Business Economics of Knowledge and Innovation

An Empirical Analysis of Role of Firms' Search Diversity

Technische Universität Ilmenau

Department of Economics Sciences and Media

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Dissertation zur Erlangung des Grades Dr. rer. Pol

Tag der Einreichung: 07.09.2021

Tag der wissenschaftlichen Aussprache : 19.01.2022

DOI: 10.22032/dbt.51510
URN: urn: nbn:de:gbv:ilm1-2022000031

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To my eternal inspiration soul, *MOHSEN*
To my most beautiful source of existence, *FATIMA*
To my warmest radiances of breath, *ZAHRA & ZOHRE*
&
To my doctrine of happiness, *MAHDI*

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1. Introduction

Competition is the driving force behind innovation and innovation is the reaction of firms to gain competitive advantage. There are different ways in which innovation and competition in the market interact based on the structural and interorganizational relations in industries. Whether firms intend to be first movers in the market or they intend to raise rivals' costs for being innovative, it is the undeniable role of information that directs the consequences of all such scenarios. For firms to sustain and prosper while competing in their offerings it is vital to introduce processes and skills based on the knowledge they acquire -from market responses (demand and supply side) to all competing choices - to solve their future problems. Innovation as the upshot of competition is a dynamic process of knowledge analysis. How this knowledge is obtained and analyzed on its way to creativity depends on many interacting contextual, environmental and structural factors. Environmental turbulences on one hand draw firms' attention into being innovative not to get behind in competition (Hannan & Freeman, 1977; Burgelman, 1991; Romanelli & Tushman, 1994; Child, 1997). On the other hand, how such strategies towards idea production yielding to sustainable competitive advantage is very much dependent on contextual framework of the firms (Burns & Stalker, 1961; Lawrence & Lorsch, 1967; Pugh et al., 1969; Blau, 1970; Perrow, 1970; Mintzberg, 1979; Chesbrough & Teece, 1998). Different paths directing those attributes and forces (environmental and contextual) into development of innovation are predominately determined by enterprises' capacity in knowledge creation and knowledge aggregation (Aygris & Schoen, 1978; Nonaka & Takeuchi, 1995). In other words, it is the environmental dynamisms which provide synergies for firms to innovate (as a perspective for creating competitive advantage), there are enabling factors of innovation as a process (context) and there are functional ecosystems throughout which innovation becomes an output. As literature suggests (Cui, et al., 2005, Hock-Doepgen et al., 2021) such functional ecosystem constitutes the so-called knowledge infrastructure which embodies internal and external knowledge management capabilities. Internal capabilities constitute technology, culture and structure and external capabilities encapsulate knowledge acquisition, conversion and application. Innovative changes can take form in association with either of the elements embodied in knowledge infrastructure. Thus, innovation is not only a breakthrough product or technology being introduced into the market but it also comprises introduction or adoption of new business models or processes. Hence searching for knowledge from the outside world, assimilating it with internal stock and

incorporating it into the innovation process plays substantial role in the success of firms' innovative journeys. Although acquiring knowledge from external environment was exercised in practice (Teece, 1986; March, 1991) even before open innovation was theorized in the seminal work of Chesbrough (2003) (*as searching and utilizing external knowledge*), it was after his trend changing formulation that it became organized as a prominent element of firms' knowledge infrastructure. Open innovation implies that knowledge development for successful innovation campaigns cannot be limited to firms' internal capacities (Gassmann & Enkel, 2004; Dahlander & Gann, 2010) such as their internal R&D investments (Dominici & Levanti, 2011; Varga et al., 2014) and employees' individual potentials (as partials of context) (Galende & De la Fuente, 2003). Rather, for firms to be able to catch up with the fast-changing market circumstances it is required to extend their search domain outside their boundaries. In fact, external sources of knowledge are the parties who shape up enterprises' surroundings. Thus, acquiring information from those actors enriches firms' (industries) idea cultivation to tackle environmental forces and to gain competitive advantage over their rivals. External knowledge strategies as components of external knowledge management capability can take different forms. Search breadth (reflecting number of sources being explored by firms) and search depth (referring to importance of different sources to explore) as prominent external knowledge acquisition practices have attracted much academic attention in open innovation literature (Katila & Ahuja, 2002; Laursen & Salter, 2006; Greco et al., 2015). Nevertheless, when analyzing how search for external knowledge affects technological and non-technological innovative transformations, in addition to the underlying generality of the acquired knowledge, it is the elemental diversity in knowledge search that is mostly emphasized to be influential on dynamics of different types of innovation rather than other aspects (Kaplan, 1998; Hargadon, 2002; Flor et al., 2018). This study proposes and codifies a search approach (as a component to search breadth) which captures diversity in search in a more dynamic and rigorous way than other search modes do. This novel search approach is utilized to analyze the impact of diversifying search (as a search strategy) for external knowledge on different types of innovation outcomes for enterprises. The role of knowledge (acquisition or development) as the most strategic resource of firms (Grant, 1996) on their way to innovative outcomes has been vastly highlighted. Furthermore, the effect of traditional external search strategies on some (rather than all) types of innovation has been treated but the dynamic role of competition in that type of literature has not been comprehensively taken into account. This thesis's further novelty lies in

investigation of how heterogenous knowledge if acquired from external sources is incorporated to explain desirability to initiate diversity of innovations in interaction either with firms' internal knowledge management capabilities (such as technology) or with market dynamisms (such as competition intensity).Since uncertainties inherent in innovative attempts raises the desirability for variety in innovation (Nelson & Winter, 1977), I shed light on how such varied spectrum of innovations is explained by diversifying strategies in search for knowledge as an open innovation process. There are three main and original analytical directions investigated in this thesis each of which has their own novel layers of analysis: 1. Knowledge search diversity and technological innovation 2. Knowledge search diversity and organizational innovation 3. Knowledge search diversity and logistics innovation.

The first direction extends towards: a) Introduction of *hybrid search strategies* for neutralizing counter-effects of individual search strategies on their way towards technological innovation. Such approach is developed based on the comparison made between the established patterns of search breadth and technological innovation and that of search diversity and technological innovation according to the outcomes of empirical analyses. b) Integration of the moderating mechanism of technology acquisition (machinery and software) into the relationship between search diversity and technological innovation. c) Integration of the industrys' merger share into the search strategies framework and analyzing its role in industrys' search diversity as an endogenous construct.

The second direction extends towards: a) Integration of the moderating mechanisms of market competition intensity and demand uncertainty into the relationship between search diversity and different modes of organizational innovation. b) Integration of the exogenous mechanism of industrys' organizational innovation density into the correlation of search diversity and of the moderating mechanisms with introduction of organizational innovation by firms in different industries.

The third direction extends towards: a) Integration of the moderating role of market competition intensity into the relationship between search diversity and logistics innovation. b) Integration of the exogenous mechanism of industrys' logistics innovation density into the correlation of search diversity and of the moderating mechanism with the introduction of logistics innovation by firms in different industries.

The above research outlines are rooted in analyses of the following four papers:

I.

Hajialibeigi, M. (2021a). Is more diverse always the better? External knowledge source clusters and innovation performance in Germany, *Journal of Economics of Innovation and New Technology*, DOI: 10.1080/10438599.2021.2007093.

II.

Hajialibeigi, M. (2021b). Two-level Defining Factors of Innovation: The Intermediate Effect of External Search Diversity. *Working Paper*. PP 1-28.

III.

Hajialibeigi, M. (2021c). Innovation in Organizations: Interactive role of external knowledge strategies and market conditions, *Ilmenau Economics Discussion Papers*, Vol. 27, No.159.

IV.

Hajialibeigi, M. (2021d). External knowledge diversity, competition intensity and innovation performance in logistics: Implications for less versus more innovative industries, *Ilmenau Economics Discussion Papers*, Vol. 27, No.157.

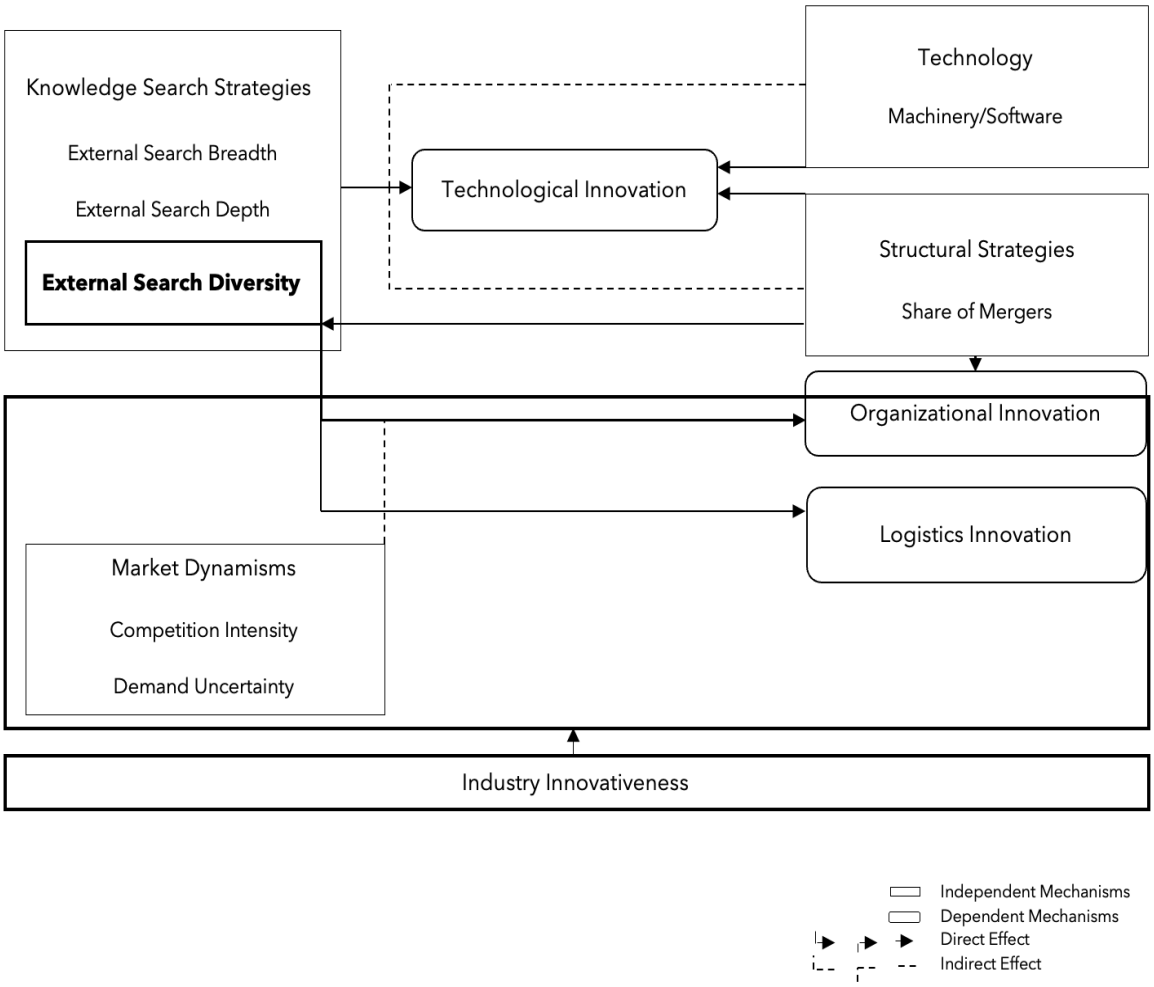

Figure 1. Conceptual framework

2. Theoretical Fundation

2.1. Dynamics of competition and innovation

2.1.1. Visiting competition and innovation

Competition is the consequence of acts of different players in a market each pursuing goals which could be divisible and repetitive thus leading to a sustainable process. Competition is like an invisible hand (Smith, 1761, 1776) which amends allocation of production enablers and labor divisions therefore makes market players behave in a way not to distress societal objectives and pursuits. However, theory suggests (Smith, 1761) that a central regulatory pattern is required to prevent immoral acts (Budzinski, 2004). There are different theories explaining dynamics of competition including classical, neoclassical and Chicago school frameworks. It is the evolutionary competitive market process theory which the analysis of this thesis is based upon (Lambkin & Day, 1989; Budzinski, 2004; Alos-Ferrer & Ania, 2005). This view has roots in the intersection of market process theory of Hayek (1937- 1975) and dynamic competition theory of Clark (1940) inspired by Schumpeter (1934) which highlights the significant potential of competition in knowledge and change (innovation) coordination. From Hayekian perspective competition is a process of hypothesized experimentation due to imperfect and subjective knowledge of demand and supply sides from one another (Kerber, 1997, 2006). Since agents cannot have certainty about the knowledge, based on which they enter the experimentation process, they see themselves in need of access to 'better knowledge' thus competition implies firms to look for more problem-solving knowledge from supply and demand side. Therefore, knowledge accumulation process in industries can be explained as the consequence of the mechanisms of 'variation' and 'selection' of hypotheses for most thriving activities (Kerber, 2006). Those mechanisms are the source to mutual learning in the markets. The knowledge accumulation process exposed through competition is determined by different factors such as distorted selection dynamics of customers or intensity of hypotheses being evaluated by firms in competition (Kerber, 2006). Knowledge base of the firm theory (Dosi, 1988) suggests that each firm to be able to compete in its products, services, image and quality, benefits from developing skills and practices based on the tacit and explicit knowledge they gain through trial of their and others' (imitative strategies) offerings in the market. Real-world competition predominantly takes place in oligopoly markets which are characterized by strategic interdependence among their actors i.e., the success of any firm's strategic move- be it pricing strategies, advertising campaigns, product

differentiations or innovation- depends on the quality of this move and also the reactions of the competitors. The strategic interdependency among competing firms implies unavoidable level of uncertainty in competitive oligopolistic markets in the sense that there is no solid way to identify the degree of success for any performed strategy. Innovation as one of these strategic moves is defined as an idea or practice which is perceived new by an addressed party (Grawe, 2009). In oligopolistic competitive markets in contrast to monopolies or situations which are protected from competition, firms by investing in research and development can gain profits by steering customers towards their own offerings against competitors'. Such difference in profit expectation is the root of the incentives for firms to innovate (Gilbert, 2006). Furthermore, if firms do not pursue innovation in competitive markets, they risk that innovation from their competing peers decrease their own demand and that shapes the second incentive channel for firms towards being innovative. This double incentive to being innovative increases the probability that the expected gains from being innovative outdo the inherent costs and risks of innovation. Next to competitive forces, two additional factors contribute to initiation of innovation activities by firms: external shocks, like technological turbulences or global market trends (economic crises, changes in tastes, …) and intrinsic motivation (engineering curiosity) which persuade firms to look for new channels towards competitive advantage. It is the opportunities and challenges identified by market forces that determine how firms or industries decide about their innovative goals. As firms test their hypotheses to discover better solutions for customers (Hayek, 1948) all the uncertainties associated with market characteristics and the imperfect knowledge transfer them to the roads of creative behaviors (innovation) or adopting behaviors (imitation) (Clark, 1940).

