialization of knowledge assets by one organization to another on a contractual basis, usually with an obligatory reward, whether in monetary terms or not. Nevertheless, this perspective of open innovation is quite different from the one proposed by von Hippel (2003), according to whom open innovation refers to a situation in which "all information related to the innovation is a public good non-rivalrous and non-excludable." Von Hippel first applied the concept of open and distributed innovation to open source software, explaining that open innovation includes the right to use the technology at no cost, and to study, modify and distribute it to others at zero cost.

However, this paper limits the definition of open innovation to that of Chesbrough, who also introduced the distinction between two forms of OI: inbound, also known as outside-in; and outbound, which refers to inside-out innovation (Chesbough, 2003). Whereas inbound refers to the part of OI involving the opening of the innovation processes of a company to a variety of external inputs and contributions, outbound refers to the transfer of unused and underutilized ideas outside the organization that can be useful to other organizations, adapted to their respective businesses or business models.

Unlike inbound, the concept of outbound is not popular, and still is underexplored in both industry and in academic research (Lichtenthaler, 2005). Chesbrough explained that the term OI describes the porous nature of organizational boundaries which makes it possible for firms to interact with their environment in the form of exploitation of external technology acquisition. Chesbrough further referred to it as a system that depends on the dynamic capability of the firm, whether internally (technology exploration) or externally (technology

exploitation), which carries out the main technology management tasks of the innovation process (Chesbrough, 2006).

Consequently, OI involves a range of both internal and external sources of technology as well as various technological channels of commercialization. Thus, a deeper consideration of the new managerial challenges in open innovation processes is applicable equally for researchers and practitioners (Chesbrough, 2006). In the same way, OOI is considered to be an independent commercialization of IP which is developed from within the portfolio of a firm, usually online using a market such as NineSigma (Katzy et al., 2013). According to Yuan et al. (2018), university technology transfer permits universities to extract benefits from their research. UTT is an important method that bring together universities and industries; it is a process to transfer, convert, and commercialize new basic university technology research. This process represents several activities that use resources from the universities to generate value-added products and services for commercialization, which then are reconfigured with respect to the change in the environment.

Inspired by the work of Chesbrough in relation to private firms, we define university outbound open innovation (UOOI) as the use of purposive influxes and leakages of knowledge, mainly from universities, to accelerate internal innovation and increase the markets for external use of innovation. We established the link between the knowledge created by the university and examine how this knowledge is transferred to other institutions or organizations using an established market, mainly for financial purposes. Thus, this study focuses only on technology exploitation, which in this case we refer to as university outbound open innovation technology transfer (UOOITT), mainly in the university context, and specifically focusing on the financial benefits. The following section discusses the outcomes of the various papers that have made up this review and summarizes the different streams of literature for better analysis.

5. FINDINGS

Table 2 presents the descriptive statistics of the 118 articles carefully selected from 42 different types of journal articles which were used in this review. However, some classifications which are not represented in this table, such as the theoretical perspective, the methods of analysis, and the journal articles, due to their magnitude, are listed in Appendices 1, 2, and 3, respectively.

Table 2: Descriptive statistics of the sample of papers reviewed

Classification variables	Values	Papers	%
Paper type	Empirical	93	78
	Review	16	13
	Conceptual	10	8
Research methods	Qualitative	71	76
	Quantitative	20	22
	Mixed	2	2
Data source	Survey	28	29
	Case study	24	26
	Interview	12	13
	Content analysis	9	9
	Investigation	9	9
	Statistical analysis	5	5
Study location	North America	46	39
	Europe	34	29
	Asia	16	14
	United Kingdom	12	10
	Mixed	5	4
	Others	5	4

With respect to the type of papers used in this review, empirical papers dominated (93 papers, accounting for 78% of the entire sample). Review papers occupied the second position in terms of type of papers used (16, accounting for 13%), whereas the last category of papers was conceptual (10, or 8%).

The second classification in Table 2 represents the methods of analysis used in this review. The qualitative method dominated, with 71 papers (76% of all classification methods). Quantitative occupied the second position (20), accounting for 22%, whereas mixed methods was the least common, accounting for only 2% of the entire sample.

A large part of the data (28, or 29%) came from surveys, mostly collected through questionnaires.

The second largest source from which data were collected for this review was case studies, with 24 studies (26% of all data sources). Twelve studies (13%) collected data through interviews, whereas 9 (9%) papers collected data via investigation. Nine studies, accounting for 9% of the research, used content analysis; statistical analysis represented 5% of the data sources; and data analysis occupied the last position, accounting for only 2% of all the research.

In terms of the locations where these studies were carried out, North America was first, with 46 studies (39% of the entire sample), with over 90% from the United States. Europe was the second most common study location, accounting for 34 studies (29%), mainly from Italy, Germany, and France, plus a few others.

Asia was the third most common study location (16 papers, 14% of the total), primarily China, Japan, and Taiwan, followed by the United Kingdom, which accounts for 10%. Finally, 5 articles (4%) came from a mixed location such as the UK and Europe, and 4% were from other countries, such as New Zealand.

Concerning the theoretical perspective (Appendix 1), each paper was classified with respect to the theory specified in the paper by the respective authors, although some of the papers did not mention any previous theory used, especially the conceptual papers. According to Appendix 1, the two most frequently used theories were resource-based and knowledge-based, each with seven studies (18%). The third most used theory was transaction cost theory, which was mentioned five times (13%).

Technological change and strategic management theories and game theory occupied the fourth and fifth positions, both occurring four times (11%), followed by stakeholder theory, with three articles

Figure 2: Classification according to the sources of data.

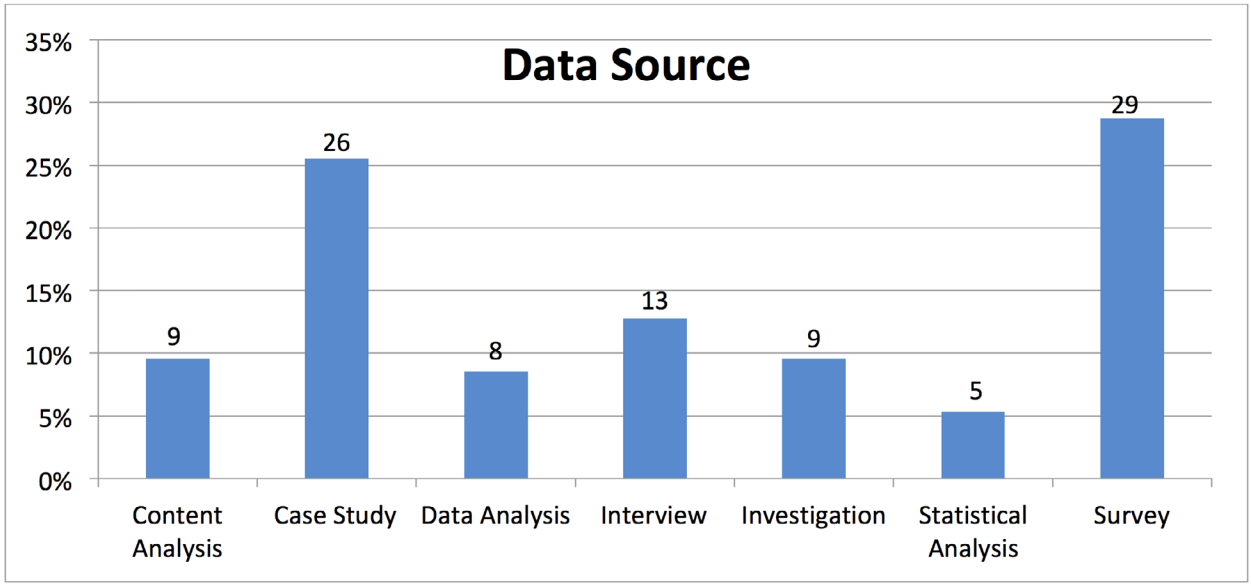
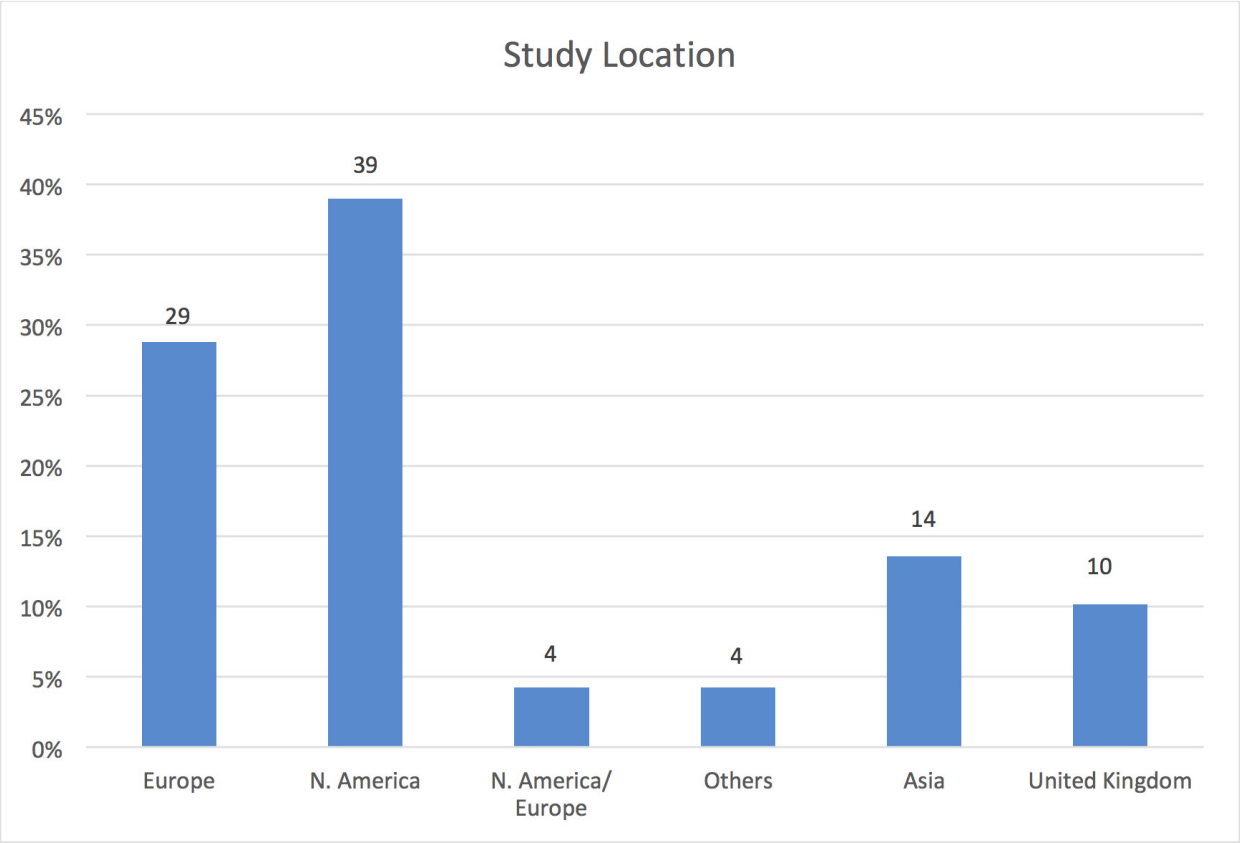


Figure 3: Classification with respect to location



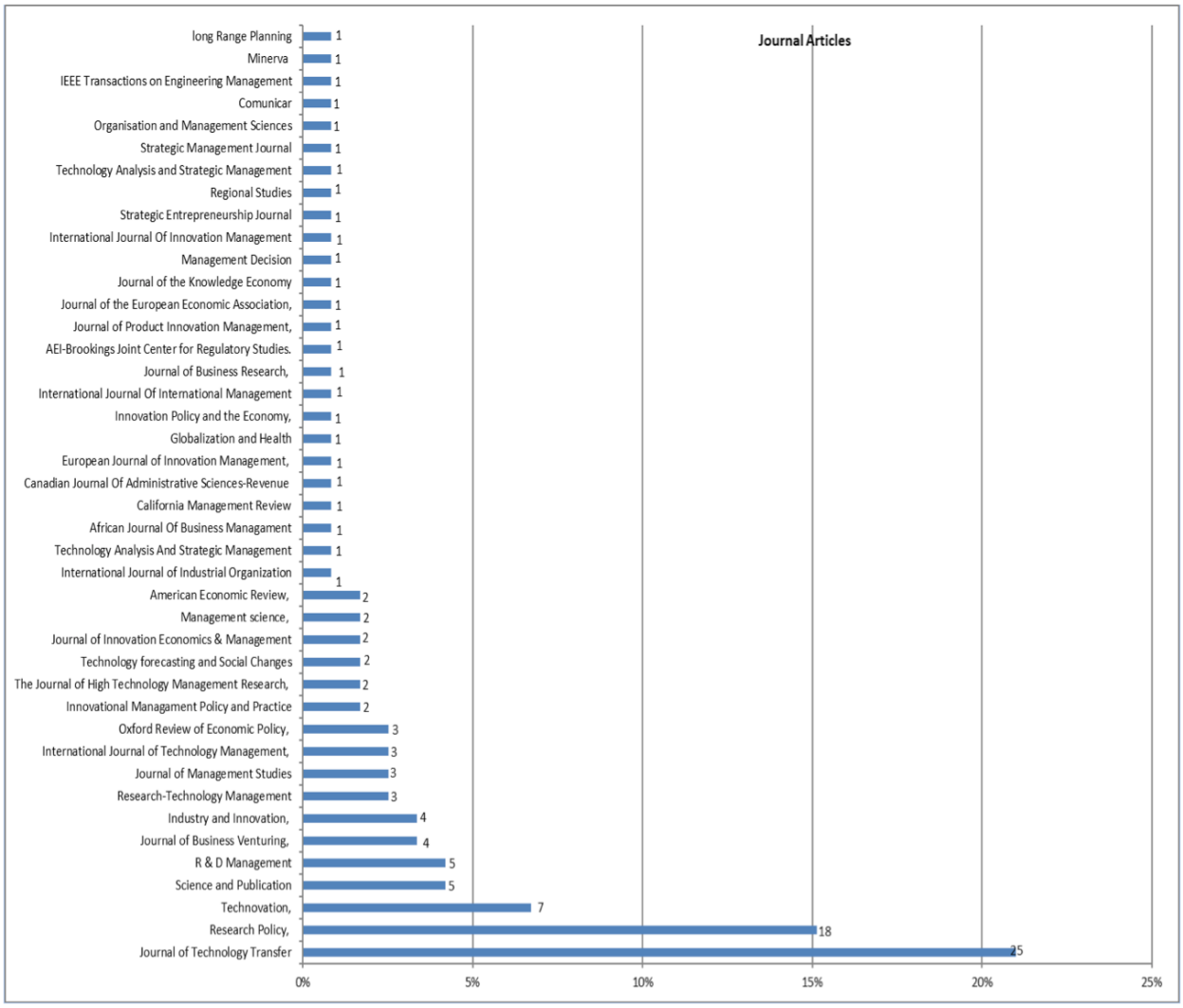
(8% of the entire research). The remaining 13 theories each were used in the journal articles only once, accounting for 3% each (Appendix 1).

