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External knowledge diversity, competition intensity and innovation performance in logistics: Implications for less versus more innovative industries

Maryam Hajialibeigi*

Abstract

Purpose: This paper analyzes the association of searching diversely as a strategy to capture external knowledge and that of competition intensity with innovation in logistics. Secondly it studies how these associations interact by examining whether they intensify or mitigate one another when jointly occur. Thirdly, it is explored whether correlations of search diversity, competition intensity and their interaction effect with logistics innovation demonstrate differences in their strength depending on logistics innovativeness of target industries.

Design/methodology/approach: By discriminating between diversifying and expanding search scope, a new search mode is identified which is more precise in examining diversity of acquired external knowledge in comparison to search breadth. *External search diversity* is formulated based on a classification of external sources according to similarities in their knowledge supply. Quantile regression is applied for the purpose of this study due to its ability in estimating different models in different quantiles of the response variable.

Findings: While positive trends are found for both antecedents, their mutual occurrence partially mitigates their individual positive relations with logistics innovation. All correlations demonstrate dynamic patterns. The strength of these correlations varies between industries with low logistics innovation rates compared to the ones with higher rates. Search diversity illustrates its highest correlation in the least innovative industries whereases competition intensity contributes the most to logistics innovation, in higher innovative ones. Their interaction effect exhibits similar patterns to those of search diversity.

Originality: The role of external knowledge management in logistics innovation and its interaction with competition intensity as a synergetic antecedent is studied for the first time in this paper in the open innovation framework.

Keywords: logistics innovation; search diversity; competition intensity; knowledge management.

JEL classification: O_3, C_1

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1. Introduction

Innovation is defined as an idea or practice which is perceived new by an addressed party (Rogers, 2003). Technological turbulences, competitive forces and global market trends persuade firms to look for new channels towards competitive advantage (Nagarajan and White, 2007). In order to gain and maintain the latter, firms pursue innovation in different directions. From new and creative products and services to processes and business practices and decision-making procedures. Logistics as the efficient and effective flow of goods, services and related information between the point of emergence to the point of consumption (Grawe, 2009) merits perspectives for innovative outcomes. 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. It can take different forms such as digital supply chain management systems, new delivery models, new inventory management systems etc. 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 services from the innovation perspective is a relatively narrow stream (Wagner, 2008; Tether and Tajar, 2008; Busse, 2010) but as literature suggests (Gellman, 1986; Wagner, 2008) there are different factors promoting innovations in logistics. There are organizational, contextual and environmental factors explaining logistics innovation (Grawe, 2009). Business practices and interorganizational relationships provide as well the opportunities for firms to optimize their supply chains in terms of their elements and the links among them and thus establish positive relationships with innovations in logistics service industry (De Carvalho and Malaquias, 2012; Richey et al., 2012). In today's world, with the globalization trends of logistics processes, knowledge plays a strategic role in logistics performance in general and in innovative pursuits in narrow sense. Due to importance of knowledge as an asset, the advancement of knowledge strategies is a crucial practice to realize efficient logistics management leading to firm performance improvements (Bagshaw, 2019). Although the importance of knowledge management in logistics performance has been highlighted in literature (Neumann and Tome, 2009; Fugate et al., 2012; Lee and Song, 2014; Durst and Evangelista, 2018) but how such knowledge management would establish relationship with innovation performance in logistics

services is still a very young research stream. Treatment of external knowledge in logistics innovation is even narrower and is limited to its role in specific forms of logistics (Xu and Ma, 2010; Marra et al., 2016). It is one of the central interests of this study to analyze the role external search strategies as highlighted enablers and identifiers of external knowledge management capabilities play in logistics innovation in different industries. Firms' attempts towards efficient and effective logistics performance are also dependent on market dynamisms in their environment as well as their own organizational structures and attributes. Competition intensity as the degree of rivalry that enterprises encounter in the markets increases the synergies for being recognized and differentiated. In markets in which close substitutes exist, strong incentives for employing new policies be it pricing strategies, establishment of new partnership relations or new business practices are created. The synergy creating effects of competition intensity on innovation in logistics implies setting up strategies in logistics operations which reduce costs and create customer values. The latter can be realized through innovative product identification methods and sustainable supply chain models which in turn increase responsiveness and reliability. Such incentive exerting relation of competition forces in markets with innovation in logistics has been of the matter of focus in previous literature (Zinn, 1996). However, this paper takes a more dynamic approach in examining that relation together with another antecedent of logistics innovation (external search diversity) and enriches the empirical literature in logistics innovation in three conducts. First, by utilizing a novel external search approach named search diversity and investigating its association with logistics innovation, this article takes the role of external knowledge management capabilities in logistics performance into account. Second by exploring the role of search diversity under the influence of competition intensity in logistics innovation, it opens a new research stream which answers to the question of how the interaction of market conditions and external knowledge management relate to logistics services. Finally, it inspects whether such interactive effect of the two different types of logistics innovation promoters, alters in different industries according to their contemporary innovative outcomes in logistics services.