2.1.2. Arrow- Schumpeter controversy

Schumpeter's school of thoughts is derived from two directions, one is discussing that capitalism is developing and the second one which has raised the controversy with the other school developed by Kenneth Arrow, is the suggestion of firms' size and power as promoting factors of innovation (for a critical overview on the discussion about so-called Neo-Schumpeter hypotheses see Müller, 1974). As Baker (2007) argues, there are reasons explaining the rationale; large firms have more investing resources for research and development especially that they are more likely to have supporters of R&D financial capitals inside their own boundaries. That in turn makes it more feasible for them to access to the financial support needed for innovative activities. Furthermore, since they have reputation and a known position in the market, there is lower risk for them to

commercialize their ideas and creativities into the market in comparison to their rivals who lack reputation and infrastructure. Arrow (1962) on the other hand suggests that competition enables innovation more than monopolistic situations. A monopolist when engaged in innovation, takes a cost which a competitive rival does not. That is to discontinue capturing monopolistic profits which the monopolist absorbs even without investing in innovative attempts. Thus, the gradual return of the innovation to a monopolist is less than the one earned by firms in a competitive setting. If the incentives for firms to engage in innovation activities is to take share of the ongoing transactions in the market, that cannot exist for monopolists because they already have great deal of the shares. Such restricted motivation for a monopolist to engage in innovative activities is termed as 'Arrow effect' or 'replacement effect' (Tirole & Aghion, 1997). In case of competitive industries, if innovation has same benefits for competing firms as it does for a monopolist, their differential return to innovation would be higher (Gilbert, 2006).

2.1.3. The interaction of competition and innovation -Role of knowledge

Competition is a synergy producing force for firms to change something whether it is lowering price to attract customers or is change in different attributes of their offerings. In either of the cases firms get involved in innovative activities. It can happen either in form of organizational and business model innovations or cost reductions or process and technological innovations. Thus, competition not only leads to higher values for customers but also benefits society as a whole. For having a direction in analyzing how competition and innovation interact, it is important to zoom into the context of the market, meaning what is it that firms are competing for. Baker (2006) sheds light on such context by distinguishing four scenarios. If firms are competing for introducing same new product or process, then innovation is promoted. When firms pursue being the first in providing the market with some innovation, attempts in achieving such goal increases. A second scenario highlighting the interaction of competition and innovation embodies the situations where firms compete for producing existing products or processes, then innovation is promoted in areas which contribute to cost reductions and quality improvement. This develops areas for potential organizational, business model or logistics innovation. On the other hand, innovation provides firms with opportunities (in terms of demand attraction) to 'escape competition' (Aghion et al., 2002). The reciprocal scenario to the latter is related to situations where more competition in product and process is expected after introduction of an innovation. In such case, incentives to invest in research and development is lessened. If firms predict that they cannot escape competition

after innovating but instead competition intensity increases, they lose incentives to pursue innovation since they foresee less profits. Even in such case if firms' incentives to escape competition after innovation is stronger than their hesitance of engagement in innovative activities due to expectation of stronger consecutive competition, they pursue innovativeness as long as their investments can be partially appropriated. The final scenario explains situations where firms have the incentive to innovate by discouraging rivals' incentives to innovate. If firms create situations (by innovating) in which rivals foresee more competition, they will have higher incentives to innovate. All scenarios above imply that innovation is inherent with uncertainty. Such uncertainty in turn introduces the desirability of generating potentials for diversity of innovations (Nelson & Winter, 1977). It is discussed in section 2.1.1 that competition is the discovery process of the superior offerings evaluated by the market and that leads to mutual learning throughout a consequent process of variation (by firms) and selection (by customers). Knowledge accumulation that benefits the market is the result of the interaction of those processes. Kerber (2006) states that the number and the diversity of the hypotheses that firms are evaluating for best solutions are the determinants of scope of knowledge development in the market. This study complements that theory by Kerber (1997, 2006) by proposing that diversity also benefits the knowledge accumulation processes and learning within organizations in addition to the whole market. Knowledge bases of the firms are their specific characteristics which are adapted to the dynamics of variation-selection process. Therefore, diversity of hypotheses is correspondent to the diversity of knowledge bases. For firms which are seeking better knowledge as a consequence of market competition, diversity is beneficial to pursue their goal. Knowledge foundations of firms (above all other incorporating factors) which have benefitted from diversity, provide better opportunities for enterprises to tackle uncertainty associated with innovation and to win the competition (gaining competitive advantage). In other words, the consequence of the competing forces in market is determined through optimization of usage of available knowledge firms have and the way they interact with others correspondingly (Dosi, 1998). The knowledge-based economy theory of firms (Dosi, 1998) suggests that firms are specific storehouses of knowledge in the sense that each find distinguished ways to deal with their problems. Such organizationally-specific knowledge takes two different forms in firms' functional structure; either in form of procedures or rule-based supporting systems. Competition as one of the incorporating factors of market dynamisms necessitates consistent enrichment and upgrading of that knowledge base to enable firms to catch

up with the market trends. Such enrichment cannot be effective by relying merely on internal sources of knowledge development since agents as mentioned earlier have their specific ways of incorporating knowledge into problem-solving procedures. That is the root to Chesbrough's seminal theory of open innovation as searching and utilizing external knowledge for production, research and marketing domains of firms' success.

2.2. Theorizing knowledge search diversity

2.2.1. Theory of open innovation

This theory is proposed by Chesbrough (2006b) based on his seminal book (2003) stating that "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively." Chesbrough and Bogers (2014) extended this definition of open innovation to'' Distributed innovation process based on deliberately managed knowledge flows across organizational boundaries using pecuniary and non-pecuniary mechanisms in line with the organization's business model''.

Open innovation is a transformation of paradigm in innovative strategies of firms from solid organizational boundaries into a flexible- border framework which results in efficient and effective interactions with external parties in pursuing innovativeness. Such transformation by firms is established and pursued as a reaction to intersecting forces of short life cycled technologies, scarce resources and high costs of in-house R&D as well as environmental trends such as globalization in research and introduction of sophisticated information and communication technologies (Gassman & Enkel, 2004). In other words, it is a paradigm shift due to strategic interdependency among actors when firms pursue innovation in a competitive and dynamic market settings. There are four factors stimulating such transforming policy taken into enterprises' accounts. As Chesbrough states (2002, 2003), availability and mobility of skilled employees, enlarging external suppliers' capabilities, unexploited available options for creating ideas as well as availability of the venture capital market are the enablers of open innovation strategies. When such flexibility is employed in organizational boundaries of firms, one of the most highlighted consequences is the ease of knowledge and information transfer (as an imperative to innovation) between the interacting entities. There are two processes defined for such knowledge transfer mechanism. The outside-in (inbound) and inside-out (outbound). A third mode has been introduced as the combination of the knowledge inflows and outflows between the actors (Gassman & Enkel, 2004; Chesbrough & Bogers, 2014). The former implies opening up innovative campaigns of the own

enterprises into external inputs and contributors (Chesbrough & Bogers, 2014). West and Bogers (2014) suggest acquiring, assimilating and commercializing external resources as inbound open innovation components. It is the business model of the enterprises which determines what external inputs to be taken. The outbound open innovation is the process of releasing unused assets and ideas outside the organizations' boundaries for external entities to use in their business models (Maarse & Bogers, 2012; Tranekjer & Knudsen, 2012; Chesbrough & Bogers, 2014). The third type implies inflow and outflow of resources for collaboration in development and commercialization of ideas (Gassman & Enkel, 2004; West & Bogers, 2012). External Knowledge strategies as open innovation processes are conceptualized and formulated by Laursen and Salter (2006). Search breadth and search depth are two strategies for exploring and exploiting external sources of knowledge as input into innovation process. External search breadth reflects scope of search by measuring number of external sources being explored by enterprises while external search depth reflects intensity of search by measuring the importance of individual external sources for idea cultivation processes of firms. These two strategies as a package provide a measure for the openness of firms in their innovation pursuits. This thesis introduces 'knowledge search diversity' as a complement to this package.

2.2.2. Open innovation firm-based view

The open innovation firm-based view suggests that opening up to external assets and factors without having any specific direction on what to look for and what firms' specific environment has to offer might be misleading and problematic (Felin & Zenger, 2017). Generality and non-specificity inherent in the knowledge supplied by the external world does not embody the particular directions towards firm-specific strategies based on firms' evaluation of what they are about (Felin & Zenger, 2016) and what they are looking for rather than merely relying on accidental encounters (Von-Hippel & Von Krogh, 2016). This view also suggests that what rests in outside environment is the result of hard work and strategic factor markets (Barney, 1986). Thus, accessing to value-creating assets involves costly efforts (Lipman & Rumelt, 2003). Before developing strategies for opening up or closing down, enterprises are better off if outlining a specific point of view, a value theory and a problem setting to decide to what they open up to (Felin & Zenger, 2017, 2020). Following firm-specific point of view leads to supply of much-needed heterogeneity into resource market (knowledge included). Thus, follows provision of more opportunities for unrecognized (by competitors) or underpriced resources which can create value

(Felin & Zenger, 2017). Otherwise, competition for creativity (relying on idea producing knowledge) deteriorates firms' opportunities of gaining advantage from their investments in external knowledge. Thus, the firm-based view in combination with open strategies improves performance of firms in respect to innovation. This thesis based on the above open innovation firm-based theory, conceptualizes and formulates a knowledge strategy as an element of open innovation process which is a component to search breadth (based on open innovation theory) and captures the diversity (rather than generality) in knowledge acquired from external sources in a more rigorous way than search breadth does. Therefore, through playing a role as a supplement to search breadth (extending search scope) it introduces a direction in search for firms (based on firm-based view) not to incur costs for redundant and 'useless' knowledge.

2.2.3. Theory of attention-based view of the firms

It is introduced by Ocasio (1997) based on Simon's work (1947) which focuses on human bounded rationality in justifying managerial decisions. Its central line suggests that managers are selective in their distribution of attention on different issues and that in turn is influenced by environments and the interactions between organizations and individuals who have been assigned with responsibilities. The selective attention distribution of individuals (including managers) is due to human limited cognitive capabilities that requires them to allocate their focus and analysis on limited number of issues at time (Teixeira, 2018).There are three core principles underlying the attention-based view of firms: Focus of attention, implying managers having patterns in their attention which are the origin to their actions therefore it is managers' attention trends which determines decision making processes in organizations. Situated attention, implying that the environmental and internal situations with which managers are involved, are determinants of the direction of their attention and their following decisions. Structural distribution of attention implying that the conceived situation by managers and the attention they pay to such situations are influenced by structure and social relationships in organizations. That in turn determines how organizations distribute and control the allocation of issues (Ocasio, 1997) and how communications and procedures take place. It is this third principle to which this thesis relates in regard of limited attention distribution capacities of organizations to knowledge-based issues and processes. In this study, the latter principle is applied to allocation of attention by firms to process differentiated knowledge that they intend to acquire from diverse sources.

2.2.4. Development of search diversity as an external knowledge strategy

Accessing to knowledge from higher number of sources is associated with higher innovation performance in literature from theoretical (Cohen & Levinthal, 1990; Rosenkopf & Nerkar, 2001) and empirical (Katila & Ahuja, 2002) points of views. Technological innovation literature has treated the associations of search breadth and search depth with innovation performance in an encompassing manner in theoretical (Laursen & Salter, 2006; Greco et al., 2015) and empirical (Chen et al., 2011; Ferreras-Mendez et al., 2015; Terjesen & Patel, 2017) studies. Some studies suggest positive relationship between search breadth and search depth on innovation performance (Leiponen & Helfat, 2010; Chiang & Hung, 2010) and there are others which propose curvilinear trends between the two of the search strategies and technological innovation (Laursen & Salter, 2006; Hwang & Lee, 2010). Exploring and exploiting more external sources yields to acquisition of more general knowledge (Flor et al., 2018). Generality in that sense might contribute firms in cultivating new ideas for fulfilling wider ranges of customer needs. But does that 'generality' give a vivid perception of the inherent heterogeneity in the acquired knowledge? In some broadening search strategies, firms might be left with redundancies in the information they have exploited from their outside world. That fact can be an origin to inefficiencies in search according to firms' access to restricted processing resources. If a scale can provide firms with a *direction* while expanding their search spectrum, performance of enterprises in respect to innovation is improved. As an example, due to similarity in nature of the provided knowledge, when firms widen their search from 'Conferences' to 'Scientific journals' they might not access to significantly differentiated knowledge in spite of the fact that search breadth in this case has been increased from one to two. In another case if firms expand their search scope from 'Conferences' to 'Private clients', they are provided with more opportunity in gaining more differentiated knowledge, although in this case as well, search breadth is increased from one to two. That said, search breadth cannot be an appropriate scale for reflecting diversity of search due to the fact that unless similarities are identified, diversity cannot be scaled. As a consequence, a direction (strategy) in search which provides a metric for optimal diversity in acquired knowledge is required for firms to optimize their search policies. In order to find that strategic metric which establishes a pattern between diversifying search and innovation performance some steps need to be taken. As an extension of the literature (Cassiman & Veugelers, 2002; Poot et al., 2009; Dong & Netten, 2017), a clustering routine is introduced and applied in this study among eleven possible sources of

knowledge as a reference; (1) Vertical class: suppliers, private clients, public clients. (2) Horizontal class: competitors (3) Societal class: government, consultants, professional associations, private research institutes (4) Specialized class: universities, conferences, scientific journals. Each class carries knowledge similar in nature but different classes supply differentiated knowledge in comparison to one another. Such reference is utilized for constructing search networks for enterprises who seek knowledge from their external environment. Finally, a diversity index is corresponded to the whole network as a united entity which allows for a deeper look into search mechanisms. Figure 2 below demonstrates an exemplified search network for a firm which exploits knowledge from five sources lying in four source classes.

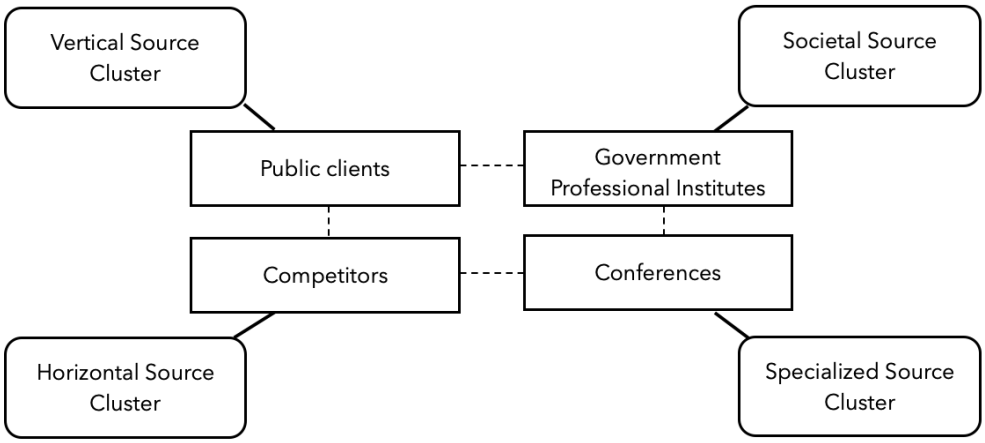

Figure 2. Search network of five sources from four classes

Inspired by the diversity index which is utilized in biology (Simpson Index, 1949) and HHI index (Hirschman, 1946; Herfindahl, 1950) utilized in economics, this thesis introduces the *knowledge diversity index* (KDI) which corresponds a heterogeneity index to search networks (Hajialibeigi, 2021a). If *N* indicates the total number of external sources (search breadth) used by a firm and n_i indicates the number of sources in each of the four categories (vertical, horizontal, societal and specialized) being used by that firm, then P_i (for i=1... 4) is defined as:

$$P_i = \frac{n_i}{N} \quad (1)$$

Then knowledge diversity index in firm level is computed through the underneath equation:

$$KDI_1 = \frac{1}{\sum_{i=1}^{4} P_i^2} \tag{2}$$

Since in some studies (Segarra-Cipres & Bou-LIusar, 2018) including this thesis, the empirical evaluation of innovation performance is conducted in industry level this study proposes a modified index for determining search diversity of external search in industries. If *N* indicates the total percentages of firms having used all eleven sources (search breadth) and if u demonstrates the percentage of firms in a specific industry using a single external source lying in cluster *i* (e.g., suppliers) then U_i is formulated as follows for each of the four source classes (for i=1, …, 4):

$$U_i = \sum u \tag{3}$$

(e.g., U_1 =summation of percentages of firms having used suppliers, private clients and public clients). The knowledge diversity index in industry level is formulated as follows for (for i =1, … , 4):

$$KDI_2 = \frac{1}{\sum_{i=1}^{4} (\frac{U_i}{N})^2} \tag{4}$$

Figure 3 below summarizes how knowledge diversity is computed in an example by construction of the source networks and how it is distinguished from external search breadth as a complement for it.