Regression analysis (20 studies, 21%) was the most popular method of analysis among the papers studied (Appendix 2). Multiple analysis or methods (16 studies, 17%), which occupied the second position, constituted those articles which used more than a single method to analyze data. Descriptive statistics and multiple case studies each were used to analyze the statistical data in 11 of the articles (11%). Five papers (5%) implemented data envelopment analysis (DEA), whereas game-theoretic models constituted about 4% of all the studies. Revenue maximization models, semi-structured interviews, and content analyses accounted for 3% each, and meta data analyses, multivariate probit models, market analyses, and input-output models each accounted for 2% of the research. The remaining 12 methods of analysis were less frequent; each had a maximum of 1 occurrence (1%).

A significant number of the articles used in this review were taken from the *Journal of Technology Transfer*: 25 articles, constituting 21% of all the papers used in this study (Appendix 3). This journal was of great significance to this paper, because it constituted the basis of the research.

The second most used journal was *Research Policy*, which included 18 (15%) of the selected articles. *Technovation* was the third most used journal, accounting for 7% of the papers. *Science and Publication* and *R&D Management* each had five articles (4% each of all the research journals). The next 12 journals contributed between 2 and 4 articles each, accounting for 30% in total, whereas the last 25 journals had only 1 article each, together constituting 18% of all the journals (Fig. 3).

Figure 4: Number of articles per journal



6. RESEARCH STREAMS

The articles that were used in this research were categorized into four research streams, which were generated chronologically with respect to their significance in this research. The classification of the four streams was based not on any prior literature but on the results of personal interpretation. This was done after carefully reading the abstract, introduction, methodology, and conclusion of the papers involved. It was determined that the papers (although explaining similar views) had different focus. This classification was done to specify the main idea of these papers to determine the categories of papers. This classification also helped to show if any of the streams had evolved, which subsequently could be analyzed. The four streams involved in this research are as follows:

- Knowledge transfer modes and intermediaries: These papers focused on the variety of ways through which academic inventions can be transferred to users, whether through intermediaries such as the technology transfer offices, university incubators (UIs), and collaborative research centers (CRCs); or through main channels, including licensing, patenting, and creating spin-offs. These papers constituted the largest percentage (35%) of the research articles.

- Strategy, organization, and management: These were articles that mentioned how the institutions administer and achieve their inventions, and discuss some of the strategies put in place by these institutions to manage the intellectual property rights. Papers in this category accounted for 25% of all the research.
- Economic and social impact: These papers mainly centered on the price or monetary value generated by academic inventions due to expansions and partnerships with different scientists or institutions. This involves benefits not only to the university, but also to enterprises and society at large, which creates a network of values and growth. The papers in this section covered 18% of all the research.
- Internal impact: These articles explained the positive outcome of innovative research, including the performance and the successes of technology transfer or collaboration (usually with government for social benefits). These papers accounted for 22% of all the research articles.

Classifying these articles into the preceding research streams showed that some papers mentioned issues concerning other research streams; however, this paper focused on the authors' main emphasis. The research streams might seem similar, but they focused on one of the streams. Citations were obtained using Google Scholar, which showed that many of the papers have been cited by other scholars, making these articles useful for this research. These streams are elaborated in the following paragraphs. About 80% of the 118 papers were used in the research streams, which demonstrated the clear difference of the articles.

6.1 Research Stream 1: Knowledge Transfer Modes and Intermediaries

The first stream is also chronologically first and is aimed at examining and analyzing the various methods and intermediaries necessary for transferring the knowledge generated by universities to different facets of society, specifically by licensing and commercializing the new inventions. Selected articles in this stream are represented in Table 2, which lists the authors and the year of publication, the citations of the articles obtained from Google Scholar in October 2017, the method used to collect data, and the main ideas and contributions.

It generally is argued that open innovation practices can be useful predominantly in moving technology off the shelves, mostly in cases in which the potential user community is small, disjointed, or not well linked to the sources of university research. Most authors thus have drawn inspiration from the pioneering work of Lichtenthaler (2005), who first mentioned the idea of technology commercialization. According to Hall et al. (2014), university research long has been considered to be the main source of possibly useful knowledge which has been commercialized in markets due to technology transfer offices. As an example, US universities created $40 billion in economic activity in 2005, which led to the creation of 628 start-ups and 4,932 licenses; in 2012, 705 start-up companies and 5,130 licenses were generated in the US according to the AUTM Licensing Activity Survey (AUTM, 2006). In addition, Weckowska (2014) and Chang et al. (2016) explained that technology transfer offices have for more than two decades drawn the attention of researchers, because most university revenue accrues from the disclosure and licensing of their inventions to these offices. Most businesses are well informed in recent years due to the growth of university technology transfer offices, coupled with the enactment of the Bayh–Dole Act (Thursby and Jensen, 2001).

Although Thursby et al. (2009) acknowledged that these offices experienced enormous growth in university licensing after the enactment of the Bayh–Dole Act in the 1980s, 26% of the patents generated in the US by universities were allocated to firms. According to Thursby et al., this proportion was even greater in Canada and in Europe. Furthermore, in recent years there has been an increase in the transfer of university technology and commercialization, usually because of licensing agreements (which have increased due to an increase in overall university resources), university start-ups, and joint research ventures (Thursby et al., 2002; Mesny et al., 2016). With an outstanding lead from the United States, most universities worldwide now have created technology transfer offices for the commercialization of public research from organizations. This has encouraged most researchers to contribute by commercializing the outcome of their research (Mesny et al., 2016).

Chatterjee and Sankaran (2015), on the other hand, highlighted the model of university technology transfer as a technology seller pooling inventions from numerous research laboratories found in a university. They further considered university transfer offices as a model of technology transfer from the university to industry, which is instrumental in creating and developing a lasting and reputable relationship across industries that could not be performed by a single lab. With the collaboration of industries, entrepreneurship among faculty members and other means of commercializing academic research have become more significant in recent years. Some universities in Asia (Malaysia, India, and Thailand) have not actually benefited from the scheme, because they still consider teaching to be fundamental, and have little or no interest in the commercialization of research, patenting, or relationships with industries (Chatterjee et al., 2015). Moreover, Rasmussen et al. (2006) stated that technology transfer can be more effective if the university focuses on entrepreneurial activities, licensing, and even the creation of spin-offs, rather than engaging in more general and diverse relationships or cooperation with industries. Rasmussen et al. focused on knowledge commercialization of the intellectual property rights of universities, which generates greater economic development and performance.

Raine and Beukman (2002) also confirmed that most universities transfer their technology to businesses and industries through the commercialization of intellectual property rights which result from the research carried out. This is due to the reduction of funds provided by governments, so that universities must seek other means of generating income and share the profits with these organizations. Carayannis (2015) stated that the commercialization of technology can be interpreted as any form of commercial use of intellectual property. This can be carried out through licensing, venture formation, or when the university internally uses the intellectual property (right to sell or license), which subsequently is commercialized by specialized companies (Giuri et al., 2013).

Furthermore, commercialization leads to new functions, such as business incubators, creating new companies (start-ups), executing innovative projects, and licensing (Kirchberger & Pohl, 2016). Thus, technology from the university easily can be taken to market due to the combination of these and other channels, whether formal or informal (Kirchberger and Pohl, 2016; Özel and Penin, 2016). Additionally, commercialization of technology resources is not limited only to the selling of a university's own products or services, but extends beyond the conversion of such approaches, including means such as patent selling, technology spin-offs, licensing, and technology-induced tactics (Kutvonen 2001; Lichtenthaler, 2005).

According to Wu (2010), licensing and patenting are the most effective ways through which technology can be transferred from universities to other entities. Wu referred to these research universities as technology transfer vehicles which convert scientific inventions into innovations, usually through licensing and patenting of the research production. In addition, Swamidass (2012) explained that a start-up may be the only or the best opportunity for the commercialization of over 70% of the total inventions which a university generates and which are never licensed to be commercialized by business units. Experience shows that many university inventions remains on the shelf if they are not licensed to start-ups, and therefore are of no benefit. This view is supported by data from the Association of University Technology Managers, which reports that from 1999 to 2007 about 30–35% of university licenses were allocated to large companies, 50–55% were allocated to small companies, and 10–15% were allocated to start-ups. Pries and Guild (2011), on the other hand, examine how commercial uncertainty, specialized harmonizing assets, technological dynamism, and other legal protection affect the choice of business models. Furthermore, the idea of academic engagement and commercialization is clarified in this review in that the former consists of traditional academic research activities which access useful resources to support the research agenda (Perkmann et al., 2013).

Considering this relationship, most pharmaceutical companies do not license their products in areas where the capacity to develop these products is low, for instance, in some parts of Asia and Africa. Furthermore, the fundamental strategy of a university after putting an invention in the commercial market is to look for established companies either in the same field of study or in related fields that

have the capacity to transform the newly developed invention or technology or knowledge into either research and development or a prevailing line of products, or using this new technology to develop a new product (Graff et al., 2002).

Table 3: Research Stream 1 - Citation counts from Google Scholar, October 2017

Authors	Cit.	Article method	Article focus and contribution
Hall et al. (2014)	14	Interview	Effectiveness of commercializing university research considering the diverse markets. Contributes to developing manager's awareness of the activities of the research community and monitor research developments.
Chang et al. (2016)	6	Conceptual	Faculty disclosure and selection of commercialization mode. Contribute to the existing literature on the impact of patent disclosure
Lichtenthaler (2005)	214	Review	Commercialization and exploitation of external knowledge and its consequences. Contribute to assisting managers to assess the utility of new approaches.
Thusby and Jensen (2001)	5	Survey	Reduction of federally funded research due to non-licensing of university patents. Contributes to the empirical literature on the industrial impact of university research.
Chatterjee and Sankaran (2015)	6	Interview	Variation of commercialization with respect to definitions and orientations. How learning occurs in TTOs, and how the learning processes involved shape learning outcomes.
Weckowska (2014)	39	Conceptual	Capacities needed by TTOs to facilitate commercial exploitation of research outputs. Contributes to novel conceptualization of the occurrence and processes of learning in TTOs, and shapes commercialization practice.
Rasmussen et al. (2006)	372	Case study	An expected increase in both University R&D and commercialization knowledge. Contributes to university responsiveness to the new role of commercialization
Özel and Penin (2016)	0	Review	Determinants and welfare implications of university intellectual property patenting and licensing strategies. Contribute more to economic development through TTOs.
Raine and Beukman (2002)	22	Content analysis	The role of university–industry liaison offices in the commercialization process. Contributes to the valorization of universities and industries.
Carayannis et al. (2015)	12	Content analysis	Practices, directions, and tasks of technology commercialization and licensing at the University of Maryland (USA). Contributes to demonstrating mechanisms to optimize and substantiate decisions concerning licensing contracts.
Mesny et al. (2016)	2	Case study	Commercialization of academic output in administrative science. Contributes to the harmonization of scholars, practitioners, and the knowledge used.
Kirchberger and Pohl (2016)	10	Review	Systematic review of current literature on technology commercialization. Contributes to providing a comprehensive and systematic overview of the current literature on technology commercialization channels to provide a better understanding of the factors that have been researched in this field.
Pries and Guild (2011)	64	Survey	Analysis of models used by universities for commercialization. When intellectual property protection is weak, a technology sale business model approach to commercialization is appropriate.
Wu (2010)	55	Survey	Analyzing the influence of successful licensing of university patents. Contribute to the complex reasoning and historical legacies underlying university decisions.

Swamidass (2012)	33	Case study	Developing appropriate polices to generate more university start-ups for technology commercialization. Contributes to advancing procedures and standardized agreements for easier licensing of university inventions to start-up enterprises
Graff et al. (2002)	117	Review	The business of technology transfer between universities and firms. Contributes to establishing unique research units that are unique in their capabilities and that have distinct relative advantages in terms of capacity and cost-effectiveness.
Giuri et al. (2013)	23	Survey	Commercializing academic patents, developed both in universities and in public research organizations (PROs). Contributes by investigating if ownership of a patent affects the eventual prospect of commercialization, comparing the commercialization outcomes of university-/PRO-owned and university-/PRO-invented patents by exploiting an extensive data set that spans multiple countries, and commercialization consequences for university/PRO patents in countries with different IPR legislative systems.
Perkmann et al. (2013)	661	Review	Academic engagement and commercialization of university–industry technology transfer. Contributes by providing the first review, synthesizing empirical results into theoretical frameworks and showing how academic engagement, which uses a methodological approach, differs from commercialization.
Thursby et al. (2009)	265	Survey	Assignment to inventor-related start-ups is less likely and higher than the share of revenue inventors receives from university-licensed patents. Contributes to policy viewpoint by sharing revenue from licensing that accrues to the inventor when inventions are assigned to and licensed by the university.

6.2 Research Stream 2: Strategic, Organization, and Management

Following the second research stream (which is considered according to previous research as the second stage of technology transfer), academic research generates institutions which organize and manage the various faculties involved in this sector. The management at this stage is not limited to the faculties, but includes the different actors involved, such as industries, government, and other third parties. This stream also mentions the various strategies through which technology transfer and exploitation is carried out. Some authors analyzed how the knowledge generated by universities is managed, and analyzed the strategies proposed to transfer this knowledge (Table 3). For example, Keupp et al. (2012) explained that strategic management of information is the use of strategic management techniques and measures to enhance the innovative activities of firms and ensure it growth and performance. Technological knowledge is becoming a foundation to maintain competitive advantage not only for high-technology industry firms, but also for some universities that conduct innovative research.

Bianchi et al. (2011) stated that the main issue in the strategic management of technology is the conversion of technical know-how into economic worth. According to Bianchi et al., this phenomenon can be conducted either internally through the combination of various technologies and know-how into a useful service which can be marketed, or by the direct selling of these innovations themselves, which is an external factor. In recent years, most universities have conducted more entrepreneurial roles, mainly as key players in the ecosystem of regional innovation with an outcome of technology transfer (Miller et al., 2016). This phenomenon usually is termed a triple helix ecosystem, which involves the interaction between universities, industries, and government, resulting in the growth. On the other hand, the diversity of stakeholders in knowledge transfer generates some cultural and institutional differences, possibly affecting the smooth acquiring, transforming, and exploiting external knowledge (Miller et al., 2016).

According to West (2008), most technical knowledge after the Second World War was managed through the condition and protection of intellectual property rights which were licensed by universities to firms either for equity payments or

for cash. Litan et al. (2008), on the other hand, explained that one of the ways through which universities manage their inventions is knowledge spill-over, also known as the process of university–industry technology transfer (Chang, 2016). This spill-over accrues either by distributing the knowledge in the process of peer review or by dispersing graduates into the labor force. Spill-over in this perspective implies that the resource changes from a private gain to a public good which then provides vital contributions to the inventions and licenses of other researchers, as well as the research and development of some industries (Chesbrough, 2003; Lach & Schankerman, 2004).