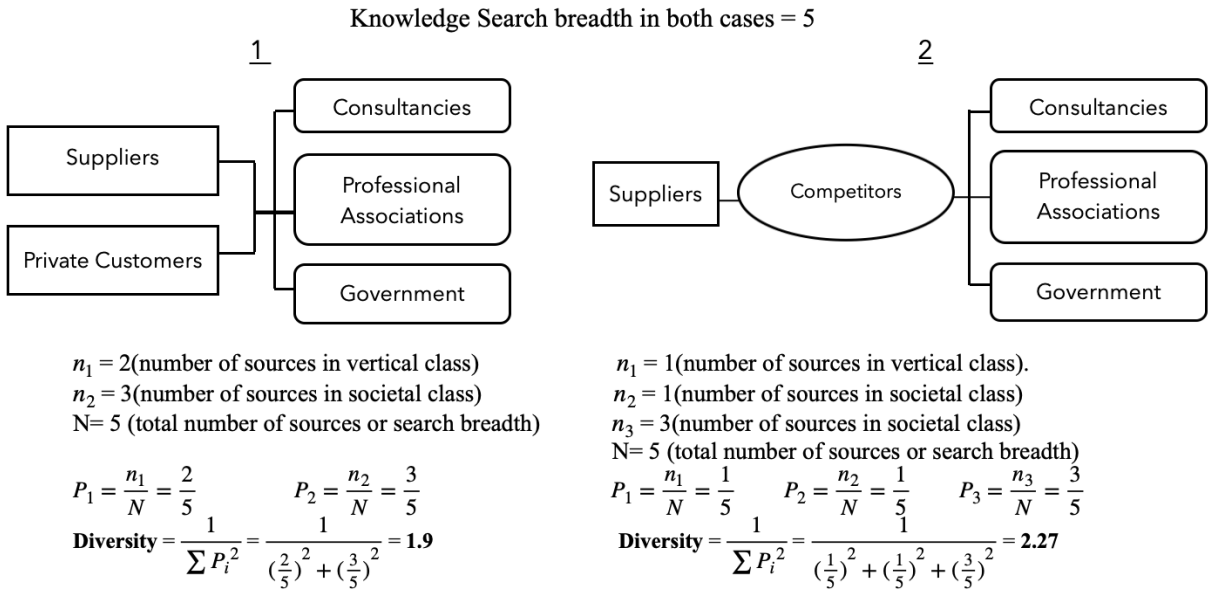

Figure 3. Verification of knowledge diversity

2.2.5. Framing search diversity in technological innovation context

2.2.5.1. Development of a hybrid search strategy towards technological innovation

Competition is the synergy driving factor for firms to make changes and to make themselves deserve customers' attentions. When firms begin their technological innovation campaigns, they encounter opportunities and challenges. To get the best result out of those challenges and opportunities, enterprises require to access to better problem-solving knowledge and it is competition and its subsequent experimentation dynamics which reveals paths to channels towards knowledge with such potentials. Exploiting diverse knowledge improves technological innovation in three conducts. First, obtaining complementary knowledge lowers uncertainties associated with competition as the process of hypothesized experimentation of all offerings to the market (Hayek, 1948, Flor et al., 2018) and strengthens firms' hypothesis development procedures towards innovation as a competitive advantage. Hence it gives firms competing in same new products or processes an advantage over their rivals towards idea creation by lowering the risk for R&D investments. Second, diverse knowledge provides firms with potential providing information for ideas about development of varied commercialization and implementation channels (Chesbrough, 2006; West & Bogers, 2014). When firms search for diverse knowledge about others' offerings and strategies and reaction of the demand to those, they are more equipped to find their ways into the market through better knowing about their rivals' delicacies and powers especially in cases when there is competition for being the first movers (Schumpeter, 1934). Third it improves the innovation process through enhancing absorptive capacity *as the ability of firms in evaluating the value in external knowledge and to assimilate it appropriately with the internally created knowledge* (Escribano et al., 2009; Ferreras-Mendez et al., 2015). As discussed in section 2.2.4 exploring more external sources (search breadth) is more likely to improve innovation performance rather than less. Nonetheless external search diversity is introduced as a component to search breadth which gives firms a clearer direction when expanding their search scope to avoid wordiness rates in knowledge they acquire and to economize scarce resources in search and hence to intensify efficiency. On the other fold, processing much differentiated knowledge necessitates firms to allocate more technological and non-technological resources. Processing much heterogenous knowledge might leave firms with shortage of necessary assets thus mitigates the initial positive impact of diversity on technological innovation faster than the one related to search breadth. The latter reasoning is also justified by attention-based theory of the firms (Simon, 1947;

Ocasio, 1997, 2011) which suggests that enterprises as systems allocate attention. Attention in the current context is referred to the process of different sources of information by firms and to extract necessary partials out of it into firms' functional framework (Dong & Netten, 2017). In this thesis by distinguishing between *diversifying* search scope and *expanding* search scope a hybrid search approach when firms pursue technological innovation is hypothesized and empirically validated. Figure 4 below illustrates a comparative theoretical stand of the explanatory power of search breadth (the dotted curve) for technological innovation and that of search diversity (the hyper-linked curve).

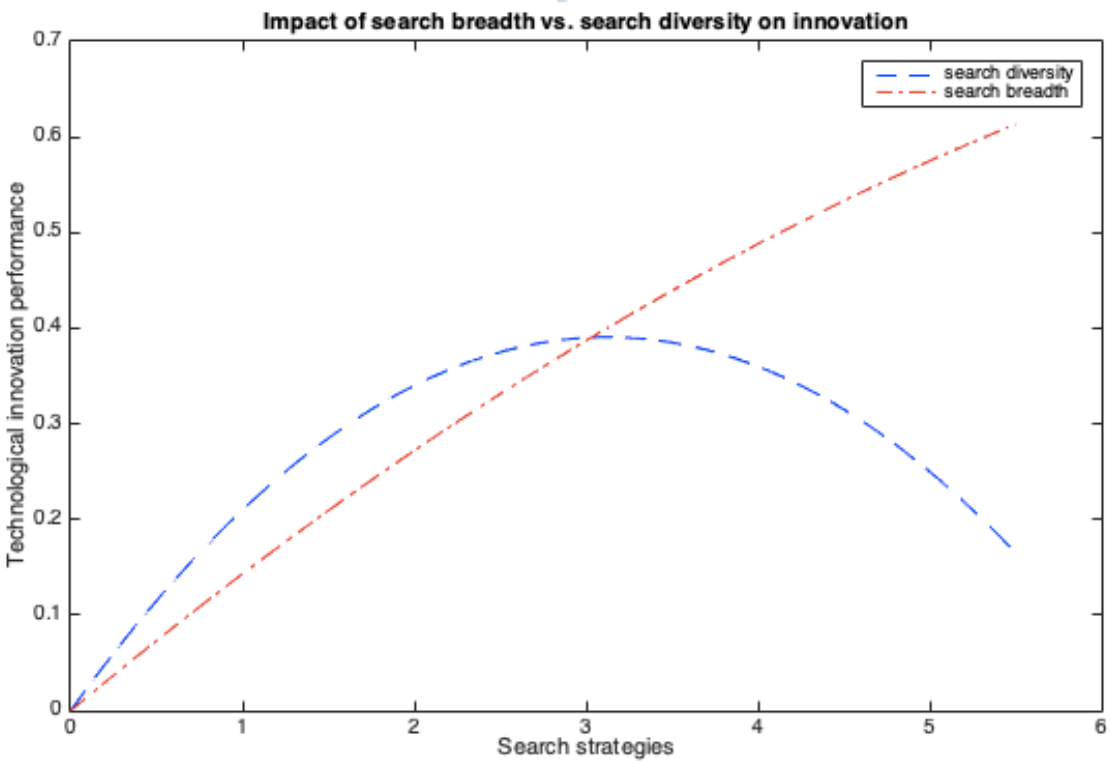

Figure 4. Search breadth, search diversity and technological innovation: Theoretical outlook

According to the discussion above firms are better off towards technological innovation performance when they initially diversify search (following the hyper-linked curve) by exploring sources from different clusters rather than expanding search by merely increasing number of sources (The slope of search diversity outperforms the one related to search breadth in the first phase). On the other hand, the downturn point in the relation between search breadth and technological innovation occurs latter (in terms of search expansion) than the one related to the

relationship of search diversity and technological innovation according to the argument above. Therefore, after the collision happening in the search breadth-innovation and search diversity-innovation patterns (due to lower slope of search breadth) firms are better off by intensifying search breadth in a way that does not help diversity or to get deeper in exploiting knowledge from same sources (intensifying search depth).

While the empirical analysis of this study in section 3.3.2 (Hajialibeigi, 2021a) indicates a similar curvilinear pattern for search diversity and technological innovation to the theoretical outlook in Figure 4, it finds a positive linear relationship between search breadth and technological innovation rather than a negative curvilinear pattern which is shown in Figure 4. Figure 5 below demonstrates such findings and highlights the proposed hybrid strategy by the solid pattern. Such empirically validated hybrid policy also provides an opportunity for a different but interesting line of interpretation (Hajialibeigi, 2021a). Many previous studies have found (empirically) curvilinear relationship between search breadth and technological innovation rather than a constantly positive one (Laursen & Salter, 2006; Hwang & Lee, 2010). That can be due to the embodied effect of diversity which was not previously identified and is extracted in this study and in form of a hybrid strategy with search breadth provides contributive insights for practitioners.

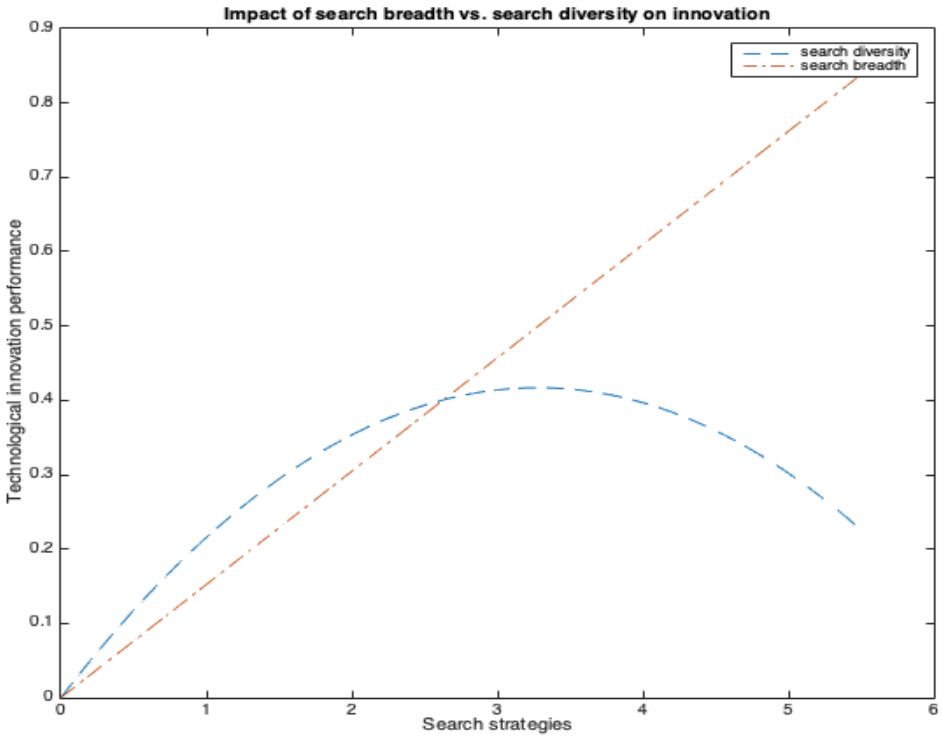

Figure 5. Search breadth, search diversity and a hybrid search strategy: Empirical outlook

2.2.5.2. Technology, search diversity and technological innovation

There are different explaining factors of innovation process as a synergic reaction to competition (see section 2.1). Competition implies firms to utilize resources for finding ways to generate competitive advantage in the game of strategic interdependency in competitive markets. Such resources can be technological (e.g., machinery and software) and non-technological (e.g., trained employees). Enterprises utilize such resources for developing and acquiring knowledge which as a strategic resource is critical in idea cultivation processes within firms. As a result, many different explaining factors of innovation which have links with knowledge creation (and acquisition) including organizational context such as personnel training (Nonaka & Takeuchi, 1995) and cooperation in technological areas (Hagedoorn et al., 2000; Keizer et al., 2002) as well as environmental enablers (Porter & Stern, 2001; Köllinger, 2008) have attracted most academic attention. Literature has thus categorized influencing factors of innovation into two levels of internal and external (Love & Mansury, 2007; Romero & Martinez-Roman, 2012). Although organizational innovation literature has treated the interdependent roles of those two categories abundantly (Mol & Birkinshaw, 2009; Hock-Doepgen, 2021), there is a narrow research stream in technological innovation which has highlighted the cruciality of analyzing those seemingly distinct promoters of innovation in interaction with one another (Lodh & Battaggion, 2011, 2015; Goelgeci et al., 2019). Looking closely into such interactive associations reveals the degree of importance of knowledge production and management mechanisms. In other words, it is the interaction of internal and external knowledge management capabilities of firms which plays the most substantial role in the success of innovation journeys (Grant, 1996; Turner & Makhija, 2006). To enrich the technological innovation literature in that direction, this study analyzes the interconnectivity of technology (as an enabler of internal knowledge management capability) and the proposed external search approach (as a promoter of external knowledge management) and demonstrates empirical results in sections 3.3.3 and 3.3.4 (Hajialibeigi, 2021b). Either firms are competing in new products and processes to be first movers and gaining partial monopolistic profits or whether they are competing in existing products and processes and pursue cost reduction procedures, it is the aggregation of their internally developed and externally exploited knowledge that determines the success of their attempts towards competitive advantage. Machines and software are inputs into the process of developing and transferring knowledge within the enterprises. Acquisition of technology in terms of machinery and software is positively related to technological innovation

performance due to its role in internal knowledge development. For instance, it facilitates the employees' training procedures and boosts knowledge transfer mechanisms inside the enterprise. On the other hand, when firms pursue diverse innovations (Nelson & Winter, 1977), they cannot merely rely on their internal capacities to produce idea cultivating knowledge. First of all, it needs large investments, second of all the potential of firms (in terms of employees' knowledge contributive capacities and technical assets for information processing) are limited. That fact becomes more highlighted in competitive situations where firms pursue idea productions with lower costs in terms of capital and time. Knowledge inherent in other agents (as repositories of distinguished knowledge in the sense that each finds their specified ways to beat problems and to win the competition (Dosi, 1998)) can contribute to innovative campaigns of firms in a more significant way than merely investing in internal knowledge production. Thus, seeking diverse knowledge from external sources can relax part of the need for investments in internal knowledge development (including employed technologies). In other words, as discussed in section 2.2.4 investing in external search diversity gives firms the opportunity to obtain complementary and integral knowledge from the external environment which refines gaps in knowledge internally produced. That in turn removes part of enterprises' dependence on technologies needed for developing similar information internally. Furthermore, external search diversity promotes technological innovation in two other ways as discussed in section 2.2.4, through facilitating establishment of new commercialization and implementation channels by promoting initiation of new external relations and through promoting absorptive capacity. Thus, technology as an internal knowledge management capability enabler and external search diversity, partially substitute one another in promoting technological innovation rather than complementing. In other words, their joint occurrence diminishes part of their individual positive associations on technological innovation.