Furthermore, over the years universities have played a significant role in knowledge transfer across the pharmaceutical industries due to their collective nature of operation. According to Chaifetz et al. (2007), this has given them a stronger negotiation position with other players in the field, because university processes rights permits them to hold key components of different end products. As explained by Ismail et al. (2011), the recommendations for most universities from the National Research Council (NRC) are that these academic institutions should implement new strategies to boost the development of new university start-ups capable of commercializing the inventions which might not have been taken off the shelf. Thus, universities need new technology transfer policies which can permit them to regularly evaluate their inventions to meet the recommendations of the NRC.

Payumo et al. (2012) suggested that research and development should aim at educating the future workforce as well as conducting a balanced program of applied, basic, and experimental development research. This will create an opportunity for universities to search for new and better ways of financing their research activities. Payumo et al. emphasized that these tools are not familiar in less-developed countries, and therefore, along with detailed understanding of the management roles and the process of technology commercialization, it is a good target for institutions seeking to advance their capacity.

Conceic et al., (2013) also argued that the type of commercial market to target by universities is a strategic decision about the transformation of knowledge into monetary value. This is because some knowledge or technologies that are invented in some universities need to target selected markets. Likewise, a university can as well manage its strategy by maintaining a close relationship with scientific industries as well as externalizing its outstanding technology (Macho-Stadler et al., 2007; Kutvonen, 2001). Moreover, new academic institutions and organizations are being developed to realize scientific research and innovations in a faster way through better management of incubators, technology transfer offices, and science parks (Libaers, 2014).

6.3 Research Stream 3: Economic and Social Impact

With respect to this stream of research, some articles discussed on the value that these inventions create not only for the university, but to the society at large through internal and external network respectively (Table 4). In this section, a greater part of the authors emphasized that economic growth comes from the value network created by these academic institutions, mainly universities, through the interaction with scientists from other institutions or industries, organizations, and the government.

Financial value or knowledge also is generated either through licensing or creating spin-offs, incubators, or university technology transfer offices, both at home and abroad, and thereby creating a long-term network within universities and other corporations. As regions and nations around the world progressively are faced with key economic challenges, they seek ways to enhance their chances of economic growth. Consequently, it is important for legislators to better comprehend the part played by universities in the creation of value in the economy (Roessner et al., 2013).

In recent years, governments have made good use of knowledge generated in academic institutions through the valorization and fostering of innovation, as well as by encouraging competition in the knowledge-based economy (Chang et al., 2008). Furthermore, the bridge of the networking system by policymakers in the creation and utilization of academic knowledge by companies greatly influences the value created in this sector and could be

Table 4: Research Stream 2 - Citation counts obtained from Google Scholar, October 2017

Authors	Cit.	Article method	Article focus and contributions
Bianchi et al. (2011)	19	Case study	The challenges of technology sales and the management of the complexity of technology transition. Contributes to the development of managerial solutions to the challenges from technology sale.
Lach & Schankerman (2004)	160	Case study	Variations in royalty sharing arrangements across universities. Contributes by giving more attention to the university sectors and their designs.
Miller et al. (2016)	22	Interview	Knowledge transfer from universities to other stakeholders through licensing. Contributes to the emergence of the knowledge economy combined with the growing complexity and role of end users as a core stakeholder within the open innovation processes.
West (2008)	38	Content analysis	Analyzes different processes of knowledge spill-over from universities to industry. Contributes by significantly improving communication applications through the theory of information building up a stream of research in open science.
Chaifetz et al. (2007)	14	Descriptive	The influence of university research intellectual property to close the gap for health innovations in poor countries. Contributes to the adoption of Equitable Access Licence by universities and public sector to proactively avoid obstacles to the production of basic medicine.
Chang (2016)	6	Interview	Decisions in faculty invention disclosure towards commercialization mode in its invention. Contributes to the commercialization of university-invented patents in a more comprehensive process of UITT and to the impact of patent disclosure.
Ismail et al. (2011)	18	Survey	Business models permitting transfer of inventions from academia to commercial entities. Contributes to understanding the creation of a semiconductor diode laser for Xerox printer business.
Chesbrough (2003)	2309	Case study	The need to make important investment decisions to ensure the future. Contributes to the synthesis of open innovation into new paradigm for managing corporate research and carrying new technologies to market.
Kutvonen (2001)	56	Review	Measuring outbound open innovation by identifying strategic objectives for external knowledge exploitation. Contributes by considering outbound open innovation as an enabler of additional strategic mobility and flexibility.
Macho-Stadler et al. (2007)	185	Theory	The role of technology transfer in universities. Contributes to characterizing empirically the correlation between technology transfer offices and revenue from licensing.
Payumo et al. (2012)	10	Case study	Presents different IP and technology commercialization policies and lessons learned to offer options to public research institutions. Contributes to understanding how government funding works in different institutions when commercializing IP technology.
Conceic et al. (2013)	44	Interview	Analyzes decisions regarding commercialization strategies of research based businesses. Contributes to recent work by determining the commercialization strategy of technology-based SMEs.
Libaers (2014)	8	Survey	Managing the interactions of foreign-born academic scientists with private firms. Contributes to the literature stream on foreign-born academic scientists in the framework of university–industry interactions.

detrimental to the economic growth of the country involved. Prior research has studied the implications of academic spin-offs, patenting, licensing in the regional economy, and the implementation of the Bayh–Dole Act on market orientation in addition to the value generated from these actions (Thursby and Thursby 2002).

Chang et al. (2008) highlighted that much value has been created in academic institutions by intellectual property rights, spin-offs, incubators, and the licensing of technology transfer. In addition, the Bayh–Dole Act in the US in the 1980s has been a source of inspiration to some Asian countries, mainly Taiwan, Japan, and Korea, which also endorsed the Science and Technology Basic Law permitting the ownership and management of IPRs in academia, which allows universities now to be in full control of their intellectual property. This accelerated the commercialization of new technologies while promoting economic development and entrepreneurial activity. This also has formed new links with other organizations to create and operate on the same platform.

However, Mowery et al. (2001) pointed out that some universities, such as the University of California and Stanford, had recorded successes in technology licensing before the passage of the laws, which have had little influence on the content of academic research. This is because these universities were large-scale patentors who have established strong relationships with already well-established institutions and organizations due to the government expansion efforts in gaining robust international protection for intellectual property. In addition, the constant increase in productivity of research and development is due to research-related activities, namely the development of new university technical know-how, and the provision of valued human capital for both faculty and students, which greatly has enhanced the growth of the national economy (Roessner et al., 2013).

The growth of academic research commercial output has drawn considerable attention from both the managers of technology and university administrators, who valorized this phenomenon by consistently engaging in commercial activities. This has led to some changes in business behavior toward universities, increasing the contribution of economy growth (Thursby et al., 2002). In addition, the social, political, and economic aspects have significantly influenced the ability of universities to economically develop and organize knowledge useful to society, contributing to both the success and economic growth (Bercovitz and Feldman, 2006).

Furthermore, there has been a shift from a traditional to a more advanced, protected, and wider approach by considering patents as sellable assets which can obtain licenses and generate enough money for academic institutions through commercialization. Studies have shown that over 40% of US patent holders account for about 99% of the entire revenue generated by US licensing, whereas the remaining 1% of revenue from licenses comes from 60% of patent holders, leading to the paradox that licensing still is relatively low in this area (Ziegler et al., 2013).

Furthermore, education, as explained by some authors, is one of the oldest academic activities that contributes to economic growth because these institutions also take into consideration the commercialization time of their technology (Carree et al., 2014; Markman et al., 2005). University administrators constantly have cited UTT as a catalyst to regional economic growth or development due to the revenue generated in the contemporary economic environment. As a result, some universities have experienced a decrease in funding from both government and other organizations (Friedman and Silberman, 2006). Moreover, higher education institutes (HEIs) for some time have played an outstanding role in the continuous generation of economic value through regional development as well as the creation of employment in the economy. Much attention also has been given to knowledge generated from the university, because it is geared toward economic growth and technology innovation, consequently, increasing competitiveness and national successes (Chang and Yang, 2008).

Because universities for some time have contributed significantly to the value creation of regional economic growth (through the conversion of scientific inventions to innovation through specific instruments, mostly licensing and patenting, and research output), it thus is necessary to examine further the influence of the growth in the licensing of

these university patents (Wu et al. 2015; Litan et al., 2007). In addition to training young minds, transmitting culture, and generating knowledge, universities act as a mediator of economic growth (Cardozo et al., 2011). Additionally, there has been an enormous encouragement by some universities in the search of alternative means through which their technology can be commercialized, which has led to the development of spin-off companies with the aim of generating more money. This is because, these universities can obtain equity in the creation of start-ups to commercialize their technology more easily than by selling the license to an already established company (Bray and Lee, 2000).

6.4 Research Stream 4: Internal Impact

According to Han and Kim (2016), most previous studies of technology transfer have shown great performance relating to the characteristics of numerous universities, including the existence of university TTOs and the type of university involved. In addition, a few former researchers have studied the relationship existing between technology transfer performance and the Bayh–Dole Act, which was created to enhance university innovation. However, there are many stakeholders in academic research institutions (namely managers of technology licensing offices, faculty, and administrators) with diverse perceptions about commercializing research, which, according to Kim and Daim (2014), makes it difficult to measure the performance. However, further research suggests that institutions should compare their practices with others by measuring the productive efficiency of the licensing practice and benchmarking studies (Anderson et al., 2007; Thursby and Kemp, 2002).

The performance of universities in the transfer of technology seems greater when the scientists of the university work alongside those of the biotechnological firms, which increases the tacit knowledge of the academic institution (Zuker et al., 2002). The case of China is a good example, in which academic research performance in technology transfer over the years has had an equivalent increase to that in the West, resulting from a synergy of the two research communities (Chen et al., 2016).

Despite the economic benefits of the valorization of university technology transfer, some countries, such as the Netherlands, do not seem to benefit from this scheme. This is because, due to the limited data provided by Dutch universities, research from these institutions cannot provide clear results regarding their performance (Vinig & Lips, 2015). In addition, Vinig & Lips considered technology transfer to be a broad and unmeasurable term. For instance, although the presence of variety of stockholders makes performance to be measured by the monetary income generated from universities, it does not measure the real performance. This is because it does not offer the potential for technology transfer that relies on university research. Therefore, technology transfer with a high dollar income could have low performance because the dollar income is less than the available potential.

According to Caldera and Debande (2016), enhancing the performance of university technology transfer draws much attention from most policymakers, and permits them to better administer their research activities in the respective institutions. These policymakers, whether in state or national government, also regard the growing research in universities as a catalyst for economic growth, which triggers the performance of these institutions (Chapple et al., 2005). To effectively measure the performance of the research carried out in an academic institution, if possible, universities should sustain completely this process, which encompasses inventing, innovating, commercializing, and transferring of the new technology (Litan et al., 2008). Despite this, there has been little analysis of efficiency in the system of university technology transfer. An analysis of US university performance determined that this varies greatly from one university to another due to the number of licenses, the formation of spin-offs, and the income generated from these licenses (McAdam et al., 2009; Siegel et al., 2007).

As explained by Calcagnini and Favaretto (2010), time is the most important factor when considering the internal impact of the university knowledge invention. Calcagnini and Favaretto applied the innovation speed theory and developed two assumptions. First, the performance of an academic institution is greater if the commercialized knowl-

Table 5: Research Stream 3 - Citation counts obtained from Google Scholar, October 2017

Authors	Cit.	Article method	Article focus
Ziegler et al. (2013)	17	Case study	Value capture through the commercialization of IP. Contributes to the implementation and deliberations on the structure of IP commercialization by universities and firms.
Carree et al. (2014)	39	Case study	The transformation of academic knowledge into regional economic growth. Contributes to transforming the outputs of new ventures into enhanced performance.
Chang et al. (2008)	10	Survey	The influence of university IPR management and external research partnerships on creating income through patenting and licensing. Contributes to the enhancement of policy implementation in the national interactions of the triple helix.
Mowery et al. (2001)	1518	Content analysis	The growth of university patenting and licensing resulting from the introduction of the Bayh–Dole Act. Contributes be presenting the comparative analysis of academic research enterprise and the innovation system of the US.
Chang and Yang (2008)	32	Case study	Knowledge generated from university drives economic growth and technology innovation. Research exploitation. Contributes to managerial and attitudinal changes between academics regarding the collaborative projects of university–industry
Roessner et al. (2013)	44	Case study	Contributions made by university licensing to the US national economy. Contributes to increasing productivity in industry, resulting in university technology growth and new knowledge generation.
Thursby and Thursby (2002)	954	Survey	Analyzes the dramatic increase in university technology transfer through licensing. Universities contribute to the economy through substantial attention on academic research from both university administrators and technology managers.
Thursby et al. (2002)	580	Survey	The increase in licensing for reasons other than increases in overall university resources. Contributes by proposing reasons for and analyzing factors associated with the shift of universities to a more productive commercialization level.
Bercovitz and Feldman (2006)	638	Conceptual	Determines the role of universities in systems of innovation. Contributes to social governance and development of relations at work and economic efficiency of absorbed knowledge.
Bray and Lee (2000)	33	Interview	The success of incubators or university parks depends on how much technology is transferred from their labs to start-ups. US universities contribute data to both equity sales and holdings.
Chang et al. (2008)	10	Survey	The adaptation of the new international IRP regulations (passed 1962–2002) by Italian universities. Contributes to understanding the rapid development of novel high-technology firms in the US economy during the 90s.
Markman et al. (2005)	386	Case study	The slow rate of technology transfer and its impact on economic growth. Contributes to the debate of policymakers for a shift from applied to basic research.
Cardozo et al. (2011)	30	Survey	Using commercialization time of patent-protected technology as a means of speeding innovation. Contributes to the understanding of the present and future evolution of the technology commercialization.

Litan et al. (2007)	49	Review	The introduction of the Bayh–Dole Act in the19 80s and growth of university innovation commercialization. Contributes to maximizing the potential for university-based inventions, resulting in the commercialization of new innovations and products.
Friedman and Silberman (2006)	657	Empirical	The increasing importance of university technology transfer activities increasingly are important as a source of regional economic development and revenue for the university.
Wu et al. (2015)	44	Survey	Determining the likelihood of individuals and institutions licensing university patents. Contributes by providing new insights into licensing for the process of commercializing university inventions.

edge can generate further revenue through licensing or creating new ventures. Second, the performance of an academic institution is greater if the university can identify what determines the speed of its innovation. Apparently, universities can become more flexible in negotiating their license agreements, which can be absorbed by other firms. As highlighted by Siegel et al. (2003), the capacities of university TTOs partially determine the performance of university commercialization, because not all results from university research are released to these transfer offices.

However, this simplifies the academic invention exploitation in the application of commercialization, because not all researchers have the interest and the ability to advance potential commercial applications of their research (Chapple et al., 2005). In addition, the increase of performance of university technology transfer can be evaluated either by profits, portraying a more diverse goal, or through the identification of some new potential partners, by creating incubators or new ventures to commercialize the exploitation of academic inventions, securing the intellectual property rights, and evaluating technological inventions (Chen, 2009 and Thursby et al., 2001).