2.2.5.3. Mergers, external search diversity and innovation

Firms decide for mergers and acquisitions either to fulfil a market power motivation or as part of their attempts for creating competitive advantage mainly through expected consequent economies of scale and scope (Trautwein, 1990; Farrell & Shapiro, 2001; Mukherjee et al., 2004; Budzinski & Kretschmer, 2016). Different studies have predicted varied and sometimes contradictory relationships between mergers and innovation performance (Federico et al., 2018; Denicolo & Polo, 2018). Based on contextual and environmental factors related to enterprises some studies

found positive relationship between mergers and innovation performance (Entezarkheir & Moshiri, 2018) and some expected overall negative patterns e.g., in terms of patents (Haucap et al., 2019). There are also others who have not found a clear trend but associated the consequences of mergers on innovation with enterprises' organizational settings (Jullien & Lefouili, 2018). Mergers correlate with innovation from different perspectives (Aghion & Tirole, 1994; Capron, 1999; Carrier, 2008; Battisti & Stoneman, 2010). Changes exerted to market structure through mergers are catalyzed into shifts in competition intensity and other market dynamisms. In that sense mergers alter environmental forces which are synergy antecedents of firms to innovate. As literature suggests (Federico et al., 2018) when mergers and acquisitions take place, incentives for innovation decreases for merging firms. That is in line with Arrow's (1962) explanation of innovation dynamics where he suggests that monopolistic structures are negatively associated with innovation incentives. That is due to violence in competition and subsequent monopolies' reluctance in giving up gaining monopoly profits through getting involved in innovation activities which are inherent with uncertainties. That is a highly supported way of looking at mergers and innovation in literature. However, that view is based on an assumption which might not be supported if the scale of analysis changes. The underlying assumption is that mergers are measurement factors to competition. That can be the case if we only consider incentives of merging parties for competing in new products and processes. But if we take post-merger incentives of others rather than merging firms for competing especially in existing products (as well as in new products) into account then an overall ambiguous relationship between mergers and innovation is deployed. This thesis by considering such unclarity in the relationship between mergers and innovation analyzes the effect of mergers on innovation as structural changes to enterprises (an enterprise having been emerged through a merger during time) rather than decisions, by making a comparison between incentives for technological and non-technological innovations post-merger. The approach above, suggests that the overall (industry level) incentives for technological innovation is improved as well as the overall incentives for creating new business models (seeking to cut costs to be able to lessen prices) or other organizational and marketing types of innovation to create higher values for customers (as non-technological innovations). In other words, industries with more mergers, can see more innovative results after a time lag. For merging parties to generate and maintain relative monopolistic position it is crucial to centralize their research activities which in turn contributes to reduction of parallel and abandoned innovative pursuits in order to achieve

economies of scale and scope post-merger. Such abandoned activities might occur because of employees' low incentives to participate in risky innovative activities due to redundant R&D projects and existence of decentralized research divisions after the merger (Rajan et al., 2000). An efficient centralization process, is the consequence of improvements in superfluous business practices, establishment of new cooperation networks, work responsibility assignments and decision-making processes. The latter, necessitates merging parties to access to complementary knowledge from their environment in order to be able to sustain through organizational (and/or marketing) innovations. Due to existence of strategic interdependency, as a reaction to merging-parties' concentration strategy, non-merging firms pursue superiority in both technological (new products and processes) and non-technological (organizational/marketing) innovations. Thus, they need to seek external knowledge in a diverse manner (to know about demand reaction to mergers, new behaviors of merging firms and suppliers' initiatives) to improve their hypothesized ideas for competitive advantage achievements. Therefore, industries with mergers are supposed to show larger search diversity than such without. That result is demonstrated in section 3.3.4 (Hajialibeigi, 2021b). Conclusion follows that there are positive trends between organizational/marketing innovation and mergers. Finally, although shifts in innovative synergies (e.g., increase in imitation rates) post-merger, might negatively affect technological innovation but this study empirically demonstrates a positive pattern between the two in section 3.3.4 (Hajialibeigi, 2021b) due to improvements of external knowledge strategies in merged entities and organizational innovations as two enablers of technological innovation.

2.2.6. Framing search diversity in organizational innovation context

2.2.6.1. Institutional theory of firms

Institutional theory of firms, has roots in sociology, economics and political sciences (Korsakiene et al., 2015). The sociological perspective considers the role of normative pressures from inside and outside of the enterprise which play roles in their institutionalization (the action of taking something new as a culture in an organization). It is the legitimacy firms gain from the outcome of decisions about their organizations that directs them towards further strategies (Zucker, 1987). Adoption of such legitimated elements are the factors contributing to their survival. Zucker (1987) appoints three drivers for institutionalizations, namely the institutional environment, other organizations and internal organizational structures. Institutional characteristics of external environment influence objectives and decisions of actors (Scott, 1987). The economic strand of

institutional theory suggests that institutions are the drivers of changes in organizations (North, 1990) and there are two types of them, formal restrictions (rules, constitutions) and informal ones (behavioral norms, self-imposed codes for directions). Furthermore, as North (1994) states, the interactions between organizations determines the emergence of new institutional frameworks (Korsakiene et al., 2015) in the market. From the political-science point of view, this theory looks at the influence of institutions on individual behaviors (Hall & Taylor, 1996). This study relates to the sociological view of institutional theory as the underlying justification for incentives of organizational transformation for firms to gain legitimacy and to have an influence in the market.

2.2.6.2. Behavioral theory of firms

It is proposed by Cyert and March (1963) and is the evolutionary extension of behavioral theory by Simon (1947) and theory of organizations by March and Simon (1958) which explains the organizational and inter-organizational behaviors. It explains the promoters of operational decisions and their outcomes. In behavioral theory of firms, decisions are treated as processes which are influenced by rational and irrational aspects. This theory endogenizes preferences and expectations of firms as explaining factors of 'bounded rationality' in determining decisions of managers (organizations) under uncertainty and complexity (Todeva, 2008). Cyert and March (1963) consider five goals firms pursue: production, inventory, market share, sales and profit. The behavioral theory suggests that organizations make active decisions to fulfill all goals. It further implies that in pursuing such goals firms follow satisficing rather than maximizing their results. The theory considers an objective of being 'good enough' for firms in the decisions they make rather than being the best. The following sections relate to the behavioral theory of firms as for explaining the objectives and incentives behind decisions for organizational transformations.

2.2.6.3. Contingency theory of markets

It implies that there is no one best way to organize an enterprise or to make decisions and that the optimal decisions are dependent on interaction of internal and external influencers. Fiedler (1993) proposed a model of contingency which is based on the dependency of organizational management on the relationship between leader and member. Morgan (2007) summarized the three underlying assumptions for theory of contingency: Management should consider alignments between environments and decisions, organizations are open systems, required to find a balance between need and goal satisfaction and externally adaptations and different types of organizations are

needed in different types of environments. The following section of the thesis relates to the theory of contingency in that organizations need to see changes in accordance with the environmental circumstances.

2.2.6.4. External search diversity and organizational innovation

Organizational innovation as Lam (2005) suggests is the introduction or adoption of an idea or behavior new to the enterprise. Institutional theory of firms (Meyer & Rowan, 1977; DiMaggio & Powell, 1983; Scott, 1987; Zucker, 1987) proposes that such transformations take place by firms to get reputation in their corresponding market. Behavioral theory of firms (Cyert & March, 1963; March & Simon, 1958) on the other hand provides a different view by suggesting that changes in organizations are functional decisions for improving performance. In either of the cases there are different antecedents of organizational innovation. In order to become more productive (through cutting costs) firms might exert transformations in their organizational mechanisms. In that case as Camison and Villar-Lopez (2014) propose organizational innovation acts as an enabler into the technological innovation process. In a second conduct technological innovation brings about opportunities and challenges which creates synergies for firms to make innovative shifts in their organizational mechanisms (Schumpeter, 1950; Lam, 2005). Thirdly environmental circumstances and contextual characteristics of firms are further promoters of organizational innovation (Hannan & Freeman, 1977; Mintzberg, 1979; Kimberly & Evanisko, 1981). A fourth direction is the capacity of enterprises to be learning organizations. Such capacity influences organizational transformations in a causal way. For firms to be able to be learning organizations some shifts in their organizational ecosystems are needed. When learning capacities about functional mechanisms are improved in enterprises, they know what transformations are needed to improve their performance. In this study three modes for organizational innovation proposed by Hammel (2006, 2007, 2009) are considered and the explanatory powers of different level inputs for each are analyzed: (1) New business practices (2) New methods of organizing external relations (3) New methods of organizing work responsibilities and decision making, are the three elements of organizational innovation which are of interest to this study.

The crucial role external search strategies can play in creative changes in organizational levels can be well recognized according to knowledge-based economy theory of the firms (Dosi, 1988, 1998; see section 2.1.3). When firms compete in their products, services and the quality of both for having partial competitive advantage they require to establish skills and practices based on the

implicit knowledge they gain by trail of their and others' offerings as well as experimenting adopting patterns of the customers. Thus, the hypothesized examination process (Hayek, 1948) of competing products and processes implies capturing diverse knowledge from the agents in the market to enable ruling and routine producing processes within organizations. On the other hand, the knowledge accumulation process trains itself in a longer run, in accordance with consistent competition. That in turn provides roots for an attribute of firms in absorbing valuable knowledge into organizational processes namely absorptive capacity which in turn filters unvaluable knowledge from being inflowed into firms' innovation activities. Thus, the strategies firms select to acquire knowledge from external sources matters in development and improvement of absorptive capacity and subsequently of business model construction (routines, practices, relations and decisions). Acquisition of heterogenous knowledge supplies more complementarity to fill gaps in internally developed knowledge and its processing and assimilation bring about necessities to refine organizational mechanisms. This leads to better estimation of demand side and implies transformations in organizational settings to deal with bigger ranges of customer needs. Thus, gives firms a better understanding in adjusting their direction in a sustainable and prospering manner. That fact helps introduction or adoption of more efficient business practices to catch up with the contemporary market patterns. Open innovation literature emphasizes on the significant role knowledge flows in performance of firms (Parida et al., 2012; Cheng & Shiu, 2015; Popa et al., 2017). The efficiency of such knowledge flows is explained by external networking structures of the firms (Pettigrew & Fenton, 2000; Powell & Grodal, 2005). Therefore, exploiting valuable knowledge implies firms to reshape their relationships with parties in their supply chain relationships and other partners. Sometimes establishment of new relations emerges from incentives for escaping competition and to take more share and power over rivals. Diversifying search scope cultivates more potentials to create new channels to external actors related to enterprises' business models. On the other hand, launching innovative campaigns and goals bring about challenges which requires decisions to be made (Nicolas, 2004). Process followed by and outcomes to decisions to be made are reliant on organizational features and firms' understanding of their environment. As discussed, diversifying search provides opportunities for enterprises to get deeper views into dynamics of their surroundings, therefore helping them in advancing their work responsibility assignments and decision-making processes according to their limited resources. On the other hand, the same reasoning about processing too much differentiated

information in technological innovation procedure applies to organizational transformations. Shortage of necessary assets might frustrate part of enterprises' capacities for performing organizational changes they find beneficial in terms of competitive advantage. Firms (decision makers of the firms) have limitations in their processing attention. Therefore, much diversity in knowledge in need of processing deteriorates part of attention-based resources of firms and that implies emergence of a downturn point in the trend between knowledge diversity and organizational innovation. Furthermore, as discussed earlier in the current chapter competition in the market implies consistent enrichment of knowledge acquired from agents involved in organizations' business models. On the other hand, knowledge accumulation process trains itself and at some point, firms do not need to diversify search for accidentally or occasionally valuable knowledge (see section 2.2.4). This study analyzes such effect and suggests a curvilinear relationship between search diversity and organizational innovation and validates it empirically in section 3.4.2 (Hajialibeigi, 2021c).

2.2.6.5. Market dynamisms and organizational innovation

It is the behavioral patterns of other players in competitive markets such as competitors, suppliers, customers, government and others which identifies the environmental dynamisms. In fact, the strategic interdependency between competitive firms creates their mutual environmental conditions. Paths for different enterprises towards enduring competitive advantage differ when it is about beneficial strategic establishments (Zheng Zhou, 2006). Voss and Voss (2000) recognize the consequences of all different driving factors in a market in three forms: Demand and the uncertainty related to it, technological turbulence (technology short life cycles) and its associated risk and competition in the market and its related intensity (strategic interdependency, see section 2.1.1). Institutional framework of markets and changes associated to it can be considered as a fourth driver being added to this scheme. When a market is identified with technological uncertainties and short product life cycles, customers' needs and preferences change rapidly, thus demand estimation becomes a challenging task (Gatignon & Xuereb, 1997). That yields to uncertain demand trends and requires firms to take actions if they want to deal with such uncertain situations to be able to find creative ways into the market. When competition is intense in the market, it can be expected that all competing firms not being able to gain partial competitive advantage through introduction of brand-new products, services or processes. Some might be competing in already existing products or services to be able to survive. They might discover

innovative processes to produce already existing offerings to the market with lower costs and consequently to set lower prices in comparison to their rivals and to attract demand. Intense competition might raise incentives for firms to pursue process shifts in order to find new ways for offering their productions (product, service or process) and thus capture partial competitive advantage this way. Under such circumstances firms have to incorporate resilience in their accordingly adjustments to be able to rapidly shift policy directions to prosper. In fact, the strategic interdependency among firms, follows their unawareness of competitors' reactions to firms' actions and vice versa thus requires them to maintain flexibility. Such resilience needs to be consolidated in their practices, networks and decisions and in a deeper level in the links between their business model elements, whether it is customer relationships, partnerships or value-added elements. For firms to be able to manage risk and costs under competitive tensions it is required to transform their organizations in appropriate time and situations even if they are competing in new products and services. Because under the influence of competition it is vital for firms to introduce their offerings using areas of creativity which are unrecognized by competitors. That also requires efficient routines and rule-based supporting systems. That in turn enables them to find an equilibrium between opportunity and benefit exploration (Shirokova, et al., 2013). Therefore, organizational innovation is considered as a plausible outcome to market dynamisms and this thesis validates that link empirically in section 3.4.2 (Hajialibeigi, 2021c). The empirical evaluations of this study additionally reveal another novel explanatory factor of the relationship between market conditions and organizational innovation which has not been examined prior to this thesis. It is demonstrated in paper 3 that the promoting associations of market conditions on different modes of organizational innovation is not similar among industries and it varies depending on the contemporary rates of organizational innovation intensity in different industries.

2.2.6.6. Market dynamisms, search diversity and organizational innovation

Schumpeter (1934) states: ''competition in the market and constantly environmental changes in markets requires firms to take potential opportunities of creating competitive advantage from new and different types of knowledge''. That suggests there is a latent interdependency between diverse knowledge acquisition and competition intensity as well as demand uncertainty. Revisiting Schumpeter's statement proposes that market dynamisms (competition intensity and uncertain demand trends in this context) which create strong synergies for re-engineering organizational ecosystems, travel partially different paths to organizational innovation compared to the ones

proceeded by diversifying search scope. Agents in market are specified archives of knowledge. Such knowledge transforms into two different mechanisms inside the enterprises, either as procedures or as rules (Dosi, 1998). That is the origin to organizational innovation. When enterprises encounter competition intensity to be able to differentiate their products or services they need to acquire complementary knowledge about active decisions and moves of other players in the market. The same dynamics is realized for enterprises in markets with high uncertainty in demand. When demand is uncertain (assumptions about market selection of the different competing offerings is disfigured) that in turn necessitates firms to create ideas about how to incorporate flexibility in their organizational ecosystems or how to optimize cost and risk management through making shifts in their practices or decisions to tackle competition and difficulties in demand pattern tracking (see section 2.2.6.5). On the other hand, as discussed in section 2.2.6.4 diversifying search scope finds its path to organizational innovations in two other directions. Firstly, through improvement of absorbing capacity as an organizational attribute. Such improvement implies organizational transformations which are followed. Secondly, through promotions in conversion and application procedures which are required for processing heterogenous knowledge rather than similar types. Therefore, these two interdependent antecedents (diverse search scope and market dynamisms) prove to have imbrications hence can be considered imperfect substitutes rather than complements towards organizational innovation. This thesis suggests and empirically validates that the individual positive association of diversified search scope and market forces with organizational innovation are diminished in their mutual presence in section 3.4.2 (Hajialibeigi, 2021c). Similar to the findings of previous section (2.2.6.5) very insightful results on the interaction effect of market conditions and diversity in search scope is proposed by this study. The joint mitigating effect of market conditions and search diversity varies among industries with different rates of introduction or adoption of organizational innovation modes.

2.2.7. Framing search diversity in logistics innovation context

2.2.7.1.Resource-advantage theory

Resource-advantage theory implies that firms seek competitive advantage in acquiring and possessing resources which contribute to achieving financial performance (Hunt & Morgan, 1996). This theory suggests that superiority in such resources results in competitive advantage in the corresponding market. Resources comprise of different types, from technological and non-

technological assets to processes to information and knowledge. Relative superiority in those resources promote firms' efficiency and effectiveness (Barney, 1991). This theory suggests that firms innovate to preserve advantage in their resources. This theory's further implications lie in discussing that firms who possess competitive advantage in their resources, involve in proactive innovations to maintain their relative superiority in that regard and the ones who stand in positions with competitive disadvantages can engage in reactive innovations to catch up with competing opponents (Hunt & Morgan, 2002; Grawe, 2009)

2.2.7.2.The Knowledge-based view of the firms

This view centralizes the role of knowledge as the most important source to enterprises' functionality and prosper. Firms' objective in pursuing innovations is primarily in differentiating themselves in their functional ecosystems and to gain comparative advantage over their rivals. This view highlights the imperativeness of knowledge in firms' technological and non-technological attempts to gain sustainable competitive advantage (Grant, 1996; Turner & Makhija, 2006).

As an integrated line of analysis based on the preceding theories, this thesis examines the roles of knowledge management strategies as one highlighted way to acquire advanced knowledge as a vital resource in firms' innovation campaigns. It also investigates the role related to competition forces as environmental synergy providers of competitive advantage in section 3.5.2 (Hajialibeigi, 2021d) with the focus on logistics innovation as one of the least treated of the kinds.

2.2.7.3. External search diversity and logistics innovation

Logistics is the efficient and effective flow of goods, services and information between the point of origin to the point of consumption (Grawe, 2009). It can take different forms such as digital supply chain management systems, new delivery models, new inventory management systems etc. Since innovation as an avenue to competitive advantage is defined as an idea or practice perceived new by an addressee (Rogers, 1995), logistics industry (according to the definition) as an incorporating framework of goods, services and information processing procedures merits perspectives for innovative outcomes. Technological turbulences, competitive forces and global market trends persuade firms to look for new channels towards competitive advantage. As Flint et al., (2005) puts it, logistics innovation comprises of logistics related services that are perceived as new and contributive to a central adopting party and is a way of remaining competitive (Kahn et al., 2006). In that sense universal marketing trends such as globalization and low durability of

technologies has highlighted logistics services as an ignite domain for firms' innovative performance. In pursuing logistics innovation, firms seek to gain competitive advantage through cost reductions or creating better values for customers and hence to increase the inherent value in their returns (Novack et al., 1996; Stank et al., 1998). Furthermore, opening up new market opportunities, improving enterprises' performance and responding to existing or forthcoming regulatory provisions are other motives behind innovative activities in logistics. Although the study of logistics from the innovation perspective is a relatively narrow stream (Wagner, 2008; Tether & Tajar, 2008; Busse, 2010) but as literature suggests (Gellman, 1986; Wagner, 2008) there are different factors promoting innovations in logistics. Organizational, contextual and environmental factors (Grawe, 2009) explain logistics innovation. Business practices and interorganizational relationships provide opportunities for firms to optimize their supply chain in terms of its elements and the links among them and thus exert positive impact on innovations in logistics industry (De Carvalho & Malaquias, 2012; Richey et al., 2012). When knowledge about customer choices and behavioral patterns as well as about supply side actors from others' strategies is imperfect and biased (strategic interdependency) then the consequence of competition for the market is based on assumptions which need to be examined through time (Hayek, 1948). To tackle such uncertainties associated to innovations exposed by competition firms take two highlighted strategies into account. To improve their knowledge accumulation strategies or to pursue variety of innovations. However, the success of the latter is dependent on the efficiency of the former. Based on knowledge-based view (Grant, 1996) and resource-advantage theory, knowledge as the most important resource has proved to have substantial influence on logistics innovation as well as other types of innovations (Kogut & Zander, 1992; Grant, 1996b; Dhanaraj & Parkhe, 2006). It is not long ago since the time the highlighted role of knowledge management has been recognized as an influencer of innovations in logistics industry. Due to importance of knowledge as an asset, the advancement of knowledge strategies is a crucial practice to realize efficient management practices including logistics management leading to firm performance (Lönnqvist, 2017). Although the essential role of knowledge strategies is appreciated (Fugate et al., 2012; Durst & Evangelista, 2018), there is only a new and lean literature analyzing the role it plays theoretically (Radhika, 2014; Durst & Evangelista, 2018). The specific repositories of knowledge in logistics service industries comprise of manufacturers, raw material suppliers, distributors, retailers and shippers (Chow et al., 2005). Access to knowledge associated to each of these interacting service

providing units contributes to firms' ability in beating innovation uncertainties. Since logistics services (as a value-based mechanism in firms' strategic framework) incorporate the linkages between supply chain members, knowledge obtained from such sources plays crucial role in finding innovative channels between supply and demand (Craighead et al., 2009). Generality and non-specificity inherent in accidentally expanding search for knowledge outside of an organization boundary might be suffering (in terms of restricted investment resources for knowledge acquisition) in some cases due to existence of redundancies and also potentially discovered (by competitors) idea creating knowledge (see section 2.2.2). Heterogeneity of knowledge (by having a direction to pursue) which has been exploited from supply members and parties who study them from a broader view provides more potential in formation of ideas. The impact of such conducted search diversity is much highlighted in logistics services as the intersecting functional area of the parties each could be considered as a source of knowledge in innovative ways to gain greater customer satisfaction. Treatment of external knowledge strategies in logistics innovation has not seen academic attention. Only the role of external knowledge (as resource and not as strategies) in specific forms of logistics (Xu & Ma, 2010; Marra et al., 2016) has been narrowly covered. To enrich theoretical and empirical research in that direction, this thesis by incorporating the proposed search strategy (external search diversity) in logistics innovation studies, takes the role of external knowledge strategies into account. Furthermore, its interactive effect with competitive forces on logistics innovation is investigated. Exploring diverse sources of knowledge some of which are elements of supply chain allows firms to gain complementary information which contributes to supply chain knowledge development by filling gaps in internally produced knowledge. Diversifying search scope can further contribute firms to advance less costly channels to customers. By providing complement knowledge, search diversity promotes advancement of promising business practices related to logistics as well as opportunities to establish beneficial external relations which in turn boosts innovative trends in logistics. Also, by provision of heterogenous information about suppliers and customers, it builds up better estimation of demand and supply as an important input into logistics processes.

This study exploits a positive course between external search diversity and logistics innovation in different industries which is a different pattern compared to the ones between search diversity and technological innovation and search diversity and organizational innovation (see section 2.2.5.1 and 2.2.6.4). Validation of that hypothesis in sections 3.5.1 and 3.5.2 (Hajialibeigi, 2021d)

provides a further view for firms pursuing varied innovations in search for competitive advantage. It demonstrates that pursuing different types of innovation cannot be resulted from following same knowledge strategies.

2.2.7.4.Competition dynamics and logistics innovation

Environmental circumstances are one determinant of enterprises' policies and directions they take in their corresponding marketplace. As discussed in section 2.2.6.5 emergence of short life cycled technologies and rapid shifts in customer preferences activates competitive forces. Competition intensity in the market creates incentives and needs for enterprises to differentiate themselves. According to theory of competition and innovation proposed by Arrow (1962) competition promotes innovation because competing firms in contrary to monopolies do not incur the replacement effect (see section 2.1.2). This theory embodies innovation in its general sense. However, when they are in competitive circumstances firms look for different possibilities to escape competition and to decrease the uncertainties associated with innovation. Studies have demonstrated that decisions and factors which decrease competition intensity restrict the need for firms to pursue innovative offerings whether it is process or product or service (Gellman, 1986; Zinn, 1986, Stapleton & Hanna, 2002). Existence of close substitutes (see section 2.2.6.5) creates the need for firms to restructure their cost models and to improve their service offerings. In logistics services, firms are mostly competing in existing processes and services and their primary objective is to gain competitive advantage through creating higher customer value and satisfaction. Therefore, intensity of competition generates high incentives for logistics service providers to look for innovative ways to either reduce the costs associated with their services or to find innovation by providing opportunities for value-added offerings. One example is the decisions of firms to focus on their own core competencies in conditions of intense competition and to outsource corresponding logistics services to enterprises who are principally functioning in logistics and in turn have proficiency in that area. Such industries possess strong knowledge base about opportunities and restrictions of their underlying market which might not be the case for other firms. In that sense outsourcing provides firms with opportunities for cost reductions associated with research and development and infrastructure foundations in area of their incompetency. That leads logistics services to compete in clients by creating higher values and more innovative logistics pursuits. Thus, even competition in products and services unrelated to logistics introduce competition in logistics services and that in turn increases logistics innovation potencies. A second

example would be the digitalization of logistics models as another strategy on the way to reduce costs and to increase customer values which can be formed into different innovative logistics services. This study theorizes competitive tensions as plausible promoters of logistics innovation and validates that conclusion empirically in section 3.5.2 (Hajialibeigi, 2021d).

2.2.7.5. Competition dynamics, search diversity and logistics innovation

Emergence of information and communication technology has raised the discussion on the high importance of knowledge management and knowledge strategies in logistics (Wang & Liu, 2010). Knowledge management impacts logistics performance in different ways. On one hand it promotes introduction of innovative organizational practices (see section 2.2.6.4) part of which could be inherent in logistics capacities. On the other hand, it improves establishment of contributive internal and external relations which increases efficiency in exchange of information between business value chain elements (Xu & Ma, 2010). Third conduct through which knowledge strategies impact firm's decision-making processes (including logistics procedures) is through improvement in organizational learning which impacts organizational performance of logistics service providers (Cooper et al., 2016). External search diversity as an external knowledge management capability element by providing firms with complementary knowledge fosters logistics mechanisms in all of the three directions. Some sources of knowledge from which diversified knowledge is captured are the substantial elements of supply chain hence optimal search diversity improves supply chain knowledge development which in turn leads to innovative logistics pursuits. Other sources, diversified knowledge is captured from, are parties who provide information about market trends and regulations which stimulates logistics providers' additional capacities in supply chain management. When competition increases, the intensity of hypothesized offerings to be evaluated by market increases (see section 2.1.3). In case of logistics services, for firms to be able to escape competition and to gain competitive advantage it is vital to pursue new services which generate higher customer values (see section 2.2.7.4). Thus, and according to the fact that more explicit knowledge about market evaluators (demand side) and market offerors (supply side) increases the probability of inventive differentiators, diversifying search for external knowledge and competition intensity interact on their way to logistics innovation. What is different about logistics innovation in comparison to other types of innovations (as discussed in section 2.2.7.3) is that either the competition occurs for new logistics processes or existing ones, diversifying search for knowledge improves the probability of success of the innovative attempts.

In summary, although knowledge strategies and knowledge diversity in particular can improve paths to logistics innovation in partially different ways than the synergy paths (exerted by competition) they have overlaps (in cost reductions and customer value progressions). Therefore, they are partial substitute antecedents of logistics innovation rather than complements. This study analyzes such interaction effect as a contribution to the literature and finds a mitigating interactive associations of competition intensity and knowledge search diversity with innovation in logistics and endorses those findings empirically in section 3.5.2 (Hajialibeigi, 2021d).

3. Empirical analysis

3.1. Data

A Metadata set is used derived from the German innovation survey[1] for evaluating the proposed hypotheses. This dataset is selected for the sake of this study (which aims to perform an analysis on the role of firms and industries' search diversity) due to its comprehensive information about incorporating factors related to innovation in one of the economically leading countries and is the latest of the series available. There are limitations associated with the dataset as well which are worth considering. Although the survey has been assessed by more than one reference in each target enterprise since it comprises of self-evaluations, common biases including desirability bias can be characterized in the responses. However, its cover for innovative behaviors of German industries as well as the high standard methods based on which the dataset has been produced, entitles it as a promising dataset for the empirical analysis in this thesis. The dataset has been used in other studies in the literature for the assessment of different factors influencing innovation behavior of firms and industries (Dong and Netten, 2017; Radicic, 2020). German innovation survey is a national survey of firm and industry level innovation encapsulating German industries information as part of the European Commission's community innovation surveys (CIS). CIS has its own contributions from industries from different countries throughout Europe. It is designed by the usage of methods developed by the Organization for Economic Cooperation and Development (OECD). Leibniz Center for European Economic Research (ZEW) has been active in gathering data regarding innovation dynamics of German industries since 1993. The survey includes annually provided statistics. It is directed on behalf of Federal Ministry of Education and Research (BMBF) and with participation of Institute of Applied Science (Infas) and Institute for Systems

[1] https://www.zew.de/en/publications/zew-expertises-research-reports/research-reports/innovations/mannheim-innovation-panel-the-annual-german-innovation-survey

and Innovation Research (Fraunhofer ISI). It contains information about a range of industries including manufacturing, service and retailing from beverage industries to textiles and information service. A two-yearly based modification exerts to the dataset for omitting firms which are not active anymore or do not function as individual bodies due to mergers or acquisitions in the market; also new entrants with their innovation activities are added. The German innovation survey is designed as a Metadata survey and its size might face changes throughout years. It provides information about introduction of new products, services and processes as well as expenditures for innovation, market advancements with new products, new services and improved processes. For the purpose of this study CIS16 is utilized which contains self-assessment innovation behavior of German industries through the time span of 2014-2016. The designed questionnaire has been answered by more than one reference in target firms thus increases the reliability in comparison to surveys which are filled in by one reference in each enterprise. The set includes data for utilization of the eleven external sources and the rate of introduction of new or significantly improved processes and products for firms in the time span of two years. The reference set makes up to 85 industries comprise of 143,608 large and SME firms in three sectors of manufacturing, service and retail. This thesis conducts analysis in industry level and makes comparisons of dynamics of knowledge strategies and innovation among different industries.