7. DISCUSSION AND CONCLUSION

Although nearly all universities carry out technology transfer activities, the distribution of successful commercialization activities is highly skewed among universities whose TTOs sometimes do not benefit financially as anticipated (Litan et al., 2007). The question of why some universities perform better than others has been studied by many authors for over the years, and reasonable answers have been found, some of which involve the general commercialization activities (Rasmussen et al., 2006) or other methods of commercialization put in place by some universities, for example, licensing or spin-offs and patenting (Siegel et al., 2007). Some universities own specific structures or carry out a variety of activities that others do not, such as operating UTTOs, research incubators, and spin-offs, among others.

Analysis of the research streams indicated that many authors (35%) mainly based their research on the commercialization modes, and studied the deficiencies in developing this sector of research. This stream of research identifies what modes of commercialization can be administered better by universities worldwide to better benefit financially from their inventions. Some of the modes identified in this stream are licensing (which forms the basis of the present research) by universities, and the creation of start-ups and technology transfer offices, which in recent years have increase because most corporations also use these offices to market their new technologies. In addition, the creation of research incubators has facilitated invention and commercialization of university knowledge, thereby enhancing the transfer of this knowledge to other institutions or organizations. Thus, given these research modes, universities around the world can select the commercialization mode that best fits their objectives. The benefits accrued to such universities will permit them to cover the cost of research and encourage the institutions to further their research in new fields of studies.

Table 6: Research Stream 4 - Citation counts obtained from Google Scholar, October 2017

Authors	Cit.	Article method	Article focus and contribution
Han and Kim (2016)	0	Multiple source	Examining the determinants of technology transfer in universities in Korea. Contributes to the creation of new firms resulting from the ineffectiveness of patents.
Caldera and Debande (2010)	178	Investigation	Investigating the role of policies on performance. Contributes by examining university technology transfer through the investigation of policies' effect on performance.
Chapple et al. (2005)	428	Case study	Investigating the relative efficacy of UK university TTOs. Contributes by presenting the first empirical evidence on the relative efficacy of UK universities and comparing parametric and non-parametric approaches to productivity dimension.
McAdam et al. (2009)	23	Case study	Means for improving the commercialization of university technology transfer using an absorptive capacity perspective. Contributes to the modern evidence affecting university technology commercialization and using absorptive capacity as an interpretive outline in this context.
Calcagnini and Favaretto (2016)	5	Survey	Innovation leaders perform better than economies with low levels of innovation investment and institutions that do not favor knowledge and technology transfer activities.
Siegel et al. (2003)	729	Interview	Analyzes the outcome of UITT processes. Contributes to improving the consideration of UITT so that managers of the process in universities and industry can enhance its effectiveness.
Siegel et al. (2007)	374	Review	The increase in commercialization rate of intellectual property at US and European universities has important performance and policy implications. Contributes to assisting policy makers and practitioners in organizing TTOs for better performance.
Thursby et al. (2001)	750	Survey	Relationship between licensing outcomes and both the objectives of the TTOs and the characteristics of the technologies. Contributes to the literature by providing evidence of universities on their purposes, in addition to a new indication on the type of inventions licensed.
Kim and Daim (2014)	5	Survey	Ways to identify time lags in the licensing process. Contributes to measuring the performance of licensing of US research institutions by suggesting a method for recognizing time lags in the process of licensing.
Chen et al. (2016)	4	Review	Outlining and evaluating the state of research about university technology transfer in China. Contributes to a deeper understanding of the advanced discussion in China compared with other nations.
Chen (2009)	172	Case study	The effects of technology commercialization incubator and venture capital. Contributes to intermediating the effects of technology commercialization capacity and the moderating effects of incubators and venture capital support on performance.
Vinig and Lips (2015)	13	Annual report	Measuring empirically the performance of Dutch university technology transfer. Contributes to the literature on university technology transfer by adding a new approach to measure its performance.
Anderson et al. (2007)	284	Conceptual	Evaluating public versus private universities in terms of procession of medical schools. Contributes to technological changes in definite subfields of nanotech.
Thursby and Thursby (2007)	164	Survey	Analyzes the success of growth in university technology transfer through licensing. Contributes in motivating inventors to disburse resources in risky innovative activity.

Litan et al. (2008)	91	Review	Progress made in innovation practices since the 1980s and its prospects. Contributes to improving the human condition, thus aiding the transfer and commercialization of findings attends the inventor and society interest.
Thursby and Kemp (2002)	581	Survey	Examining the overall productivity of university licensing activity and the productivity of individual universities. Contributes to measuring the success of a university's technology transfer.
Zuker et al. (2002)	1132	Content analysis	Analysing university tacit knowledge transfer to firms. Contributes by recommending affordable bibliometric measures which are better than, but not perfect substitutes for, costly to construct star measures.

Furthermore, about 25% of all the research papers discussed strategies as well as how inventions are managed during licensing. In this stream, some researchers concluded that for a university to succeed in taking its research off the shelf, the university needs to implement better and new strategies, such as enhancing the existing faculties for better production or creating new institutions. These strategies can be implemented or administered better by managing the various outlets (TTOs, spin-offs, and incubators) so that the university can successfully commercialize the invented technologies. This also is a chance for university administrators to bring in skilled managers or researchers who have the potential to get the research off the shelf and into the market.

In addition, almost 18% of the articles focused on the economic and social impact, which is considered to be one of the goals of each university engaged in the commercialization of research. As explained by most authors, the aim of carrying out research in universities is to take it into the commercial market. Thus, this stream of research shapes out the fact that any research ready for the market must possess a certain value of importance not only to the university but also to society at large, because the knowledge created in such institutions must be transferred to other facets of the economy. Therefore, universities have tried over the years to analyze the value created by these inventions to measure the level of social and economic growth in the economy. Here, studies focus mostly on the valorization of technology transfer by universities due to the involvement of organizations and the government, known as the triple helix era.

The last stream (composed of 22% of the articles) discusses the internal impact of the university and how it can be analyzed or measured. Universities in recent years have engaged in the production and marketing of technology with the aim of acquiring some financial benefits to carry on with further research. However, most of the articles in this stream discussed how universities have put in place procedures to measure their performance, which will permit them to decide either to continue in that research field or to engage in new research fields with enormous benefits. Furthermore, not all technology that is generated in the university is licenced; these unlicensed technologies either are for internal use or already exist in the market because of time lag (from the creation to the commercialization). Nevertheless, performance in the academic field can be a measure which permits academia or administrators to successfully transfer long-term technology or knowledge with outstanding performance. Thus, all research when put to market is expected to have a positive impact on both the university (in monetary form) and society (economic growth).

Unlike in the past, when universities aimed at carrying out basic research, there has been an evolutionary change in the global activities of universities over the years which has led universities gradually to change from carrying out only basic research to adding a much more commercialized level. Many universities now compete among each other, especially in the domain of advancement of innovation and technology transfer. This has strengthened the relationship between universities and industry at the level of technology transfer from universities to industry (Jensen and Thursby, 2001). The creation and transfer of knowledge from universities to other

organizations not only capitalizes on the advantages of these institutions, but to a greater extent is geared toward societal benefits which can foster regional development. Spin-out companies and licensing arrangements are highly funded because of the successes recorded in the commercialization of useful technology generated from basic research (McAdam et al., 2009). However, such developments usually are accompanied by risk of uncertainty, with a greater demand for resource funding. Thus, there is a need to minimize related developmental risk while increasingly allocating resources.

This paper focused on a specific part of an enormous literature dealing with technology transfer from academia, by systematically reviewing the literature involving the economic exploitation of the knowledge produced and marketed by universities, irrespective of its form. This was done through the systematic analysis of the literature in 34 academic journals and 100 papers specifically dealing with the topic. This review is the first to analyze systematically the literature on the financial benefits generated by universities from the vast knowledge produced in these institutions and the best means through which income can be generated, whether through licensing, the creation of spin-offs, or commercializing and transferring these inventions to other institutes or corporations.

The paper provided a brief introduction to and background on outbound open innovation, which was first emphasized by Chesbrough (2003). Universities are more diverse in their organizations because they have many faculties which are specialized in the production and marketing of intellectual property. Technology and biotechnological industries are some examples, which produce and market medical technology and other materials (Macho-Stadler et al. 2007). With the creation of university technology transfer offices, there has been a significant turning point in the commercialization of university inventions, because these offices facilitate the flow and transfer of this knowledge (Siegel et al., 2007, 2004; Graffet al., 2002; Carree et al., 2014). Through the key role played by universities in the creation of knowledge, licensing accords, spin-offs, academic start-ups, and the process of technology transfer, they are highly considered by this research which has enriched the study in many dimensions (Swamidass, 2012; Giuri et al., 2013).

This research is not without its limitations. We considered only journal articles and reviews, without necessarily taking into consideration other sources such as conference papers, books, and others. In addition, we did not provide any time limit, but narrowed the search to the required papers by considering only articles that had most of the keywords of interest. The number of papers used in this research might not reflect the exact expectation of the results to be obtained because the field of study still is growing, with much to be published in the future. Furthermore, most universities during this process face challenges such as limited research funding, lack of follow-up of young researchers, competition with other institutions, knowledge spill-over, and many others, which highly differentiate some universities from others. Some authors (e.g., Goldfarb & Henrekson, 2003) considered that the incorrect allocation of incentives to universities could lead to unsuccessful commercialization of university technology. An example is Swedish universities, which have unsuccessful technology transfer compared with that of universities in the US.

There is no doubt that there are alternative ways through which research from universities can be transferred or commercialized to other institutions or organizations. This study addressed the issue by grouping the research articles into four streams, knowledge transfer modes and intermediaries, strategic organization and management, economic and social impacts, and the internal impact or performance recorded by these institutions. From this classification, it is evident that although not much is written on the intermediaries and various modes of commercialization, there still is a wide range of opportunity to better enhance this stream of research.

This research thus could be a starting point for most academic institutions, especially universities which are more engaged in carrying out research as a basic activity. This is because this study addressed issues that are relevant to the invention and commercialization of university research, such as the modes of commercialization of licensing, organization and management of strategies for licensing, economic growth and social networks in the creation of value, and the internal impact or performance of these universities. The literature on

university technology exploitation is carefully categorized in a technology commercialization context, characterized from different viewpoints through the analysis of the various modes.

Furthermore, this research could be developed further by first differentiating state universities from private universities to analyze the aforementioned issues separately. The results could demonstrate whether state-owned universities benefit as much from licensing their research as do private institutions, and the means of commercialization through which these benefits come. In addition, future studies can focus on a single continent, country, or region and can integrate other aspects determining the financial benefits of university licensing, such as environmental, social, cultural, political, or religious factors. Likewise, it could be necessary to analyze whether the licensing of IP can be influenced by existing markets during the licensing period. Finally, one of the aforementioned channels or modes could be concentrated on and exploited to determine exactly the financial benefit that this channel accrues to the university. Thus, there is a need to further analyze the measurement of success of technology commercialization or licensing and to compare these successes with those of other modes.

EXTENDED SUMMARY/IZVLEČEK

V zadnjih letih se univerze vse bolj ukvarjajo s trženjem in licenciranjem intelektualne lastnine, predvsem v obliki prodaje patentov, licenciranja tehnologij in pogodbenih raziskav. Kljub temu, da so razlogi za slednje znani, se v povezavi s tem pojavljanjo določena vprašanja na katere je potrebno najti odgovore. V prispevku so avtorji preučevali, kako točno poteka omenjeno trženje in licenciranje ter pod katerimi pogoji lahko univerze izvajajo takšne dejavnosti. Prispevek temelji na pregledu obsežnega dela literature o prenosu tehnologije iz akademskih krogov in sistematičnem pregledu raziskav o tem, kako gospodarstvo izkorišča znanje, ki je pridobljeno in (v kakršni koli obliki) prodano s strani univerz. Bolj natančno, omenjene raziskave predstavljajo analizo različnih načinov komercializacije intelektualne lastnine. Preučevanje slednjih je pokazalo, da je licenciranje glavni način prenosa tehnologije, medtem ko so analize uspešnosti različnih načinov raziskovanja drugi najpogostejši način. Nadalje, prispevek vključuje pregled raziskav, ki preučujejo vrednost sodelovanja in povezav, ter raziskav, ki preučujejo tematiko iz perspektive managementa. Avtorji so v prispevku analizirali literaturo, objavljeno v 42 različnih akademskih revijah in skupno 118 posameznih znanstvenih študijah. Ta prispevek je prvi, ki ponuja sistematično analizo literature glede finančnih koristi, ki so jih univerze deležne ob prenosu tehnologije, in analizira najboljše načine za ustvarjanje dohodka, npr. licenciranje, komercializacija in prenos znanja ali tehnologije na druge institucijam oziroma ustanove.

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APPENDICES

Appendix 1

Theoretical perspective	Frequency (percentage)
Resource and capability based	7 (16%)
Knowledge-based theory	7 (16%)
Transaction cost theory	5 (12%)
Technological change and strategic management theories	4 (9%)
Game theory	4 (9%)
Stakeholder theory	3 (7%)
Open innovation theory	1 (2%)
Investment risk perspective	1 (2%)
Organizational Theory	1 (2%)
Information theory	1 (2%)
Innovation speed theory	1 (2%)
Both deductive and inductive approaches	1 (2%)
Agency theory	1 (2%)
Endogenous growth theory	1 (2%)
Grounded theory	1 (2%)
Hannan and Carroll's theory	1 (2%)
New growth theory	1 (2%)
Shannon's communication theory	1 (2%)
Status characteristics theory	1 (2%)
Total	**43 (100%)**

Appendix 2

Methods of Analysis	Frequency (percentage)
Regression (probit, Tobit, time lag, linear, etc.)	20 (21%)
Multiple methods	16 (17%)
Descriptive statistics	11 (11%)
Multiple case study	11 (11%)
Data envelopment analysis (DEA)	5 (5%)
Game-theoretic model	4 (4%)
Revenue maximization model	3 (3%)
Semi-structured interview	3 (3%)
Content analysis	3 (3%)
Meta data analysis	2 (2%)
Multivariate probit model	2 (2%)
Market analysis	2 (2%)
Input-output model	2 (2%)
Cohort analysis	1 (1%)
Cognitive model	1 (1%)
Company Start-up Model	1 (1%)
Comparative cross case analysis	1 (1%)
Business model	1 (1%)
Deductive and Inductive Approach	1 (1%)
Desorptive capacity model	1 (1%)
Absorptive capacity model	1 (1%)
Conceptual model	1 (1%)
Panel analyses and cross-section estimates	1 (1%)
Social network analysis	1 (1%)
Theoretical analysis	1 (1%)
Total	**96 (100%)**

Appendix 3

Journals	Frequency	Percentage
Journal of Technology Transfer	25	21%
Research Policy	18	15%
Technovation	8	7%
Science and Public Policy	5	4%
R & D Management	5	4%
Journal of Business Venturing	4	3%
Research-Technology Management	3	3%
Industry and Innovation	4	3%
Oxford Review of Economic Policy	3	3%
International Journal of Technology Management	3	3%
Aei-Brookings Joint Centre for Regulatory Studies	2	2%
Innovation-Management Policy & Practice	2	2%
The Journal of High Technology Management Research	2	2%
Journal of Innovation Economics & Management	2	2%
Management Science	2	2%
Journal of Product Innovation Management	2	2%
International Journal of Industrial Organization	2	2%
American Economic Review	2	1%
African Journal of Business Management	1	1%
California Management Review	1	1%
Canadian Journal Of Administrative Sciences-Revue Canadienne Des Sciences De L'Administration	1	1%
Technology Analysis And Strategic Management	1	1%
European Journal of Innovation Management	1	1%
Globalization and Health	1	1%
Regional Studies	1	1%
Innovation Policy and The Economy	1	1%
International Journal of Innovation Management	1	1%
Journal of Business Research	1	1%
Technology Forecasting and Social Changes	1	1%
Journal of Management Studies	1	1%
Journal of The European Economic Association	1	1%
Journal of The Knowledge Economy	1	1%
Management Decision	1	1%
IEEE Transactions on Engineering Management	1	1%
Organisational Science	1	1%
Strategic Management Journal	1	1%
Long Range Planning	1	1%
Minerva	1	1%
COMUNICAR	1	1%
Total	**118**	**100%**

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A MULTI-INFORMANT ASSESSMENT OF ORGANIZATIONAL AGILITY MATURITY: AN EXPLORATORY CASE ANALYSIS

Tomislav Hernaus
University of Zagreb, Faculty of Economics and Business
thernaus@efzg.hr

Marija Konforta
marija.konforta@gmail.com

Aleša Saša Sitar
University of Ljubljana, School of Economics and Business
alesa-sasa.sitar@ef.uni-lj.si

Abstract

The paper provides a multi-informant assessment of agility maturity from an organizational point of view. We applied the Organizational Agility Maturity Model (Wendler, 2014) within a case study of an oil company to determine whether and to what extent there was managerial/employee (informant) agreement between agility assessment across different hierarchical levels. A multi-grade fuzzy method used inputs from three academic subject matter experts and 26 organizational informants to calculate response data–based weighted means. Empirical results indicate inconsistency in assessment ratings across agility dimensions and agile criteria; single-informant scores significantly exceeded multi-informant scores. Furthermore, we found that top managers, compared with other managerial layers as well as employees, are more pessimistic (or perhaps more realistic) when assessing the overall agility maturity of the company. In other words, data indicate that the more generalized the role of the informant, the more critically they assess agility attributes.

Keywords*: Organizational agility; Maturity model; Multi-informant data; Case study.*

1. INTRODUCTION

Organizational agility, defined as "a dynamic capability of an organization to respond quickly in accordance with the dynamic demands of the customers" (Vinodh, Devadasan, Reddy& Ravichand, 2010: 7159) recently has become a preferred design strategy for complex systems (Kates, Kesler& DiMartino, 2021) operating in a volatile and uncertain environment (Teece, Peteraf& Leih, 2016). Representing a comprehensive organizational practice that makes a difference [e.g., 37% faster revenue growth, 30% higher profits (Walter, 2020)], it has been targeted increasingly in the business world. Accordingly, the assessment of agility is important and has resulted in several maturity model developments (Vinodh & Aravindraj, 2015).

The literature on agility still is underdeveloped and has not validated pioneering theoretical and methodological frameworks for assessing this strategizing concept. Specifically, a missing consensus about the constitutive agility dimensions limits the understanding and the applicability of existing empirical evidence (Wendler, 2014). We do not possess knowledge about how different aspects of agility interact to increase the overall organizational agility maturity (Walter, 2020). Previous research

also indicated inconsistencies in the assessment of organizational phenomena by different informants and on different hierarchical levels (Kumar, Stern& Anderson, 1993). Despite the prevailing practice of using single key informants, more recent studies found that multiple informants provide more-accurate evaluations for less documented organizational characteristics and processes (Bou-Llusar, Beltran-Martin, Roca-Puig& Escrig-Tena, 2016). Furthermore, in some studies, top managers' scores, which usually are attributed to organizational level phenomena, were found to differ from estimations of lower-level informants because managers at different levels and employees perform different tasks and perceive strategic organizational practices differently (Wendler, 2014). Therefore, questions about who should assess agility (a single or multi-informants), and to what extent, if at all, we might expect to find differences in perceptions of organizational agility, still are waiting to be answered.

This paper addressed some of these issues by offering a multi-informant assessment of agility maturity from an organizational point of view. Field survey research was carried out on a sample of 26 organizational members (top-, middle-, and low-level managers, and employees) by using a confirmatory and multi-grade fuzzy approach. We calculated and compared both baseline (i.e., manifest and observed) agile criteria, underlying (weighted latent) dimensions of organizational agility, and total organizational maturity agility index score across a Croatian oil company.

Potential contributions of the paper are threefold. We replicated Wendler's Organizational Agility Maturity Model, thus extending the theoretical applicability of this particular whole- organization assessment tool by indicating which aspects of agility are particularly important to increase overall organizational agility maturity and how agility dimensions and criteria interact with each other. Next, we improved the methodology by moving beyond the dominant single-informant approach and showing whether differentiated results occur across hierarchical layers if we apply a multi-informant discussion. Finally, our study practically identified areas in which the case studied organization should focus to enhance the overall organizational maturity score.

2. THEORETICAL BACKGROUND

2.1 Organizational agility maturity models

The idea of corporate agility dates back to 1982 and has been gaining an increasing attention during the last decade. From an initial "corporate responsiveness to output goals" (Brown & Angew, 1982: 30), the concept has been advanced into agile production/manufacturing (e.g., Gunasekaran, 2001) and agile organization design (e.g., Worley, Williams& Lawler, 2014; Holbeche, 2018), and most recently has been used as a guiding principle of HR/workforce planning (e.g., Gibson, 2021). Seemingly, agility as a dynamic capability and agility principles as guiding practices nowadays are required not only in the boardroom but also across the entire organization (Gunsberg et al., 2018).

The concept of agility was found to be relevant particularly for complex and large organizations characterized by a differentiated structure and multiple operations. As summarized by Zhang and Sharifi (2000), it comprises two main factors: (1) responding to changes (anticipated or unexpected) in proper ways and in due time; and (2) exploiting changes and taking advantage of changes as opportunities.

A more specific focus and consensus about the dimensionality of this concept is needed. Several organizational agility models have been suggested; Leppanen (2013) provided an overview and benchmarking insights. Kumar and Motwani (1995) were among the first to devise a model for measuring and computing the agility index (i.e., the strategic agile position of an organization). Zhang and Sharifi (2000) proposed a conceptual model for implementing agility in manufacturing organizations with agility drivers, agility capabilities, and agility providers as three constituting blocks. Walter (2020) identified four agility categories: agility drivers, agility enablers, agility capabilities, and agility dimensions.

To the best of our knowledge, the most methodologically sound approach to date is that of Wendler (2014, 2016), who developed the Organizational Agility Maturity Model consisting of six high-level dimensions, partitioned into a larger number of agile criteria based on numerous corresponding agility concepts and attributes. The model

was validated and slightly adapted by Gunsberg et al. (2018), ultimately highlighting the following six dimensions of organizational agility: Leadership and management, Innovation, Strategy, Culture, Learning and change, and Structure. A complete hierarchical structure of the organizational agility concept and its dimensions is provided in Tables 1–6.

The aforementioned static, content-wise approach to organizational agility should be supplemented further by an equally important dynamic, process-wise approach. In other words, we argue that agility should be viewed not only as a more–less or yes–no decision, but rather perceived as a journey or continuum, characterized by different evolutionary stages or maturity levels. The path to agility is a development process that affects all parts of an organization, ultimately increasing the business performance and strengthening market competitiveness (Vázquez-Bustelo et al., 2007; Wendler, 2014; Walter, 2020).

Maturity models represent anticipated, desired, or typical evolutionary change of a set of related practices (e.g., Becker, Knackstedt& Pöppelbuß, 2009) and show the degree to which core principles (in the present case, the organizational agility concept) are implemented (Gren, Torkar& Feldt, 2015). According to Wendler (2014: 1201-1202) and Gunsberg et al. (2018: 1322), we can define four distinct agility maturity stages/levels:

(1) Non-agile—"Organizations show no or only rare properties of organizational agility. Agile values are principally unknown, and the technological basis is fragmented and unable to support communication processes effectively. Only a minority of employees and managers share capabilities necessary to implement agile values and actions."

(2) Agility basics—"Organizations share basic properties of organizational agility. Agile values and technological prerequisites underscoring agility are partly implemented in some but not the majority of departments. Likewise, some but not the majority of employees share agile capabilities and some managers in the organization are able to manage change in an appropriate way."

(3) Agility transition—"Organizations manage to disseminate agile values and to establish an appropriate technological basis in most parts of the organization. Many employees and managers share the idea of agility and possess corresponding capabilities. Change is mostly welcomed and handled accordingly. In many instances, the organization promotes teamwork and establishes structures that are flexible enough to cope with upcoming changes."

(4) Organizational agility—"Organizations manage to establish a sufficient technological basis throughout the complete organization, and agile values are shared and accepted completely, too. All employees and managers have the capabilities to successfully work in an agile and changing environment and the structure is flexible enough to quickly and constantly react to upcoming changes."

For each dimension of the maturity model, the level of agility is assessed independently for each single sub-dimension, enabling an alternative in which the organization holds different maturity stages in specific sub-dimensions at a certain time. This difference is intended because the approach reflects the real state of the transition toward an agile organization, and it is unlikely that an organization is able to improve every aspect simultaneously and at the same pace (Wendler, 2014). It could be used both for internal (comparing agility maturity scores of a single organization in different time points) and external (comparing agility maturity scores of several organizations at a single time point) benchmarking purposes.

2.2 Single- vs. multi-informant research designs

Management research relies heavily on a single (key-)informant design (Gupta, Shaw& Delery, 2000; Wagner, Rau& Lindermann, 2010) to make empirical inferences about organizational reality. This traditional data collection strategy assumes that a single person is able to provide accurate information about all the variables that refer to the whole organization (Gerhart, Wright& McMahan, 2000; Bou-Llusar et al., 2016). Although key-informant [i.e., "an expert who is most knowledgeable of the organization or issue" (Lavrakas, 2008: 407)] responses are likely to be relatively accurate (Homburg et al., 2012), this methodological choice has been challenged increasingly due to concerns

about the degree of variation of raters' assessments (Bainbridge, Sanders, Cogin& Lin, 2016). Each key informant (e.g., HR manager, chief strategy officer, or organization design expert)—chosen on the basis of theory and/or data driven criteria (Johnson, 1990)—has an idiosyncratic perspective of organizational functioning.

In single-informant research designs, we cannot determine what proportion of item variance is trait variance (Guide & Ketokivi, 2015), and often struggle with single-informant bias, that is, a common method bias derived from single-source studies (Podsakoff et al., 2003; Jordan & Troth, 2020). In addition, single key informants might not always be able to judge complex organizational issues for large companies, thus providing less-accurate and unreliable assessment (Homburg et al., 2012). Furthermore, because perceptions differ substantially among individual respondents, they are subject to perception biases, and are subjective in collecting and interpreting information they find relevant and important when reporting particularly on non-documented organizational characteristics (Ernst & Teichert, 1998).

Therefore, a multi-informant data collection strategy recently emerged as more viable approach for conducting rigorous organizational research (Bou-Llusar et al., 2016). The key benefit of using two or more informants per organization to provide responses lies in the higher validity and reliability of survey data (Wagner et al., 2010; Homburg et al., 2012). For instance, evaluating corporate strategy from a single source (e.g., a top manager's perspective) may not give the real picture; instead, the executive assessment may be seen almost as speculation (Bowman & Ambrosini, 1997). Moreover, empirical evidence indicates that differences exist when a multi-informant research design is adopted, compared with a single-informant design (Bou-Llusar et al., 2016).

Following the data collection recommendations of Wagner et al. (2010), we measured and analyzed whether organizational agility maturity scores pooled from multiple informants vary compared with single- or key-informant assessment. Answering this research question is important if we want to gather reliable evidence on organizational agility. Failure to account for informant bias may lower the degree of correspondence between informant reports and the concept of organizational agility which they are intended to represent, thereby jeopardizing the validity of any substantive findings (Kumar, Stern& Anderson, 1993). There is no single agility expert in organizations that would have the knowledge and experiences needed to provide an adequate (consistent and unbiased) evaluation of all agility dimensions and criteria. Achieving agility maturity also requires the involvement of different individuals in different departments. Furthermore, agility relates to softer issues (innovation, culture and values, learning and change, etc.) that rarely are formally written down, hampering objective assessment, as was found for new product development processes in organizations (Ernst & Teichert, 1998). By acknowledging evidence from other research domains indicating dissimilarities in single- versus key-informant accuracy (e.g., Wilson & Lilien, 1992; Homburg et al., 2012; Krause, Luzzini& Lawson, 2017), we likewise assume that a similar rule of thumb should be valid for organizational agility measurement, Therefore, we developed the following hypothesis:

Hypothesis 1: Organizational agility assessment score differs between single- and multi-informant research designs.

2.3 Multi-level assessment of organizational agility

Organizational assessment preferably is done collectively, and usually takes into account inputs collected from different hierarchical levels. Diverse categories of informants often are interviewed or surveyed throughout the organizational diagnosis process. When considering strategic or strategy-like concerns (such as organizational agility), managers at three qualitatively different yet interrelated levels (top-, middle- and first-line management) might be sampled together with an expert panel (e.g., Hambrick, 1981).

Top managers are strategy explorers who plan organizational long-term efforts and prioritize resource allocations across units (Bettis & Prahalad, 1983). They have a bird's-eye view of an organization and strive to identify internal strengths and weaknesses to capitalize on environmental opportunities (Ireland et al., 1987). Middle-level managers

mediate between expectations expressed by top managers and tasks performed by lower-level supervisors (Parsons, 1960). Thus, they combine formal structure with informal structure to meet unit-level targets. First-line supervisors perceive alternatives relative to the organizational ability to do "things right" (Drucker, 1973) on the shop floor. In other words, they strive to exploit successfully the organizational strategic position (Ireland et al., 1987). These three level-specific managerial groups perform different tasks and might perceive market, organizational, and work practices differently.

The pioneering study by Lifson (1953) found that rater differences cover up to one-third of performance measurement variance. This was corroborated by Lance (1994), clearly signaling that measurement variance exists in multi-informant studies. For instance, Ireland et al. (1987) noted that perceptions of strengths and weaknesses of strategy formulation process vary systematically across managerial levels. Hambrick (1981) found that strategic awareness consistently decreases moving down the hierarchical ladder, and Snow and Hrebiniak (1980) posited that the knowledge about a corporate strategy is lower at lower levels of the organizations.

On the other hand, research studies covering domains such as strategy (e.g., Walter et al., 2013), human resource management (HRM) (e.g., Diefendorff, Silverman& Greguras, 2005), or organizational psychology (e.g., Liu, Borg& Spector, 2004) reported on measurement equivalence or multiple informant consensus. For example, Phillips (1981: 412) found empirical evidence that "high ranking informants tended to be more reliable sources of information than their lower status counterparts on some issues but not on others, with no discernible pattern emerging across all measures."