3.2. Methodology

In this thesis, the association of the proposed external search strategy (knowledge search diversity) with diverse types of innovation is analyzed individually and in interaction with other promoters of different types of innovation. Quantile-Quantile plots for all sections of analysis are performed and normality of residuals are supported (Bai & Ng, 2005). For some variables skewness is observed therefore and due to the fact that the analysis is performed in the industry level, other than OLS, GLS and robust OLS, quantile regression is also performed. This decision is made due to quantile regression's ability in producing robust results absence of linearity assumptions as well as its ability in finding the associations in different percentiles of the response (dependent variable). Therefore, it is able to produce contributive insights about dynamics of knowledge management and innovation in industries with different densities in introducing innovation. Also, quantile regression is able to approximate the downturn point in curvilinear relationships and since an inverted U-shaped relationship for external knowledge diversity and some types of innovation

is predicted in this study, it is found to be a powerful analytical method and flexible one to deal with non-normality of residuals, skewness and outliers.

3.3. Technological innovation

In this part of the analysis, external source clusters (see section 2.2.4), search diversity and search breadth are considered as independent variables, technological innovation performance as the dependent variable, R&D expenditures, industry differentiation dummy and market scope as control variables. All variables' (including dependent, independent and control variables) calculations and ranges (for the analysis related to section 2.2.5.1) are summarized in Table 1 below.

Table 1

Summary of measures for source clusters, breadth and diversity of search and technological innovation

Variable	Description	Scale
Vertical cluster	u_j: the percentage of firms having used sources (j) in vertical cluster nu_j: the percentage of firms not having used source (j), (j=1,2,3), weight of vertical cluster: $x_1 = \frac{\sum_{j=1}^{3} u_j}{\sum_{j=1}^{3} nu_j}$	0-4
Horizontal cluster	u_j: the percentage of firms having used sources (j) in horizontal cluster nu_j: the percentage of firms not having used source (j), (j=1), weight of horizontal cluster: $x_2 = \frac{uj}{nuj}$	0-5
Societal cluster	u_j: the percentage of firms having used sources (j) in societal cluster nu_j: the percentage of firms not having used source (j), (j=1,2,3,4), weight of societal cluster: $x_3 = \frac{\sum_{j=1}^{4} u_j}{\sum_{j=1}^{4} nu_j}$	0-7
Specialized cluster	u_j: the percentage of firms having used sources (j) in specialized cluster nu_j: the percentage of firms not having used source (j), (j=1,2,3), weight of specialized cluster: $x_4 = \frac{\sum_{j=1}^{3} u_j}{\sum_{j=1}^{3} nu_j}$	0-6
Diversity	Inverse of the summation of fraction of clusters divided by total sources squared $\frac{1}{\sum_{i=1}^{4}(\frac{U_i}{N})^2}$	0-2
Breadth	Summation of percentages of usage of all eleven sources in each industry, $\sum_{i=1}^{11} u_i$	0-3
R&D	In house R&D expenditure	27-110
Industry dummy	Whether industries belong to manufacturing, service or retail (Corresponded to the highest percentage of firms in each industry)	2=retail,1=manufacturing, 0=service
Market size	weighted average of percentage of firms in the industry who sell in local, national, European and international markets with 1,4,8,16 as weights respectively	0-30

Technological innovation performance	The aggregate average of percentages of firms with new or significantly improved products, services and processes	19-91%

3.3.1. The associations of the four source clusters with technological innovation

There are studies who have previously analyzed the association of the (individual) external knowledge sources on different types of innovation. Mol and Birkinshaw (2009) found out that exploiting knowledge from market-based sources (customers and competitors) and professional sources (professional research institutes) are positively correlated with new management practices. Their empirical study evaluates the individual effect of each source on management innovation in contrary to the analysis of this study which evaluates the sources in clusters based on closeness in type of knowledge they supply. Another difference of their work is that they do not provide a comparison between the effect of market-based sources and professional-based sources on managerial innovation. Another similar investigation is done by Medase and Abdul-Basit (2020) in which 'uncommon' sources of knowledge (according to (their) previous literature) have been incorporated to the analysis of the effect of individual external sources (similar to work of Mol & Birkinshaw, 2009) on four types of innovation (Process, product, organizational, marketing). They found different substantiality of the effect of different sources on different types of innovation. They also do not provide a comparative analysis between the effect of these types of knowledge sources. Their categorization (direct and indirect market players) has not been inherent with the connection of those sources in the essence of knowledge they provide but only based on sources' distance with firms which cannot reflect any information about identity of knowledge they provide. In that sense they do not propose any knowledge-based categorization. A further distinction of the analysis of this thesis in this section lies in the corresponding measurement of each cluster. This study's measurement incorporates width and weight (through percentages of firms having used and percentages of firms not having used clusters of sources in each industry) of usage of each cluster in each industry while the latter work of Medase and Abdul-Basit (2020) only combines percentages of usage of each source with simple arithmetic addition. The impact of the four different external source clusters introduced in section 2.2.4 on technological innovation are analyzed. The empirical analysis demonstrate that all four types of clusters (vertical, horizontal, societal, specialized) exert positive impacts on technological innovation. Further it is demonstrated that the more intense the horizontal and vertical classes are explored, the magnitude of the

positivity between knowledge from different clusters and technological innovation is bigger than the ones related to societal and specialized clusters. Ordinary least squares and generalized least squares are performed and results are consistent in both methods and are illustrated in Table 2. The evaluating model is equated as follows:

(5)

$$Y = \beta_0 + \sum_{i=}^{4} \beta_i x_i + \beta_5 R\&D\ intensity + \beta_6 marketsize + \beta_7 industry\ dummy$$

Y estimates product/process innovation performance and x_i demonstrate aggregation value of source clusters for *i=1… 4.* R&D intensity reveals a positive association with innovation which is statistically significant and consistent with literature (Love & Mansury, 2007; Ebersberger & Herstad, 2013). The industry distinction variable negatively associates with the innovation, which can be interpreted due to higher rates of new or significantly improved offerings in service sector in comparison to manufacturing and retail. Market size has statistically significant and positive effect on innovation, which is based on the reason that the industries who serve bigger markets are more likely to afford accessing to essential resources for their innovation activities and have more capacities to commercialize their innovation outcomes rather than the ones active in smaller markets like local territories.

Table 2

OLS and GLS for source clusters and innovation

	OLS	GLS
Vertical cluster	9.50 ***	10.42***
	(3.062)	(2.967)
Horizontal cluster	7.31***	7.01***
	(2.38)	(2.329)
Societal cluster	4.19***	3.88***
	(1.352)	(1.367)
Special cluster	3.47**	3.15***
	(1.815)	(1.741)
R&D	3.19***	2.79***
	(0.69)	(0.729)
Industry dummy	-7.16***	-6.13
	(2.651)	(2.806)
Market size	1.19***	1.22***
	(0.299)	(0.282)
Intercept	-6.72*	-4.49
	(10.056)	(10.154)
R^2	0.56	0.57
Adjusted R^2	0.52	0.53

Note: *p<0.1; **p<0.05; ***p<0.01 - standard errors are in parenthesis. Dependent variable is innovation performance

3.3.2. Knowledge search breadth, search diversity and a hybrid strategy for technological innovation

Since the proposition of the new external search strategy is introduced in this thesis for the first time, there are no analysis having investigated its relationship with different types of innovation. However, there are many studies who have analyzed the association of other external search strategies on innovation. The pioneering one is the study of Laursen and Salter (2006) which introduced the two primary external search strategies (search breadth and search depth) and provided measurements for them. They found out a negative curvilinear relationship between the two strategies and innovation. Leiponen and Helfat (2010) and Chiang and Hung, 2010 found a positive relationship between these two strategies and innovation. Since external search diversity is a complement to search breadth, proposition of the hybrid strategy (see section 2.2.5.1) demonstrates that the stronger curvilinear relationship found by previous studies is due to the diversity of search which has not been extracted before. The empirical investigation of this thesis leads to positive effect of search breadth and curvilinear effect of search diversity. OLS, GLS and quantile regressions (in conditional median of the response) are performed to analyze the impacts of search diversity and search breadth on technological innovation. Statistically significant results are obtained for the quantile regression as well with kernel and bootstrapping methods with 1000 iterations at p=0.5 (50^{th} percentile of the response). Findings are presented in Table 3 and 4 below.

The testing models are built up in the following ways:

(6)

$$Y = \beta_0 + \beta_1 breadth + \beta_2 R\&D\ intensity + B_3 marketsize + B_4 industry\ dummy$$

(7)

$$Y = \beta_0 + \beta_1 diversity + \beta_2 diversity^2 + \beta_3 R\&D\ intensity + B_4 marketsize + B_5 industry\ dummy$$

The following three findings are validated comparing the existing patterns between search breadth, search diversity as a component and supplement to search breadth and technological innovation:

- External knowledge breadth is positively related with innovation performance.
- External search diversity establishes an inverted U-shaped relationship with innovation performance.

- Diversifying search scope in the beginning accelerates innovation more substantially than general expanding of knowledge exploration up to a downturn point.
- The diminishing effect of diversity on innovation occurs more slowly than the reinforcing positive one

Table 3

OLS and GLS for breadth and innovation

	OLS	GLS
Breadth	0.15*** (0.04)	0.15*** (0.05)
R&D	0.03*** (0.007)	0.03*** (0.007)
Industry Dummy	-0.05** (0.03)	-0.05*** (0.02)
Market size	0.007*** (0.002)	0.008*** (0.003)
Intercept	0.16*** (0.05)	0.17*** (0.04)
$\boldsymbol{R^2}$	0.546	0.553
Adjusted $\boldsymbol{R^2}$	0.524	0.531

Note: *p<0.1; **p<0.05; ***p<0.01 - standard errors are in parenthesis. Dependent variable is innovation performance

Table 4

OLS, GLS and quantile regression for diversity and innovation, (p)= 0.5

	OLS	GLS	quantile kernel	quantile bootstrap
Diversity	0.25**	0.23**	0.22*	0.23**
	(0.1)	(0.097)	(0.128)	(0.095)
Diversity squared	-0.04**	-0.03**	-0.03	-0.03**
	(0.018)	(0.018)	(0.024)	(0.017)
R&D	0.03***	0.03***	0.03***	0.03***
	(0.007)	(0.007)	(0.008)	(0.006)
Industry dummy	-0.06**	-0.05**	-0.09***	-0.09***
	(0.027)	(0.028)	(0.032)	(0.026)
Market size	0.01***	0.01***	0.009***	0.009***
	(0.002)	(0.003)	(0.003)	(0.002)
Intercept	0.28***	0.29***	0.349***	0.349***
	(0.036)	(0.042)	(0.046)	(0.033)
R^2	0.52	0.51	0.61	0.63
Adjusted R^2	0.49	0.48	0.60	0.61

Note: *p<0.1; **p<0.05; ***p<0.01 - standard errors are in parenthesis. Dependent variable is innovation performance

Based on the findings this study suggests a hybrid external knowledge strategy (by initially diversifying and gradually expanding and deepening) for technologically pursuing innovation firms (see section 2.2.5.1).

3.3.3. Interaction of technology and external search diversity on technological innovation

The analysis of the interactive role of internal and external explanators of innovation has been studied but the interaction of knowledge search strategies and internal knowledge management enablers has not been of the focus in previous studies. Frank et al., (2016) investigated the effects of the two different innovative activities in Brazilian industry on innovation output. They find positive relationship between internal and external R&D (called market orientation) and negative relationship between machinery and software acquisition and innovation output, while in this thesis interaction of external knowledge management and technology acquisition is analyzed and a mitigating effect is found. Curvilinear relationship with external knowledge strategy (search diversity) and positive pattern between technology acquisition and innovation is resulted. The association of technology (as an internal knowledge management capability element) on technological innovation and its interaction effect with external knowledge diversity (as an external knowledge management capability element) is explored. Expenditure on machinery/software acquisition in each industry is considered as the proxy for technology as the independent variable. External search diversity is also treated as an explanatory variable. Technological innovation performance as the dependent variable, R&D expenditures, industry differentiation dummy and market scope as control variables are incorporated. The evaluating regression model is built up as the following:

$$Y = \beta_0 + \beta_1 diversity + \beta_2 machinery\&software + \beta_3 industrysize + B_4 industrydummy + B_5 totalR\&D + \beta_6\, diversity * machinerysoftware \quad (8)$$

Where Y estimates technological innovation performance.

According to the literature (Mansfield, 1968; Hannan & McDowell, 1984) larger firms have higher capacities and abilities to appropriate their innovation investments. Thus, there is a possible positive relationship between firm size and innovation performance. That can be extended to industries with bigger market spectrums. Industries with firms who are active in bigger markets have higher capacities to commercialize their innovation outcomes. Industries which cover bigger markets have bigger possibilities to afford accessing to fundamental resources in respect to time and quality. Furthermore, there are possibly higher market shares for firms who are active in bigger markets. Literature has also shown a positive trend between market share and innovation due to

more commercialization channels that firms in bigger markets might have access to (Blundell et al., 1999; Giroud & Müller, 2010; Entezarkheir & Moshiri, 2018). Training expenditures for innovative activities should also be controlled in models where innovation performance is the dependent variable. Firms' heterogeneity is controlled by industry dummy to supervise how different sectors might affect innovation. It indicates to be negatively correlated with product/process innovation due to the fact that newly introduced or highly improved services have higher rates in industries under study than products and processes introduced by manufacturing or retail sectors. Total R&D intensity (including in-house and external sponsoring expenditures) is also an input into the innovation performance estimating models and it has been indicated in literature that it follows a positive impact on innovation performance (Love & Mansury, 2007). Training expenditures for innovation activities found to illustrate a positive relationship with product/process innovation performance. That can be interpreted due to the fact that trained employees have higher capacities and higher incentives to take part in creating new ideas. The following two findings are validated empirically and illustrated in Table 5 below:

- Technology (machinery/software) is positively influencing technological innovation performance
- Technology (as an internal KM influencer) in interaction with external search diversity (as an external KM influencer) loses part of its positivity in relation to technological innovation.