Such opposing results suggest that scholars should not ignore the issue and need to check the measurement equivalence across different groups of informants prior to performing statistical analyses (Rungtusanatham et al., 2008). Incorporating a stream of research that considers variance in measurement to be a consequence of existing differences in the information- (Homburg et al., 2012) and knowledge-base of different raters (Phillips, 1981; Wagner et al., 2010; Bou-Llusar et al., 2016), and similar to Wendler (2014), who found differentiation among managers' responses, we hypothesize the following:

Hypothesis 2: Organizational agility characteristics (i.e. agility dimensions and agile criteria) are perceived differently at different hierarchical levels.

3. METHODOLOGY

3.1 Sample and collection of data

To understand the complex issue of organizational agility, field survey research was conducted on a sample of respondents from a single case study organization. We analyzed a large Croatian state-owned oil company. Core activities of the case subject include oil transportation and storage of crude oil and petroleum products. The company operates a strategic oil pipeline, which is recognized as a project of common interest in the European Union. To adapt to dynamic changes in the labor market, the company has established a number of policies to ensure the efficient flow of business processes with the professional development of each employee. Organizational HRM practices are based on open communication that creates a transparent environment in which the personal development of each employee is encouraged, increases technological competitiveness, and ensures fast and efficient transfer of knowledge and skills, all of which are needed to assure organizational agility.

Targeted participants in our study occupied managerial roles at different hierarchical levels, although we also decided to collect data from a group of employees who did not have managerial responsibilities. Our cross-hierarchical sample included 25 multiple informants (five top managers, six middle-level managers, four first-line supervisors, and 10 employees), plus a single key informant (an HR manager). Thus, we followed a recommendation that at least five responses are needed to obtain a reasonable aggregate of subjective judgments at the informant level (Homburg et al., 2012). An exception was made in the case of lower-level supervisors, but it still is considered acceptable because most researchers choose two or three multiple informants (Kumar, Stern& Anderson, 1993; Wagner et al., 2010). To make data aggregation possible, each respondent was provided with the same set of questions; the responses collected remained

anonymous, and were analyzed as composites. The average respondent was female (61.5% women) and just over 45 years old (61.5% of respondents were in the age range 40–50 years), with a university degree (50.0% of sampled informants) and had more than 12 years of organizational tenure (92.3% of respondents had more than nine years of work experience).

3.2 Research questionnaire

A self-report paper questionnaire, originally developed by Wendler (2014) and further validated by Gunsberg et al. (2018), was adapted slightly for our hierarchical assessment of organizational agility. The survey questions on a five-point Likert agreement scale required respondents to report on actions, activities, values, and capabilities contributing to the actual degree of agile maturity in the following dimensions: Leadership and management, Innovation, Strategy, Culture, Learning and change, and Structure. The questionnaire had two to six items per criterion for specific dimension).

Initially, a Cronbach's α was calculated for each set of items (i.e., agility criteria) related to respective agility dimensions. Such an approach was taken because not all agility criteria constructs contained a satisfying number of items (i.e., a minimum of three: trust, style, and skills). The reliability analysis provided acceptable values that were above the established cut-off point of α = 0.70 suggested by Nunnally (1978). An exception was the leadership and management dimension (α = 0.661), although it still was within the tolerable range of internal consistency.

A multi-grade fuzzy assessment of agility (e.g., Yang & Li, 2002; Vinodh et al., 2010) was introduced *a priori* (before administering the survey in the field) to determine the relative importance of different agile characteristics (attributes, criteria, and dimensions) constituting the Organizational Agility Maturity Model (Wendler, 2014). A benchmarking analysis of available agility assessment approaches (Vinodh & Aravindraj, 2015) showed that this approach to assessing organizational agility is superior to conventional scoring approaches.

3.3 Procedure

Following an approach proposed by Bottani (2009), three academic subject matter experts (SMEs) provided useful inputs about the relative importance of agility characteristics covered by this research, which eventually enabled us to develop a three-level weighting scheme (Zhang & Sharifi, 2000). The first-level index represents six dimensions of agility; the second-level index represents 16 agile criteria; and the third level index represents 52 agile attributes. Before calculating a single common response, we checked for degree of agreement among SMEs. Intra-class correlation (ICC) was found to be 0.859 ($p < 0.001$), revealing good consistency among raters. This enabled us to compute unweighted group means pertaining to each specific agility dimension, criteria and attribute (Tables 1–6).

Table 1. Single-factor assessment and weights for Leadership and management dimension provided by subject matter experts.

Organizational agility enablers			**Subject matter expert ratings**					
Agility dimension	Agile criteria	Agile attributes	Individual-level assessment			Group-level assessment		
I_i	I_{ij}	I_{ijk}	SME_1	SME_2	SME_3	W_{ijk}	W_{ij}	W_i
Leadership and Management	**Risk**	Risk1	0.40	0.40	0.40	0.40	-	-
		Risk2	0.30	0.20	0.30	0.27	-	-
		Risk3	0.30	0.40	0.30	0.33	-	-
		Risk (total)	0.31	0.50	0.36	-	0.39	-
	Style	Style1	0	0.40	0	0.13	-	-
		Style2	1	0.60	1	0.87	-	-
		Style (total)	0.69	0.50	0.64	-	0.61	-
	LEAD (Total)		0.20	0.15	0.15	-	-	0.17

Table 2. Single-factor assessment and weights for Innovation dimension provided by subject matter experts.

Organizational agility enablers			**Subject matter expert ratings**					
Agility dimension	Agile criteria	Agile attributes	Individual-level assessment			Group-level assessment		
I_i	I_{ij}	I_{ijk}	SME_1	SME_2	SME_3	W_{ijk}	W_{ij}	W_i
Innovation	**Flexibility**	Flex1	0.20	0.35	0.15	0.23	-	-
		Flex2	0.20	0.15	0.20	0.18	-	-
		Flex3	0.30	0.25	0.40	0.32	-	-
		Flex4	0.30	0.25	0.25	0.27	-	-
		Flex (total)	0.50	0.50	0.45	-	0.48	-
	Proactivity	Proact1	0.35	0.40	0.45	0.40	-	-
		Proact2	0.40	0.20	0.30	0.30	-	-
		Proact3	0.25	0.40	0.25	0.30	-	-
		Proact (total)	0.50	0.50	0.55	-	0.52	-
	INNOV (Total)		0.15	0.15	0.15	-	-	0.15

Table 3. Single-factor assessment and weights for Strategy dimension provided by subject matter experts.

Organizational agility enablers			**Subject matter expert ratings**					
Agility dimension	Agile criteria	Agile attributes	Individual-level assessment			Group-level assessment		
I_i	I_{ij}	I_{ijk}	SME_1	SME_2	SME_3	W_{ijk}	W_{ij}	W_i
Strategy	**Engagement**	Engag1	0.50	0.40	0.40	0.43	-	-
		Engag2	0.30	0.40	0.40	0.37	-	-
		Engag3	0.20	0.20	0.20	0.20	-	-
		Engag (total)	0.40	0.20	0.45	-	0.35	-
	Industry awareness	Industr1	0.25	0.30	0.35	0.30	-	-
		Industr2	0.55	0.40	0.45	0.47	-	-
		Industr3	0.20	0.30	0.20	0.23	-	-
		Industr (total)	0.40	0.30	0.40	-	0.37	-
	Planning	Plan1	0.25	0.20	0.10	0.18	-	-
		Plan2	0.25	0.30	0.10	0.22	-	-
		Plan3	0.20	0.20	0.35	0.25	-	-
		Plan4	0.10	0.10	0.25	0.15	-	-
		Plan5	0.20	0.20	0.20	0.20	-	-
		Plan (total)	0.20	0.50	0.15	-	0.28	-
	STRAT (Total)		0.10	0.20	0.10	-	-	0.13

Table 4. Single-factor assessment and weights for Culture dimension provided by subject matter experts.

Organizational agility enablers			**Subject matter expert ratings**					
Agility dimension	Agile criteria	Agile attributes	Individual-level assessment			Group-level assessment		
I_i	I_{ij}	I_{ijk}	SME_1	SME_2	SME_3	W_{ijk}	W_{ij}	W_i
Culture	**Accountability**	Account1	0.45	0.40	0.25	0.37	-	-
		Account2	0.25	0.30	0.35	0.30	-	-
		Account3	0.30	0.30	0.40	0.33	-	-
		Account (total)	0.40	0.30	0.30	-	0.33	-
	Trust	Trust1	0.35	0.60	0.35	0.43	-	-
		Trust2	0.65	0.40	0.65	0.57	-	-
		Trust (total)	0.30	0.30	0.40	-	0.33	-
	Values and principles	Values1	0.20	0.20	0.15	0.18	-	-
		Values2	0.25	0.20	0.30	0.25	-	-
		Values3	0.20	0.10	0.25	0.18	-	-
		Values4	0.15	0.15	0.05	0.12	-	-
		Values5	0.05	0.10	0.05	0.07	-	-
		Values6	0.15	0.25	0.20	0.20	-	-
		Values (total)	0.30	0.40	0.30	-	0.33	-
	CULT (Total)		0.15	0.20	0.20	-	-	0.18

Table 5. Single-factor assessment and weights for Learning and change dimension provided by subject matter experts.

Organizational agility enablers			**Subject matter expert ratings**					
Agility dimension	Agile criteria	Agile attributes	Individual-level assessment			Group-level assessment		
I_i	I_{ij}	I_{ijk}	SME_1	SME_2	SME_3	W_{ijk}	W_{ij}	W_i
Learning and Change	**Organizational learning**	Organ1	0.35	0.40	0.45	0.40	-	-
		Organ2	0.40	0.30	0.35	0.35	-	-
		Organ3	0.25	0.30	0.20	0.25	-	-
		Organ (total)	0.50	0.30	0.50	-	0.43	-
	Skills development	Skills1	0.60	0.50	0.65	0.58	-	-
		Skills2	0.40	0.50	0.35	0.42	-	-
		Skill (total)	0.30	0.35	0.20	-	0.28	-
	Workforce capability	Work1	0.30	0.40	0.30	0.33	-	-
		Work2	0.30	0.20	0.30	0.27	-	-
		Work3	0.40	0.40	0.40	0.40	-	-
		Work (total)	0.20	0.35	0.30	-	0.28	-
	LEARN (Total)		0.30	0.15	0.30	-	-	0.25

Table 6. Single-factor assessment and weights for Structure dimension provided by subject matter experts.

Organizational agility enablers			**Subject matter expert ratings**					
Agility dimension	Agile criteria	Agile attributes	Individual-level assessment			Group-level assessment		
I_i	I_{ij}	I_{ijk}	SME_1	SME_2	SME_3	W_{ijk}	W_{ij}	W_i
Structure	**Adaptability**	Adapt1	0.50	0.30	0.45	0.42	-	-
		Adapt2	0.30	0.30	0.30	0.30	-	-
		Adapt3	0.20	0.40	0.25	0.28	-	-
		Adapt (total)	0.50	0.40	0.40	-	0.43	-
	Collaboration	Collab1	0.15	0.40	0.15	0.23	-	-
		Collab2	0.25	0.10	0.20	0.18	-	-
		Collab3	0.35	0.30	0.30	0.32	-	-
		Collab4	0.25	0.20	0.35	0.27	-	-
		Collab (total)	0.30	0.30	0.40	-	0.33	-
	Cooperation	Cooper1	0.40	0.35	0.25	0.33	-	-
		Cooper2	0.40	0.35	0.45	0.40	-	-
		Cooper3	0.20	0.30	0.30	0.27	-	-
		Cooper (total)	0.20	0.30	0.20	-	0.23	-
	STRUC (Ttotal)		0.10	0.15	0.10	-	-	0.12

Importantly, Wendler's original model also included Communication as a leadership dimension of agility. However, we decided to follow Gunsberg's validated version of the questionnaire, which discarded the Communication criterion from further analysis. Another methodological choice made by the authors was to consider each agility dimension of organizational agility not only as an aggregate index of specific agile criteria and respective attributes, but also as a standalone agility category.

Next, to measure and quantify agility within the sampled organization, the degree of agreement among SMEs (relative importance judgments) was incorporated into the calculus of informants' absolute organizational agility responses. For all agility criteria and each corresponding dimension, the response data–based weighted means (van Bruggen et al., 2002) were calculated over the whole sample as well as for different informant groups. This allowed us to compare and investigate variability at all relevant levels of analysis within an organization (Nishii & Wright, 2008).

Finally, to calculate an overall (organizational) agility assessment score, we proportionally reduced a 10-point agility measurement scale proposed by Yang and Li (2002) to a five-point agility measurement scale, and decided to depart from the five stages to apply a more recent four-stage visualization of organizational agility maturity (Wendler, 2014; Gunsberg et al., 2018) using the following scoring ranges: non agile [1, 2.5]; agility basics [2.5, 3.5]; agility transition [3.5, 4.5]; and organizational agility [4.5, 5.0]. Thus, the agility maturity index (I) was computed hierarchically following a layered structure:

(1) the assessment of baseline agile attributes I_{ijk} (absolute scores from 1 to 5).

(2) agile criteria I_{ij}

$$I_{ij} = \Sigma (I_{ijk} \times W_{ijk})$$

(3) agility dimension I_i

$$I_i = \Sigma (I_{ij} \times W_{ij})$$

(4) the agility index I

$$I = \Sigma (I_i \times W_i)$$

where

i = number of an agility dimension (ranges from 1 to 6),

j = number of an agile criteria (ranges from 1 to 16),

k = number of an agile attribute (ranges from 1 to 52),

W_{ijk} = SMEs' weight of an agile attribute (ranges from 0 to 1),

W_{ij} = SMEs' weight of an agile criteria (ranges from 0 to 1), and

W_i = SMEs' weight of an agility dimension (ranges from 0 to 1).

4. RESULTS

Table 7 provides the agility scores of the examined informant groups. Weighted mean values indicated variation in perceptions of agility characteristics at different hierarchical levels, and revealed within-informant differences in the maturity levels of each particular agility dimension and agile criteria. The small (sub-)sample size did not allow us to run inferential tests of significance; therefore, the data analysis and results are descriptive and context-specific. However, in addition to presenting mean values and standard deviations, we conducted a gap analysis (observed versus actual score; single- versus multi-informant ratings) to determine which differences were of a sufficient magnitude to be further interpreted.

4.1 Observed and actual agility scores

The highest *observed* agility dimension scores (i.e., the average of weighted mean values) across the multi-informant sample (N = 25) were for Learning and change (M = 0.85, SD = 0.17) followed by Innovation (M = 0.72, SD = 0.15). The lowest observed score was obtained for Structure (M = 0.39, SD = 0.09). In terms of agile criteria, Proactivity (M = 1.73, SD = 0.37) and Organizational learning (M = 1.58, SD = 0.32) dominated, whereas Cooperation (M = 0.82, SD = 0.18) and Skills development (M = 0.87, SD = 0.21) were assessed as the weakest agility characteristics. Comparing the results with unweighted mean values of the total sample (not reported in the study but available upon request), Learning and change (M = 3.44, SD = 0.68) and Structure (M = 3.37, SD = 0.71) were the most highly-evaluated agility dimensions. At the level of agile criteria, Organizational learning (M = 3.65, SD = 0.72) and Risk (M = 3.64, SD = 0.93) were rated the highest.

The highest actual agility dimension scores (i.e., the maximum weighted mean value for a criterion) followed a similar pattern when observing agility dimensions, because Learning and change (M = 1.07) and Innovation (M = 0.96) once again were perceived as having the most significant contribution to the overall organizational agility. On the other hand, Strategy and Structure had the lowest actual score (M = 0.53). Management style (M = 2.36) and Proactivity (M = 2.29) were the most highly graded agile criteria, whereas Cooperation (M = 1.07) and Skills development (M = 1.12) were placed at the other end of the continuum.

The gap analysis of observed versus actual scores further showed that largest discrepancies were in terms of Leadership and management at the agility-dimension level (MD = 0.25), and Style (MD = 0.89) and Adaptability (MD = 0.68) at the agile-criteria level. On the other hand, Planning (MD = 0.10), Strategy (MD = 0.11), and Structure (MD = 0.14) assessment scores varied marginally across the cohort of study informants.

The organizational agility maturity index was computed by applying the multi-grade fuzzy assessment approach. Interestingly, each study respondent provided a unique, idiosyncratic assessment of the organizational agility. The distance between maximum and minimum index values was notable; the scoring ranged from 1.71 to 4.47. The majority of respondents (88.0%) indicated that the sampled organization is currently either in the third stage of agility transition [3.50, 4.50] or in the second stage of agility basics [2.50, 3.50]. Specifically, eight informants assessed that the case study organization reached the early agility transition [3.50, 4.00], and six informants assessed their employer as late-agility basics [3.00, 3.50]. Furthermore, only three respondents characterized the focal organization as being non-agile [below 2.50], and none perceived it to be at the highest level of organizational agility maturity [above 4.50].

4.2 Key- versus multi-informant assessment scores

To test our first hypothesis, a gap analysis was performed to compare assessments made by the HR manager (key-informant) and other organizational members (multi-informants). Although Vinodh, Madhyasta, and Praveen (2012: 657) suggested a rationale for determining weak points—"if the organization secures less than 50% of the stipulated score, then the criterion is found to be weak"—our measurement scale was not compatible with such an approach. We also were not able to apply effect-size statistics due to sample-size constraints, but we used the following rationale: if the calculated gap, that is, the mean difference (MD) between the observed and actual score for each agility dimension or agile criteria was larger than the average difference score for six agility dimensions (0.20) or 16 agile criteria (0.45), then it was characterized as a weak score that needs improvement. The same rationale was applied in the case of the single- versus multi-informant gap, in which the average difference scores for agility dimensions (0.17) and agile criteria (0.30) were used as a baseline for determining the presence of a significant deviation.

It seems that the key informant and other study informants perceived the overall agility quite differently. The former perceived the sampled organization to be at the changeover between the third and fourth stages of organizational agility maturity, with a score of 4.47. The latter group of raters was more pessimistic in their evaluations, categorizing the sampled organization between second and third stages (M = 3.43, SD = 0.68), a sizeable mean difference compared with single-informant's score (M = 1.04). A further breakdown of this overall index mapped against agility characteristics shows that the agility key- and multi-informant assessments differed both in absolute and in relative terms. Their organizational agility assessment found consensus only in the case of Strategy (MD = 0.06), whereas substantial mean differences were found for Learning and change (MD = 0.24), Innovation (MD = 0.23) and Structure (MD = 0.22). Regarding the agile criteria evaluation, small differences were reported for Trust (MD = 0.09) and Industry Awareness (MD = −0.02), whereas equal scores were given for Planning (MD = 0.00). On the other hand, the most significant variation was for Proactivity (MD = 0.72) and Organizational learning (MD = 0.46), followed by five other agile criteria with substantial relative difference scores. The aforementioned results indicate that we can accept our first hypothesis and conclude that significant differences exist in ratings by single- (key) and multi-informants.

4.3 Organizational agility across informant groups

To test our second hypothesis, two types of comparisons were conducted across different informant groups (top-, middle-, and first-line managers; employees; and key informant). First, a composite-level data analysis showed some inconsistency in ratings across the examined hierarchical levels. Surprisingly, the lowest overall agility index score was reported by top managers (M = 3.19, SD = 0.66), followed by first-line managers (M = 3.37, SD = 1.17) and employees (M = 3.50, SD = 0.67), whereas middle-level managers provided the highest average agility maturity score (M = 3.55, SD = 0.40). As mentioned previously, the key informant's assessment significantly exceeded the scoring of other informant groups (M = 4.34).

A component-level data analysis found interesting response patterns. Specifically, a certain level of managerial (and employee) agreement does exist when assessing the importance of each agility dimension. Informant groups were consistent in rank ordering of agility dimensions (1—Learning and change, 2—Innovation, 3—Culture, 4—Leadership and management, 5—Strategy, and 6—Structure). An exception occurred only in the case of the key informant, who perceived Structure to be slightly more important than Strategy (MD = 0.03). Furthermore, similarities in perceptions were notable at the lower level of analysis; all respondents agreed on top six agile criteria (Proactivity, Organizational learning, Flexibility, Risk, Style, and Adaptability) and on the agility characteristics which are the least important (Skills development, Workforce capability, Planning, Cooperation, and Accountability). Evidently, different informant groups are "all on the same page" in their perceptions of the importance of agility dimensions and agile criteria within the case study organization, which resulted in rejecting the second hypothesis.

Table 7. Weighted mean values across informant groups.

Agility dimension	Agile criteria	Informant group				Inter-informant comparison				
		Top-level managers	Mid-level managers	First-line managers	Employees	Key informant	Multi-informant (top+middle+low+empl)		Gap analysis	
		M (SD)	M (SD)	M (SD)	M (SD)	M	Actual score	Observed score (SD)	Actual vs. observed	Single vs. multi-informant
Leadership and Management	Risk	1.31 (0.27)	1.51 (0.18)	1.40 (0.49)	1.32 (0.23)	1.83	1.95	1.38 (0.27)	0.57	0.45
	Style	1.30 (0.41)	1.18 (0.42)	1.53 (0.75)	1.71 (0.49)	1.83	2.36	1.47 (0.52)	0.89	0.36
	LEAD (Total)	0.44 (0.11)	0.46 (0.08)	0.50 (0.21)	0.52 (0.11)	0.62	0.73	0.48 (0.12)	0.25	0.14
Innovation	Flexibility	1.51 (0.36)	1.50 (0.26)	1.45 (0.61)	1.48 (0.29)	1.88	2.01	1.48 (0.34)	0.53	0.40
	Proactivity	1.58 (0.32)	1.70 (0.41)	1.95 (0.41)	1.73 (0.37)	2.45	2.29	1.73 (0.37)	0.56	0.72
	INNOV (Total)	0.71 (0.14)	0.72 (0.14)	0.74 (0.25)	0.72 (0.14)	0.95	0.96	0.72 (0.15)	0.24	0.23
Strategy	Engagement	1.23 (0.51)	1.26 (0.27)	1.09 (0.42)	1.21 (0.27)	1.47	1.68	1.21 (0.07)	0.47	0.26
	Industry awareness	1.12 (0.26)	1.11 (0.24)	1.17 (0.34)	1.13 (0.26)	1.11	1.59	1.13 (0.25)	0.46	-0.02
	Planning	0.79 (0.29)	0.96 (0.13)	0.88 (0.35)	0.93 (0.18)	1.09	1.19	1.09 (0.22)	0.10	0.00
	STRAT (Total)	0.41 (0.12)	0.43 (0.07)	0.41 (0.14)	0.43 (0.09)	0.48	0.53	0.42 (0.09)	0.11	0.06
Culture	Accountability	0.83 (0.32)	1.02 (0.23)	0.93 (0.42)	1.10 (0.22)	1.42	1.33	1.00 (0.28)	0.33	0.42
	Trust	0.90 (0.32)	1.12 (0.18)	0.94 (0.29)	1.11 (0.33)	1.13	1.65	1.04 (0.29)	0.61	0.09
	Values and principles	0.98 (0.23)	1.08 (0.23)	1.10 (0.34)	1.09 (0.23)	1.25	1.41	1.07 (0.24)	0.34	0.18
	CULT (Total)	0.49 (0.14)	0.58 (0.09)	0.53 (0.19)	0.59 (0.13)	0.69	0.78	0.56 (0.13)	0.22	0.13
Learning and Change	Organizational learning	1.43 (0.32)	1.77 (0.25)	1.45 (0.48)	1.60 (0.25)	2.04	2.04	1.58 (0.32)	0.46	0.46
	Skills development	0.79 (0.20)	0.98 (0.14)	0.86 (0.32)	.83 (0.20)	1.12	1.12	0.87 (0.21)	0.25	0.25
	Workforce capability	0.89 (0.20)	1.03 (0.09)	0.90 (0.35)	0.94 (0.23)	1.20	1.31	0.94 (0.22)	0.37	0.26
	LEARN (Total)	0.78 (0.16)	0.94 (0.08)	0.80 (0.29)	0.84 (0.16)	1.09	1.07	0.85 (0.17)	0.22	0.24

Structure	Adaptability	1.24 (0.50)	1.42 (0.33)	1.32 (0.49)	1.38 (0.37)	1.79	2.03	1.35 (0.39)	0.68	0.44
	Collaboration	0.98 (0.29)	1.11 (0.18)	1.10 (0.28)	1.16 (0.26)	1.38	1.49	1.10 (0.25)	0.39	0.28
	Cooperation	0.81 (0.19)	0.88 (0.14)	0.78 (0.28)	0.82 (0.17)	1.07	1.07	0.83 (0.18)	0.24	0.24
	STRUCT (Total)	0.36 (0.09)	0.41 (0.07)	0.38 (0.13)	0.40 (0.09)	0.51	0.53	0.39 (0.09)	0.14	0.22
Agility Maturity Index		**3.19 (.66)**	**3.55 (0.40)**	**3.37 (1.17)**	**3.50 (0.67)**	**4.34**	**4.47**	**3.43 (0.68)**	**1.04**	**0.91**

5. DISCUSSION AND CONCLUSION

The study spotlights the methodological challenges of assessing organizational agility. We applied the Organizational Agility Maturity Model (Wendler, 2014) within a case study of an oil company to determine whether and to what extent there was managerial/employee (informant) agreement between agility assessment across different hierarchical levels. A multi-grade fuzzy method used inputs from three academic subject matter experts and 26 organizational informants to calculate response data–based weighted means. Empirical results indicate inconsistency in assessment ratings across agility dimensions and agile criteria; single-informant scores significantly exceeded multi-informant scores. However, there was consensus among informants about the overall agility maturity, that is, the sampled organization currently is in the second phase of agility basics, moving toward the third level of the agility transition.

We contribute to the management literature by responding to the call for more research on whole-organization agility maturity models (Sherehiy et al., 2007; Wendler, 2012; Gunsberg et al., 2018). First, our multi-perspective and multi-stakeholder assessment revealed that score differences exist not only across informant groups, but among different agility characteristics. Thus, we confirmed the initial evidence of Wendler and Stahlke (2014) that agility assessment is rather subjective and results in noticeable variations when comparing the answers given by different respondents. Obviously, individuals' cognitive perceptions of organizational attributes, their knowledge base (Wagner, Rau& Lindermann, 2010), position in the organization, and/or type of responsibility affects the objectivity of assessment (Ireland et al., 1987). However, our study offers opposing insights about who has a more optimistic perspective on agility. Contrary to Wendler and Stahlke (2014), we found that top managers, compared with other managerial layers and employees, are more pessimistic (or perhaps more realistic) when assessing the overall agility maturity of the company. In other words, the data indicated that the more generalized the role of the informant, the more critically they assess agility attributes. Such contradictory results in the field may require additional and more rigorous research on the topic.

Second, in ranking specific agility dimensions and criteria, different-level informants agreed that some dimension of the agility maturity model might be considered as more important in achieving organizational agility. Although agility maturity models generally treat all dimensions and attributes as equally important (Wendler, 2012; Gunsberg et al., 2018), our study shows that Learning and change, Innovation, and Culture are more-indicative dimensions of the process of agile transformation as employees continuously learn new knowledge and skills, proactively suggest improvements, and recognize and respond to opportunities from the environment. Structure and Strategy (i.e., cooperating in teams and across functions, and updating strategies and processes) were ranked as less critical. On the agility journey, changing structure and strategy might have limited impact if employees do not change their

behavior to embrace learning and change. Our research thus indicates that in the process of becoming agile, some dimensions should come first. Future research should test if this applies also in different organizations and different industries.

The selection of a research design and methodological choices can shape study results. In light of the ongoing discussion about the strengths and weaknesses of single- versus multi-informant data collection (e.g., Rungtusanatham et al., 2008; Wagner, 2010; Homburg et al., 2012), we tested for consistency of agility ratings from multiple sources. Similar to Bou-Llusar et al. (2016), we found differences in the results obtained using the single-informant and the multi-key-informant research designs. The former—the HR manager in the sampled organization—perceived the overall organizational agility to be significantly (one maturity level) higher than did the other study informant groups. However, we also more thoroughly analyzed the data received from multiple informants. It appeared that certain differences also existed among different informant groups (i.e. top- versus middle-level managers, and top- versus first-line managers). Misfits in between-informant and within-informant group ratings indicate that attention should be paid when deciding who should evaluate organizational-level constructs and practices, because "the assessment cannot be divorced from the assessor" (Ireland et al., 1987: 482). We recommend collecting organizational agility data from multiple, carefully selected key informants. Such an approach supports the differential accuracy assumption (Huselid & Becker, 2000), and accepts that some raters are more knowledgeable than others in assessing specific agility characteristics. Furthermore, multi-informant research designs mitigate the risk of a common method bias (Bou-Llusar et al., 2016).

Bridging the gap between theory and practice is not always straightforward. Although we neither originated the agility maturity model [i.e., the Organizational Agility Maturity Model (Wendler, 2014)] nor developed the organizational agility assessment research procedure [i.e., the multi-grade fuzzy approach using weighted mean values (Vinodh et al., 2010)] used in this particular study, we provided an easy-to-understand example that explains to strategy/HR/organization design professionals and managers in general how to calculate and benchmark organizational agility both within and between organizations. Furthermore, several interesting company-specific insights for improving agility practices can be gained from our analysis. For instance, the case study organization is not yet agile. Although the maturity path to high levels of agility is straightforwardly defined in the literature, we noticed some details in the agility dimension and agile criteria levels that might be relevant for making informed agility improvement decisions.

Unweighted mean values of the total sample reported in the results highlighted Learning and change and Structure as the most highly evaluated agility dimensions, and Organizational learning and Risk most highly evaluated agile criteria. On the other hand, *weighted* mean value scores ranked the Learning and change dimension highest, followed by Innovation. The difference in these two types of mean values is that the former indicates the presence of each agility characteristic in absolute terms (a level of development in the organization), whereas the latter assesses the relative importance (i.e., the level of the agility dimension/criterion importance), indicating how much it contributes to the actual agility maturity stage of an organization. To determine improvement priorities that will guide corporate initiatives and actions toward the targeted organizational agility maturity stage, organizational decision-makers need to focus on those agility characteristics with the most significant yet still underscored contribution.