Table 5

OLS and GLS for machinery/software acquisition and innovation with mediating effect of search diversity

Variable	OLS	GLS
Diversity	0.994** (0.466)	0.9713** (0.472)
Machinery/software	0.0089*** (0.0009)	0.0079*** (0.0009)
Industry size	0.0035 (0.002)	0.0050 (0.0025)
Industry dummy	-0.046** (0.021)	-0.042** (0.022)
Total innovation expenditure	0.007* (0.0039)	0.0058* (0.0039)
Diversity * machinery/software	-0.015** (0.006)	-0.015** (0.007)
R^2	0,696	0,643

Adjusted $\boldsymbol{R^2}$	0,673	0,617

Note: *p<0.1 ; **p<0.05 ; ***p<0.01 - standard errors are in parenthesis .dependent variable is innovation performance

3.3.4. Mergers, search diversity- technological versus non-technological innovation

The role of M&A on innovation has been evaluated differently. Entezarkheir and Moshiri (2018) found a positive trend between M&A and innovation, however they do not distinguish between technological and non-technological innovations. Haucap (2019) found negative impact of M&A on patents. While no specifically focusing study on M&A and organizational innovation exists (to the best knowledge of the author), this thesis makes a comparison between the trends M&A makes with technological vs. non-technological innovation (see section 2.2.5.3) and with search diversity as an external knowledge strategy. While, Lodh and Battagion (2014) found positive relationship between M&A of related firms and search depth (as an external knowledge acquisition strategy) and M&A of unrelated firms and search breadth, this thesis finds a positive association between general M&A and the proposed knowledge acquisition strategy (search diversity).Thus, being a merged entity is the independent variable throughout the whole analysis in this section and search diversity, technological and non-technological innovation are dependent variables. Market scope, industry dummy, total expenditure for research and development and training expenditures for innovative activities are included as control variables. The evaluating model is equated as:

(9)

$$Y = \beta_0 + \beta_1 mergers + \beta_2 industrysize + \beta_3 industry\ dummy + B_4 totalR\&D + B_5 training$$

Where Y estimates search diversity and technological and non-technological innovation performances. Ordinary least squares and robust ordinary least squares are employed for empirical validations in this part of the analysis. Industry differentiation dummy illustrates a positive relationship with external search diversity. That implies manufacturing and retail industries under study have access to more diverse knowledge from external sources or have bigger incentives to access to more diverse information. For firms (industries) active in smaller regions synergies to seek diverse knowledge from external channels are heightened when they pursue innovation. Their internal knowledge production and transfer procedures might not be as efficient as that of bigger international firms to fulfill complementarity in their knowledge supply. To compensate they need to quest differentiated knowledge sources for information. Therefore, there is an inverse

relationship between market scope and external search diversity. Merging parties would have access to more differentiated knowledge sources to leverage their information apprehending strategies and therefore the more being evolved as merged entities firms in an industry, the more diverse knowledge firms in that industry have access to. Furthermore, findings demonstrate an overall positive trend for mergers with both types of innovations. Organizational transformations are among first priorities of merged party's executives and that has a high potential to yield to innovative organizational practices and structures. That is due to the fact that organizational and strategic inefficiencies relating to mergers need to be removed for merging entities if they wish to maintain their power. Moreover, they need to keep a credential position in the corresponding market and that in turn creates incentives for marketing innovation. On the other hand, uncertainties and risks that are joined with research, elaborates some discouragements in merging parties' employees' incentives for participating in (mostly technological) innovation activities. Furthermore, product/process innovation pursuits are enhanced (as well as organizational innovative strategies) as the reaction of non-merging enterprises to concentration strategy of merging parties (see section 2.2.5.3). Therefore, both types of innovation are positively explained by mergers (in industry level) except that the impact of mergers on organizational/marketing innovation is more substantial than that of product/process innovation. There are three findings confirmed and illustrated in Table 6, Table 7 and Table 8 respectively:

- Organizational structure of being merged entities is positively correlated with external knowledge diversity in the industry.
- Organizational structure of being merged entities is positively correlated with technological and non-technological innovations in the industry.
- Organizational structure of being merged entities has more vivid footprints in non-technological innovation rather than technological type in the industry.

Table 6

OLS and robust OLS for merger and external search diversity

Variable	OLS	Robust OLS
Merger	0.01*** (0.003)	0.01* (0.003)
Industry size	-0.02*** (0.005)	-0.03*** (0.004)
Total innovation expenditure	0.09*** (0.004)	0.09*** (0.005)
Industry dummy	0.07 (0.05)	0.07* (0.05)
R2	0,819	0,0819
Adjusted R2	0,810	0,80

Note: *p<0.1; **p<0.05; ***p<0.01 - standard errors are in parenthesis. dependent variable is external search diversity

Table 7

OLS, GLS and robust OLS for merger and technological innovation

variable	OLS	GLS	Robust OLS
Merger	0.1*** (0.03)	0.1*** (0.04)	0.1*** (0.035)
Industry size	0.8*** (0.16)	0.9*** (0.16)	0.8*** (0.16)
Industry dummy	-0.3 (1.7)	-0.3 (1.7)	-0.3 (1.8)
Total innovation expenditure	0.2* (0.1)	0.2* (0.1)	0.2*** (0.1)
Training expenditure	0.8*** (0.07)	0.9*** (0.07)	0.9*** (0.07)
R2	0,823	0,806	0,823
adjusted R2	0,812	0,786	0,810

Note: *p<0.1; **p<0.05; ***p<0.01 - standard errors are in parenthesis. dependent variable is technological innovation

Table 8

OLS, GLS and robust OLS for merger and non-technological innovation

variable	OLS	GLS	Robust OLS
Merger	8.28*** (0.4)	8.28*** (0.4)	8.3*** (0.4)
Industry size	-0.6 (0.3)	-0.6 (0.3)	-0.6* (0.3)
Industry dummy	0.5 (3.6)	0.5 (3.7)	0.5 (3.7)
Total innovation expenditure	1.3 (1.5)	1.3 (1.5)	1.3 (1.5)
Training expenditure	-0.4** (0.15)	-0.3** (0.15)	-0.3*** (0.16)
R2	0,898	0,886	0.9
adjusted R2	0,891	0,864	0.88

Note: *p<0.1; **p<0.05; ***p<0.01 - standard errors are in parenthesis. dependent variable is non-technological innovation

3.4. Organizational innovation

In this part of the analysis, external search diversity, competition intensity, demand uncertainty and their interactions are treated as the independent variables. Three organizational innovation modes (new business practices, new methods of organizing external relations, new methods of organizing work responsibilities decision making) are incorporated as dependent variables. Machinery/software acquisition, training expenditures and total R&D expenditures are also incorporated as control variables. Quantile regression utilizing bootstrapping method with 1000 iterations is performed (Green, 2008; Mohammadi, 2008) because the analysis of this thesis is performed in industry level and thus results are evaluated in respect to different percentiles of the response. This leads to provision of insights about organizational innovation in different industries. This thesis performs testing models in three quantile levels (t=0.2, t=0.5, t=0.8) for each of the three dependent variables and compares the results.

Table 9

Summary of measures for search diversity, market dynamisms and organizational innovation

Variable	Description	Scale
Diversity	Inverse of the summation of fraction of clusters divided by total sources squared $\frac{1}{\sum_{i=1}^{4}(\frac{U_i}{N})^2}$	0-2
Machinery/software acquisition	Expenditure on machinery/software acquisition	7.5-71
Training expenditure	Expenditure on training activities	4.3-60.6
Total R&D	All in-house and external R&D activities expenditures	27-110
Competition intensity	Percentage of innovative firms in each industry with high coemption intensity in their industry	0-29%
Uncertainty in demand	Percentage of innovative firms in each industry facing with uncertainty in demand	0-32%
New business practices	Percentage of firms having introduced newly or immensely improved business practices	1.6-10%
New external relations	Percentage of firms having established new external relations	1.4-10%
New decision making	Percentage of firms having introduced newly or immensely improved decision-making procedures	0-9%

3.4.1. Knowledge search diversity and organizational innovation

The role of external knowledge sources in interaction with firms' context (firms' size, employee education, market scope) on new management practices has been analyzed by Mol and Birkinshaw (2009). They found positive relationship between knowledge from external knowledge sources and firms' internal context with introduction of new practices and a mitigating interaction effect between the two. Hock-Doepgen et al., (2021) investigated the association of internal and external knowledge management capabilities on business model innovation with the intermediate effect of risk-taking capacity of firms. While they find positive relationship between internal and external KM and strengthening impact of risk-taking tolerance, they have not incorporated interaction effect of environmental dynamisms with knowledge management. Also, none of the studies have considered the role of external knowledge in terms of search strategies on different types of organizational innovation and comparisons of the finding between the three types which this thesis has provided.

3.4.2. Interaction of market dynamisms and search diversity on organizational innovation

Equation (10) produces results for three models 1,2,3 (three percentiles, see section 3.4) which estimates the coefficients of knowledge diversity, competition intensity and their interaction effect. Equation (11) on the other hand produces results of models 4,5,6 (three percentiles, see section 3.4) which evaluates the coefficients of knowledge diversity, demand uncertainty and their interaction effect. *Y* corresponds to the estimated rate of the three organizational innovation modes.

(10)

$$Y = \beta_0 + \beta_1 diversity + \beta_2 diversity^2 + \beta_3 Competitionintensity + B_4 machinery/software + \beta_5\, totalR\&D + \beta_6\, trainingex + \beta_7 diversity * competitionintensity$$

(11)

$$Y = \beta_0 + \beta_1 diversity + \beta_2 diversity^2 + \beta_3 demanduncertainty + B_4 machinery/software + \beta_5\, totalR\&D + \beta_6\, trainingex + \beta_7 diversity * demanduncertainty$$

Based on the analysis in section 2.6.6.4 the results validate negative curvilinear relationship between search diversity and different modes of organizational innovation. Also, the synergy-inducing factors in markets (competition intensity and uncertain demand trends) follow positive trends with organizational innovation in its three types (see section 2.2.6.5). The joint occurrence

of these two antecedents of organizational innovation mitigates their individual impacts on organizational innovation (see section 2.2.6.6).

Table 10 illustrates the results related to organizational innovation type 1: *new business practices* captured by models 1,2,3 and models 4,5,6. Table 11 presents results for organizational innovation type 2: *new external relations* and Table 12 demonstrates same analysis for organizational innovation type 3: *new work assignment methods and decision-making processes*. As for control variables, industry size, total R&D intensity and machinery and software acquisition expenditures are employed in the models. Much automation in business disciplines might reduce firms' (industries') incentives for investing in innovative ways to implement their practices. Thus, this variable follows a negative relationship with organizational innovation. This result is contrary to the impact analysis of machinery/ software acquisition on technological innovation (see section 3.3.3) where a positive trend is expected (Frank, et al., 2016). Total R&D expenditure (including in-house and external sponsoring expenditures) follows a positive trend with organizational innovation. Training expenditure is also controlled in the models and it has overall positive impact on organizational innovation.

Table 10

Quantile regression models for analysis of introduction of new business practices in three levels

	(1) t = 0.2	(2) t = 0.5	(3) t = 0.8	(4) t = 0.2	(5) t = 0.5	(6) t = 0.8
Diversity	6.14*** (1.9)	4.48*** (1.2)	5.91*** (1.13)	5.21*** (1.91)	3.75*** (1.35)	4.2*** (0.9)
$Diversity^2$	-4.54*** (1.44)	-3.13*** (0.99)	-4.36*** (0.88)	-3.65** (1.42)	-3.0*** (1.1)	-3.7*** (0.67)
Competition intensity	0.6** (0.23)	0.68*** (0.14)	0.4*** (0.14)	----------	----------	----------
Demand uncertainty	----------	---------	----------	0.63*** (0.22)	0.3** (0.14)	0.26** (0.13)
Machinery/ Software	-0.05*** (0.01)	-0.02** (0.01)	-0.01 (0.01)	-0.04** (0.01)	-0.02* (0.01)	-0.02* (0.008)
Total R&D expenditure	0.57*** (0.12)	0.44*** (0.07)	0.32*** (0.07)	0.48*** (0.14)	0.34*** (0.09)	0.23*** (0.06)

Training expenditure	0.04*** (0.02)	0.03*** (0.01)	0.01 (0.01)	0.03** (0.01)	0.01 (0.01)	0.003 (0.007)
Competition* diversity	-0.86*** (0.39)	-0.93*** (0.24)	-0.47* (0.24)	----------	----------	---------
Demand uncertainty*diversity	----------	----------	----------	-0.82** (0.34)	-0.23 (0.23)	0.07 (0.001)
Pseudo R^2	0.42	0.43	0.45	0.41	0.42	0.53

Note: *p<0.1; **p<0.05; *** p<0.01 - standard errors are in parenthesis. Dependent variable is new business practice

These results raise interesting interpretations and insights for theory and practice especially that the analysis is performed in industry level. Search diversity indicates stability in its positive linear and negative non-linear impacts on business practices in different percentiles of the response. Note that in this analysis different percentiles of the response are in fact the **contemporary intensity of innovative business practices in industries**, thus results follow that the impact of search diversity on new business practices does not change substantially between industries with low intensity of new business practices and the ones with higher number of enterprises being innovative in that sense. On the other hand, results do not demonstrate such stability in impact of competition intensity and demand uncertainty in different industries. Their impact on new business practices is very much dependent to the percentiles (meaning industries with low, medium and high intensity in introducing new business practices), as an example according to Table 10, the positive impact of competition intensity on new business practices drops significantly from percentile 50^{th} to percentile 80^{th} (from 0.68 to 0.4). That implies the synergies created by competition intensity for introducing new business practices is lower in industries with high number of enterprises who have introduced new business practices recently (during the time span of the study: 2014-2016). The dependency of uncertain demand trends on new business practices on intensity of that type of innovation in different studies can also be seen from results in Table 10. Also, the diminishing interaction impact of search diversity and competition intensity and that of search diversity on new business practices show volatility among industries with different rates of new business practices. Another interesting insight derived from the results is related to the situations where the positive linear trend of search diversity with business practices gets close to be identical with its non-linear negative impact. In that case (Table 10, model 6) it can be seen that the moderating interaction

impact of search diversity and uncertainty in demand turns into a positive but statistically insignificant coefficient. In other words, in situations where the positive and negative influence of search diversity are nearly identical their interaction impact with market dynamisms on organizational innovation is neutralized (happened once in this type but happening more in upcoming Table 11,12).

Table 11

Quantile regression models for analysis of establishment of new external relations in three levels

	(1) t = 0.2	(2) t = 0.5	(3) t = 0.8	(4) t = 0.2	(5) t = 0.5	(6) t = 0.8
Diversity	5.58*** (1.9)	5.29*** (1.29)	5.91*** (1.13)	6.24*** (1.68)	4.43*** (1.23)	3.25*** (0.84)
Diversity^2	-4.37*** (1.57)	-4.01*** (0.99)	-4.36*** (0.88)	-4.83*** (1.24)	-3.5*** (0.97)	-3.1*** (0.62)
Competition intensity	0.65*** (0.24)	0.35*** (0.13)	0.4*** (0.14)	----------	----------	----------
Demand uncertainty	----------	---------	----------	0.64*** (0.2)	0.33** (0.15)	0.25** (0.11)
Machinery/ Software	-0.03** (0.02)	-0.02** (0.01)	-0.01 (0.01)	-0.04*** (0.01)	-0.04*** (0.01)	-0.02** (0.006)
Total R&D expenditure	0.48*** (0.14)	0.35*** (0.08)	0.32*** (0.07)	0.46*** (0.13)	0.4*** (0.08)	0.22*** (0.06)
Training expenditure	0.03 (0.02)	0.01 (0.01)	0.01 (0.01)	0.03** (0.01)	0.01 (0.01)	0.006 (0.006)
Competition* diversity	-0.92** (0.39)	-0.74*** (0.24)	-0.35* (0.23)	----------	----------	---------
Demand uncertainty*diversity	----------	----------	----------	-0.85** (0.34)	-0.16 (0.26)	0.03 (0.2)
Pseudo R^2	0.42	0.46	0.49	0.43	0.46	0.55

Note: *p<0.1; **p<0.05; *** p<0.01 - standard errors are in parenthesis. Dependent variable is new external relations

Similar stable results for search diversity on type 2 of organizational innovation is obtained (of course by considering different magnitudes in coefficients). Instability exists in the influence of both market conditional forces (competition intensity and demand uncertainty) on new external

relations in different percentiles but with different patterns compared to type1 organizational innovation. Volatility of the diminishing interactive influence of search diversity and market conditions is also followed for type 2 innovation but again with different patterns to those related to type 1.

Table 12

Quantile regression models for analysis of establishment of new decision-making processes in three levels

	(1) t = 0.2	(2) t = 0.5	(3) t = 0.8	(4) t = 0.2	(5) t = 0.5	(6) t = 0.8
Diversity	5.2** (2.49)	5.8*** (1.33)	4.8*** (1.17)	4.9* (2.54)	4.27*** (1.29)	3.7*** (0.97)
$Diversity^2$	-4.00** (1.93)	-3.09*** (1.02)	-4.04*** (0.9)	-3.42* (1.92)	-3.37*** (1.15)	-3.3*** (0.76)
Competition intensity	0.52 (0.34)	0.6*** (0.16)	0.11*** (0.15)	----------	----------	----------
Demand uncertainty	----------	---------	----------	0.68** (0.28)	0.34** (0.14)	0.17 (0.11)
Machinery/ Software	-0.05** (0.02)	-0.03*** (0.01)	-0.02** (0.01)	-0.05*** (0.02)	-0.03*** (0.01)	-0.01 (0.006)
Total R&D expenditure	0.62*** (0.17)	0.45*** (0.08)	0.38*** (0.08)	0.46*** (0.14)	0.35*** (0.08)	0.24*** (0.07)
Training expenditure	0.05** (0.02)	0.02* (0.01)	0.02* (0.01)	0.04** (0.02)	0.01 (0.01)	0.006 (0.01)
Competition* diversity	-0.69 (0.55)	-0.8*** (0.26)	0.14 (0.24)	----------	----------	---------
Demand uncertainty*diversity	----------	----------	----------	-0.87* (0.48)	-0.18 (0.24)	0.2 (0.2)
Pseudo R^2	0.36	0.38	0.46	0.36	0.4	0.49

Note: *p<0.1; **p<0.05; *** p<0.01 - standard errors are in parenthesis. Dependent variable is new business decision making processes and new ways of organizing work responsibilities

Similarity with type 1 and type 2 organizational innovations in the stability of impacts of search diversity is obtained. Synergies created by market forces for introducing type 3 (new work

assignments and decision-making processes) is also different across industries with different rates of introduction of that type (volatility of coefficients in different percentiles). Instability in the diminishing joint impact of search diversity and market forces are also followed for this type of innovation. Only that the neutralized influence also happens in the joint impact of search diversity with competition intensity (Table 12, model 3) as well as with uncertain market demands (models 5,6, Table 12).

Following findings are validated and demonstrated through analysis of this section:

- External search diversity establishes a negative curvilinear relationship with different types of organizational innovation in the industry.
- Market dynamisms (competition intensity and demand uncertainty) provide synergies for enterprises to engage in introduction of different types of organizational innovation in the industry.
- The joint occurrence of external search diversity with market dynamisms mitigates the positive impact of the latter on different types of organizational innovation in the industry.
- The synergy producing mechanisms of competition intensity and uncertain demand for different types of organizational innovation is *dependent on the rate of introduction* of such innovative practices (either of the three types) in different industries.
- The diminishing impact of external search diversity and market dynamisms on different types of organizational innovation is *dependent on the rate of introduction* of such innovative practices (either of the three types) in different industries.
- In situations where the positive linear and negative non-linear impact of search diversity on different types of organizational innovation are nearly identical, its mitigating effect with market dynamisms on organizational innovation is neutralized.

3.5. Logistics innovation

The investigation of the impact of external knowledge strategies is an enriching pursuit for the logistics innovation literature as well as examination of its effects under the influence of an environmental driver and provides contributive insights for theory and practice related to logistics services. External search diversity and competition intensity are treated as the independent variables. Innovation in logistics services is incorporated as the dependent variable. Industry size, total R&D expenditures and market scope are also incorporated as control variables. For the

analysis in this section, quantile regression is utilized due to its robust results and the interesting inferences it produces for the sake of this study's analysis in industry level rather than firm level. Four levels of analysis are considered based on different percentiles of the response (logistics innovation) in this part. Bootstrapping method with 1,000 iterations is applied to quantile regressions (Lesage, 1999; Green, 2008; Mohammadi, 2008).

Table 13

Summary of measures for search diversity, competition intensity and logistics innovation

Variable	Description	Scale
Diversity	Inverse of the summation of fraction of clusters divided by total sources squared $\frac{1}{\sum_{i=1}^{4}(\frac{U_i}{N})^2}$	0-2
Industry size	Total number of enterprises	29-74449
Total R&D	All in-house and external R&D activities expenditures	27-110
Competition intensity	Percentage of innovative firms in each industry with high coemption intensity in their industry	0-29%
Market scope	weighted average of percentage of firms in the industry who sell in local, national, European and international markets with 1,4,8,16 as weights respectively	0-30
Logistics innovation	Percentage of firms who have introduced any of the 7 types of innovative output in each industry	0-63.2%

3.5.1. Knowledge search diversity and logistics innovation

The role of external knowledge strategies on logistics innovation has not been empirically studied. analysis of knowledge as a resource input into organizational learning process integrated with other assets has indicated significant positive association of knowledge (as a resource) with logistics innovation (Persson & Virum, 2001; Chapman et al., 2003; Panayides & So, 2005). Xu and Ma (2010) have studied the relationship between knowledge management and performance of logistics services without considering innovation results in such enterprises.

On the other hand, the competitive environment has been indicated to be a synergy-creating enabler to innovations in logistics (Gellmann, 1986; Zinn, 1996) which is consistent with the findings of this thesis. But its interactive role with external knowledge strategies has not been addressed in the literature prior to this thesis.

3.5.2. Interaction of competition dynamics and search diversity on logistics innovation

There are 4 models estimating the coefficients of independent variables. Models 1,2,3,4 illustrate the coefficients computed in four levels, t= 0.2, t= 0.5, t= 0.7, t= 0.8 respectively. Table 14 below presents the findings. The evaluating regression is equated as follows:

(12)

$$Y = \beta_0 + \beta_1 diversity + \beta_2 Competitionintensity + B_3 industrysize + \beta_4\, totalR\&D + \beta_5 marketscope + \beta_6 diversity * competitionintensity$$

According to the analysis in section 2.2.7.3 the results prove a positive trend between search diversity and logistics innovation. Based on the line of reasoning in section 2.2.7.4 there is a synergy producing relationship between competition intensity as an environmental force and logistics innovation. There are three variables to be controlled in the evaluation of the impacts of the two independent variables.

Market scope which is a proxy for the scope of activation of each industry, meaning that what the average breadth of the markets, enterprises in each industry are active in and serve. This variable demonstrates a positive influence on logistics innovation due to the fact that enterprises and industries with bigger market scopes have more resources as well as networks of relations which enables them to improve their logistics for instance through outsourcing or through establishing more efficient relations with different suppliers. On the other hand, the industry size demonstrates a negative impact on logistics innovation, which can be interpreted by difficulty of finding innovative ways leading to cost reductions and new value creation due to existence of higher number of suppliers and competitors in larger industries in comparison to smaller ones.

Total expenditure for innovation establishes a positive relationship with logistics innovation which means it does not travel a different path to logistics innovation as the ones to other kinds of innovation.

Table 14

Quantile regression models for analysis of logistics innovation in four levels

	(1) t = 0.2	(2) t = 0.5	(3) t = 0.7	(4) t = 0.8
Diversity	19.42***	13.87**	11.75*	6.45
	(6.27)	(6.3)	(6.04)	(8.4)

Competition intensity	0.02**	0.03***	0.04***	0.03***
	(0.006)	(0.007)	(0.008)	(0.01)
Market scope	1.00***	1.14***	1.18***	1.02***
	(0.16)	(0.14)	(0.14)	(0.2)
Total R&D	3.1***	2.12***	1.6***	1.7**
expenditure	(0.67)	(0.7)	(0.5)	(0.76)
Industry size	-0.5e-4*	-0.001***	-0.002***	-0.002***
	(3e-4)	(3e-4)	(3e-4)	(4e-4)
Competition* diversity	-0.31***	-0.24**	-0.22**	-0.13
	(0.1)	(0.01)	(0.1)	(0.14)
Pseudo $\boldsymbol{R^2}$	0.36	0.38	0.38	0.34

Note: *p<0.1; **p<0.05; *** p<0.01 - standard errors are in parenthesis. Dependent variable is logistics innovation

By looking into the results interesting insights can be inferred in course of logistics innovation. Unlike the case with organizational innovation (examined in sections 3.4.1), external search diversity demonstrates high volatility in its relationship with logistics innovation. It has substantial influence on logistics innovation in industries with lower number of logistics innovative enterprises (low percentile of the response, t= 0.2). That substantiality in its effect is smaller in industries with medium number of logistics innovative enterprises (t=0.5). Although this reduction in search diversity's impact on logistics innovation does not continue in higher percentiles (t=0.7), but there is decline in its significancy (statistically). The very interesting insight comes out from very high percentiles (t=0.8). Not only search diversity does not improve logistics innovation in industries with high number of logistics innovative enterprises but also its interaction effect with competition intensity in such industries does not play significant role. This is different in terms of the impact of competition intensity on logistics innovation. Unsimilar to the impact of competition intensity on organizational innovation (analyzed in section 3.4.2), competition intensity in contrary to search diversity demonstrates a stable impact on logistics innovation in different percentiles. That implies its association with logistics innovation in industries with low percentages of logistics innovation is similar to its association with logistics innovation in industries with high rates of that type of innovation. The diminishing effect of search diversity on the relationship between competition intensity and logistics innovation indicates a consistent decline from industries with low rates of logistics innovation to industries with higher rates of the latter. That means, search diversity diminishes the impact of competition intensity on logistics innovation in a more sensitive

way (more substantially) than in industries with higher number of logistics innovation enterprises. Conclusions of the analysis of this section follow:

- Diversifying external search establishes a positive association with logistics innovation in the industry.
- Competition intensity provide synergies for enterprises to engage in introduction of different types of innovative changes in logistics services.
- The joint occurrence of external search diversity with competition intensity mitigates the positive impact of the latter on logistics innovation in the industry.
- The synergy producing mechanisms of competition intensity for logistics innovation is ***not*** *dependent on the rate of introduction* of such innovative changes.
- The contributive effect of diversifying external search on different logistics innovative changes is *dependent on the rate of introduction* of such innovative changes.
- The diminishing effect of external search diversity and market dynamisms on logistics innovation is *dependent on the rate of introduction* of such innovative changes and its more substantial in industries with lower number of logistics innovation enterprises in comparison to industries with higher number of such enterprises.

4. Conclusion and implications

Knowledge base firm theory (Dosi, 1988) and knowledge-based economy theory (Dosi, 1998) highlight the role of competition as a knowledge producing process which has been emerged from Hayek (1948) fundamental theory of competition. He considers competition as a hypothesized experimentation thorough market and highlights the role of knowledge in winning the game. The role of different types of knowledge on firms' roads into innovation (as a competitive advantage) has also been appreciated from very early in the history of competition and innovation literature (Schumpeter, 1934; Arrow, 1962). For the aim of taking an encompassing and new look into the economic dynamics of knowledge in innovation in competitive circumstances, this study sheds light on the relationship between external knowledge strategies and different types of innovation by introducing a novel complementary external knowledge strategy to the primary ones existing in literature. The proposed strategy is able to capture the heterogeneity inherent in the external knowledge acquired by firms from different external knowledge sources in a more dynamic way.

Thus, provides a direction in search to help firms not to rely on accidentally information encounters when they open up their innovation activities (see section 2.2.2). In searching for external knowledge, it is its extent, depth and diversity of search that matters and benefits enterprises on their ways to successful innovation. Prior to this study diversity and extent have been perceived and embodied in calculation of search breadth in a mixed manner. This thesis distinguishes between diversifying and expanding search scope and demonstrates that such distinction in concept provides firms with more opportunities in setting their search policies as well as directions for broadening their search scope. To be able to theorize and formulate that novelty, this study considers a network structure for external sources towards which firms create linkages. That is a secondary contribution of this thesis to the previous literature which used to consider sources of knowledge as individual providers of promoting knowledge rather than considering consequences of networking enablers. In addition to conceptualization, an index to calculate the inherent diversity in network of knowledge sources is formulated in enterprise as well as industry level.

It is analyzed that diversifying external knowledge improves technological innovation up to a threshold where a downturn happens due to limitations in resources for processing much diverse information. A hybrid strategy of search breadth and diversity is suggested which proposes strategic solutions in exploring knowledge from outside to neutralize the counter-effects of diversifying search on one hand and those of merely broadening search on the other. That is proposed to be done by expanding search (without helping diversity) or by deepening search through exploiting same sources for more knowledge. This thesis takes a deeper look into antecedents of different types of innovations. It analyzes interactive effects of different level antecedents and demonstrates how different paths to innovation can have intersections. Furthermore, it demonstrates how the associations of different innovation antecedents with innovation results in industries are dependent on the innovation intensity in different industries.

While technology is considered to be an improving factor of technological innovation when isolating its impact, its joint manifestation with knowledge diversity declines some of that positive effect due to partial relaxation of need for internal knowledge producing technology. Mergers being considered as structural changes (rather than decisions) in organizations are suggested to differently influence technological and non-technological innovations as well as organization's ability in diversifying their stock of external knowledge.

Organizational innovation is indicated to be associated with search diversity in a curvilinear manner similar to technological innovation. Through a contributive quantile regression, it is demonstrated that the role of search diversity is not very much dependent on the situation of organizational innovation in industries. On the other hand, market dynamisms as well as their interaction effect on organizational innovation are dependent to contemporary intensity of organizational innovation in different industries which is a highlighted implicative contribution of this thesis.

Logistics innovation is indicated to be positively correlated with knowledge diversity. In contrary to the case of organizational innovation, the association of search diversity with logistics innovation is indicated to be volatile across industries while that of market dynamisms (competition intensity) correlates with that type of innovation irrespective of the intensity of logistics innovativeness of industries.

The underlying theme of this thesis is in the analysis and illustration (in through empirical investigations) of different mechanisms for external knowledge management in relation to different sorts of innovativeness. It is substantially highlighted how vastly the environmental and contextual factors are determining the establishment of knowledge acquisition strategies and how those interplay with the result of investments in different types of innovation. The role of knowledge complementarity in interaction with other inputs into innovation processes are examined. It is illustrated that external knowledge strategies are inherent with different dynamics towards different types of innovation in relation to other enablers such as technological influencers, environmental factors, organizational settings and structural changes of enterprises and industries. From practical point of view, it is indicated that there are different paths for enterprises to economic performance (different types of innovative changes). It is crucial for decision makers to consider the internal and external context of their entity and to flexibly and feasibly set their external knowledge management strategies in a way that its dynamic interacting consequences with the context and environment leads to efficacy and effectiveness and in turn to success in their market prosper.

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