The gap analysis of observed versus actual scores showed that the largest discrepancies exist in terms of Leadership and management at the agility-dimension level, and in terms of Style and Adaptability at the agile-criteria level. Therefore, management can consciously increase the agility level of the case study organization by focusing on and providing resources to repair "the weakest link in the agility chain," such as Cooperation and Skills development, or by developing "the flagship agility drivers," such as Proactivity and Organizational learning. An intervention on both sides of the gap is another viable alternative. To make effective organization design decisions, insights generated by a multi-grade fuzzy approach need to be supplemented with the scoring approach initially applied

for calculating unweighted mean values. This will indicate not only which agility characteristic needs to be addressed, but also the point of departure toward a higher agility maturity score.

To correctly draw inferences from the present case study-based research, some limitations should be addressed. First, one should be cautious when generalizing the findings of this study. Our sample covered a respectable number of informants, but all were from a single company. Thus, although we can make evidence-based conclusions about a very specific business environment, the study does not provide universally valid results. The findings should be validated across different organizational, industrial, and national contexts. Second, this study did not adequately take into account individual differences. However, informants often represent a heterogeneous group of individuals with different professional and functional backgrounds. Because not all members of an organization possess the same knowledge and information related to agility characteristics (Bou-Llusar et al., 2016), one should control for informants' competencies to ensure the validity of informants' reports (Wagner, Rau& Lindermann, 2010). Furthermore, future research could benefit from collecting multi-informant data in such manner that each respondent evaluates not the whole set of agility characteristics, but also report on a few specific characteristics about which he or she is most knowledgeable. Finally, the organizational agility maturity should be measured over time by using a longitudinal research design. Periodical assessments of the agility dimensions and respective agile criteria could follow a development portfolio process (Jager-van Vliet, Born& van der Molen, 2019) to indicate potential improvement areas.

This thorough organizational assessment confirms that a systematic and all-inclusive approach to measuring organizational agility is worthwhile. We believe that this study—which is illustrative rather than confirmable—offers helpful insights into organizational agility to both organizational scholars and business managers. Although the approach has its merits, three important issues were raised by Walter (2020): (1) developing and implementing agility is expensive; (2) not all business environments demand that organizations pursue agility; and (3) an agile organization is not permanently agile. Each organization is a unique social system and requires an idiosyncratic approach. Organizational agility has been recognized as a dynamic capability that serves the purpose of being successful. However, although the agility concept and derived assessment tools might be useful for making informed and well-argued decisions, they certainly are not a panacea for organizational survival and development challenges.

EXTENDED SUMMARY/IZVLEČEK

V članku je predstavljena ocena agilne zrelosti s strani več ocenjevalcev z organizacijskega vidika. Model zrelosti organizacijske agilnosti (Wendler, 2014) je bil uporabljen v okviru študije primera naftne družbe, in sicer z namenom, da bi ugotovili, ali in v kolikšni meri je bilo prisotno ujemanje med manager/zaposleni (ocenjevalec) pri oceni agilnosti na različnih hierarhičnih ravneh. Večrazredna metoda je za izračun tehtanih povprečij odgovorov uporabila vhodne informacije treh akademskih strokovnjakov in 26 organizacijskih ocenjevalcev. Empirični rezultati kažejo na neskladnost ocen zrelosti organizacijske agilnosti v različnih dimenzijah agilnosti in agilnih merilih; ocene posameznega ocenjevalca so bistveno presegle ocene več ocenjevalcev. Poleg tega je bilo ugotovljeno, da so vrhnji managerji v primerjavi z drugimi vodstvenimi sloji in zaposlenimi bolj pesimistični (ali morda bolj realistični) pri ocenjevanju splošne agilnosti zrelosti podjetja. Z drugimi besedami, podatki kažejo, da bolj kot je posplošena vloga ocenjevalca, bolj kritična je njihova ocena atributov agilnosti.

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Appendix: Survey questions

Risk

Risk1 Organization has information systems and technologies that enable decentralization in decision making.

Risk2 My staff acknowledge mistakes quickly.

Risk3 Regarding organization staff, we trust them to get their job done.

Leadership style

Style1 Managers within my portfolio acknowledge and tolerate ambiguity.

Style2 Regarding organization staff, we offer reward and recognition not only for individuals, but for the team and their contribution to the overall organization.

Flexibility

Flex1 In the organization, we are able to rapidly gain the approvals needed.

Flex2 The organization has information systems and technologies that are standardized or comparable among different departments and/or business units.

Flex3 Managers within my portfolio flexibly deploy their resources (material, financial, human, etc.) to make use of opportunities and minimize threats.

Flex4 Managers within my portfolio quickly implement changes in products and/or services.

Proactivity

Proact1 The organization has a process for managing suggestions for improvement, new ideas, and solutions from all levels.

Proact2 The organization has information systems and technologies that provide rapid feedback on operations and keep intelligence on changing conditions.

Proact3 Managers within my portfolio recognize opportunities for innovation in services and/or processes which will deliver benefits for the organization.

Engagement

Engag1 In the organization, we closely collaborate with and encourage feedback from our customers and partners.

Engag2 In the organization, we design our processes to include early feedback and adaptation.

Engag3 In the organization, we focus on our core competencies and delegate further tasks to our partners.

Industry awareness

Industr1 In the organization, we have processes to inform ourselves about information technology innovations.

Industr2 In the organization, we examine our environment systematically to anticipate change.

Industr3 In the organization, we select our partners and subcontractors by quality criteria (rather than by cost-based decisions).

Planning

Plan1 In the organization, we align all our activities to customer requirements and needs.

Plan2 In the organization, we react to approaching changes by immediately updating our business strategy and processes.

Plan3 The organization prefers a proactive continuous improvement rather than reacting to crisis or fire-fighting.

Plan4 We develop staff skills with a view ro INS' long-term future development.

Plan5 We encourage staff to upgrade their skills and training.

Accountability

Account1 The organization values a culture that embraces accountability from top to bottom.

Account2 My staff are prepared to take responsibility for their own decisions.

Account3 We encourage staff at lower levels to make decisions and take responsibility.

Trust

Trust1 The organization prefers transparency of information for staff.

Trust2 The organization values a culture that nurtures an environment where people trust and respect each other.

Values and principles

Values1 In the organization, we strategically invest in appropriate technologies and have a clear vision how information technology contributes to business value.

Values2 The organization has a strategic approach, which fosters learning as a crucial element.

Values3 The organization prefers a values-based leadership approach.

Values4 The organization prefers implementation of guiding principles with clear direction, so that all staff understand their contribution.

Values5 The organization prefers simplicity, i.e., skipping product and or service features that go beyond customer requirements.

Values6 The organization values a culture that considers changing customer-related requirements as opportunities.

Organizational learning

Organ1 My staff are willing to learn continuously from one another and to pass their knowledge to others.

Organ2 My staff are willing to learn and are prepared to constantly access, apply, and update knowledge.

Organ3 My staff sense, perceive, or anticipate the best opportunities which come up in our environment.

Skills development

Skills1 Managers with my portfolio maintain an informal management style with focus on coaching and inspiring people.

Skills2 My staff have a broad range of skills which can be applied to other tasks when needed.

Workforce capability

Work1 The organization has staff that have a good understanding of how their own job relates to INS overall.

Work2 The organization has information systems and technologies that provide information helping our staff to quickly respond to change.

Work3 My staff are self-motivated.

Adaptability

Adapt1 My staff can re-organize continuously in different team configurations to meet changing requirements and the newly arising challenges.

Adapt2 My staff rotate among different activities, tasks, positions or departments.

Adapt3 We provide opportunities for staff to multi-skill, e.g. job rotation and job mobility.

Collaboration

Collab1 In the organization we encourage early involvement of several departments and/or functions in new service development.

Collab2 The organization has information systems and technologies that make organizational information easily accessible to all staff.

Collab3 The organization prefers flat hierarchies or simple structures to eliminate barriers between individuals and/or teams.

Collab4 The organization values a culture that considers teamwork as an integral part.

Cooperation

Cooper1 In the organization, we jointly operate across different functions and /or portfolios for strategic decision-making.

Cooper2 My staff collaborate closely with different teams and across portfolios.

Cooper3 My staff works in small teams in their projects.

AUTHOR GUIDELINES

1. GENERAL INFORMATION

All articles submitted to the Dynamic Relationships Management Journal are double-blind reviewed. The manuscript should submitted via e-mail to the editor (matej.cerne@ef.uni-lj.si). Send two files: one that contains author contact information along with the text, references, tables, figures, and exhibits; and one where author contact information will be deleted. Authors should keep an exact, extra copy of the manuscript for future reference.

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Manuscripts must be written in English. Authors are responsible for the quality of written English and proof reading of the text is required.

Manuscripts should be double-spaced (including references) in 12 point font, with pages numbered consecutively throughout the entire paper. (The title page is page one.) Text alignment should be justified. Margins should be one inch (2.5 cm) at the top, bottom and sides of the page. Manuscripts inclusive of all text, references, tables, figures, appendices etc. should be no longer than 30 pages and should not exceed 60.000 characters including spaces. Authors should provide a summary, which will be published in Slovene (for foreign authors, translation will be provided by editors).

Manuscripts that report quantitative analyses of data should typically include descriptive statistics, correlation matrices, the results of statistical tests and so forth. If these items are not included in the manuscript, they should be reported in a separate technical appendix. Authors of manuscripts that report data dependent results also must make available, upon request, exact information regarding their procedures and stimuli (excluding data).

If we receive files that do not conform to the above requirements, we will inform the author(s) and we will not begin the review process until we receive the corrected files.

The author(s) submitting the manuscript for review should clearly indicate to the editor the relation of the manuscript under review to any other manuscripts currently under review, in press or recently published by the authors. The editor may ask the authors to submit copies of such related papers to the Editorial Board.

2. GENERAL INSTRUCTIONS

1. First page: Name of author(s) and title; author(s) footnote, including present positions, complete address, telephone number, fax number, email address, and any acknowledgment of financial or technical assistance.
2. Second page: Title of paper (without author's name) and an abstract of no more than 250 words substantively summarizing the article. Also include up to six keywords that describe your paper for indexing and for web searches in your manuscript.

3. Next: Text alignment justified with major headings and subheadings flush with the left margin. The introduction should state clearly the objective of the paper as well as the motivation and the context of the research. The literature review should be limited to the articles, books and other items that have a direct bearing on the topic being addressed. In empirical papers, details of the empirical section tests should not be included in the paper itself. The conclusion should summarize key findings and state their importance to the field. Footnotes should be kept to an absolute minimum and must be placed at the foot of the page to which they refer. They should not be used for citing references.
4. Then: Tables, numbered consecutively, each on a separate page. If tables appear in an appendix, they should be numbered separately and consecutively, as in Table A-1, A-2, and so on.
5. Next: Figures, numbered consecutively, each placed on a separate page. If tables appear in an appendix, they should be numbered separately, as in Figure A-1, A-2, etc.
6. After conclusion: Longer summary (1-2 pp, depending on length of article) in Slovenian language (for foreign authors, translation will be provided by editors).
7. Last: References, typed in alphabetical order by author's last name and in APA style.

3. TABLES

1. The table number and title should be centered and placed above the table.
2. Source(s) should also be provided and centered below the table: i.e. Mabey & Gooderham, The impact of management development on perceptions of organizational performance in European firms, 2005: 136.
3. Designate units (e.g., %, $) in column headings.
4. Align all decimals.
5. Refer to tables in the text by number only. Do not refer to tables by "above," "below," and "preceding."
6. If possible, combine closely related tables.
7. Clearly indicate positions of tables within the text on the page where they are introduced: e.g. Table 1 about here.
8. Measures of statistical significance should be reported within the table.

4. FIGURES, PHOTOGRAPHS AND CAMERA-READY ARTWORK

1. For graphs, label both vertical and horizontal axes. The ordinate label should be centered above the ordinate axis; the abscissa label should be placed beneath the abscissa.
2. Place all calibration tics inside the axis lines, with the values outside the axis lines.
3. The figure number and title should be typed on separate lines, centered and placed above the figure.
4. When appropriate, source(s) should also be provided and centered below the figure (see example under the Tables section).

5.Clearly indicate positions of figures within the text on the page where they are introduced.

6. Once a manuscript has been accepted for publication, complex tables and all figures must be submitted both electronically and as camera-ready (hard) copy. Do not embed figures in the Word file; instead, submit them separately in the program in which they were created (i.e., PDF, PowerPoint, Excel).
7. Lettering should be large enough to be read easily with 50% reduction.
8. Any art not done on a computer graphics program should be professionally drafted in India ink.
9. Do not submit photographs or camera-ready art until your manuscript has been accepted. If the photograph or artwork is completed, submit copies.

5. MATHEMATICAL NOTATION

1. Mathematical notation must be clear and understandable. Since not all journal readers are mathematically proficient, the authors should ensure that the text (i.e., words) also conveys the meaning expressed by the mathematical notation. We recommend that extensive mathematical notation (e.g., proofs) should be provided in a separate technical appendix.
2. Equations should be centered on the page. Equations should be numbered; type the number in parentheses flush with the left margin. If equations are too wide to fit in a single column, indicate appropriate breaks.

   Unusual symbols and Greek letters should be identified by a note.

6. REFERENCE CITATIONS WITHIN THE TEXT

Cite all references at the appropriate point in the text by the surname of the author(s), year of publication, and pagination where necessary. Pagination (without 'p.' or 'pp.') to give the source of a quotation or to indicate a passage of special relevance, follows the year of publication and is preceded by a colon, i.e. Parsons (1974: 238). Page numbers should be given full out, i.e. 212-230 not 212-30. When providing quotes, these should be in italics. In general, references to published works must be cited in text according to the guidelines for APA style (for more information see the DRMJ website).

7. REFERENCE LIST STYLE

1. **Single Author:** Last name first, followed by author initials.

   Berndt, T. J. (2002). Friendship quality and social development. *Current Directions in Psychological Science, 11*, 7-10.
2. **Two Authors:** List by their last names and initials. Use the ampersand instead of “and.”

   Wegener, D. T., & Petty, R. E. (1994). Mood management across affective states: The hedonic contingency hypothesis. *Journal of Personality & Social Psychology, 66*, 1034-1048.
3. **Three to Six Authors:** List by last names and initials; commas separate author names, while the last author name is preceded again by ampersand.

   Kernis, M. H., Cornell, D. P., Sun, C. R., Berry, A., & Harlow, T. (1993). There’s more to self-esteem than whether it is high or low: The importance of stability of self-esteem. *Journal of Personality and Social Psychology, 65*, 1190-1204.

4. **Organization as Author**

   American Psychological Association. (2003).

5. **Unknown Author**

   Merriam-Webster's collegiate dictionary (10th ed.).(1993). Springfield, MA: Merriam-Webster.

6. **Two or More Works by the Same Author:** Use the author's name for all entries and list the entries by the year (earliest comes first).

   Berndt, T. J. (1981).
   Berndt, T. J. (1999).

   References that have the same first author and different second and/or third authors are arranged alphabetically by the last name of the second author, or the last name of the third if the first and second authors are the same.

For other examples, see the DRMJ website.