The rest of the paper is organized as follows: First the theoretical background on external knowledge strategies as open innovation process factors is advanced and the new search mode is elaborated. Second, the different contributive roles of knowledge search diversity and competition intensity and their interactive effect on logistics innovation are hypothesized. In the following section the analytical models for assessing the advanced hypotheses are presented. Research

findings are proposed in the following section. Finally theoretical and practical implications as well as the conclusion to the whole discussion are argued.

2. Theoretical Background

Chesbrough and Bogers (2014, 3) provide an extension to the original theory of open innovation (Chesbrough, 2003), which considers this terminology as '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.' Such extension proposes four underlying building blocks for open strategies of firms when pursuing innovation: the role of managed knowledge flows in innovation ecosystem of firms, innovation as a process into functional infrastructure of enterprises, incorporated flexibilities in organizational boundaries in terms of knowledge flows, the role of enterprises' business models as the most determining benchmark for employing routines and procedures. In other words, open innovation is a policy transformation under which knowledge flows are imperatives of success in innovation campaigns of firms and therefore implies firms to shift from solid organizational boundaries into flexible-border frameworks when pursuing innovation. Chesbrough (2002, 2003) counts four elements which prompt that policy transformation; Ability and mobility of trained and experienced employees, broadening external suppliers' competencies, undiscovered potencies of idea production options and availability of venture capital market. Such flexibility facilitates efficient and effective interactions with external parties in terms of knowledge transfer. The latter in turn, highlights the importance of management of knowledge flows in terms of knowledge acquisition strategies, conversion mechanisms and implementation procedures. As for externally acquisition of knowledge in open innovation framework two primary strategies are introduced and measured by Laursen and Salter (2006). Search breadth which reflects the scope of search for external knowledge (number of external sources being explored for knowledge) and search depth reflects the intensity of search (degree of importance of each source for being exploited for knowledge). As suggested by Laursen and Salter (2006), these two metrics as a bundle provide a scale for degree of *openness* of enterprises for innovation. As suggested by literature (Kline and Rosenberg, 1986; Lundvall, 2007) interconnecting with external parties and exploring external knowledge improves firms' performance in terms of innovative outcomes. Expanding search scope (search breadth) leads to gain general information which is a treasured input into innovation process and increases enterprises' chances to confront fertile knowledge (in terms of its potential in leading to

creativities). Although accessing to knowledge from more sources is more likely to associate with higher innovation performance (Cohen and Levinthal, 1990; Rosenkopf and Nerkar, 2001) but as suggested by open innovation firm-based view (Felin and Zenger, 2017), opening up to external supplies, without having a direction on what knowledge to look for and what particular information the environments have to offer, would be misleading and inefficient. The generality and non-particularity inherent in the knowledge offered by external world does not provide the directions towards firms-specific strategies (innovation policies in particular) thus implies firms to solely rely on coincidental confrontations (von-Hippel and von- krough, 2016) with knowledge supplies. Acquiring resources -including knowledge- which have the propensity to create value takes costly effort. Thus, if firms follow firm-specific policies while they open up, much more heterogenous spectrum of resource offerings will be provided to the markets. Therefore, firms would be presented with more opportunities to discover knowledge related creativities which are undiscovered by competitors. This latter reasoning highlights the degree of importance of heterogeneity in acquired knowledge as the most strategic resource in firms' innovative pursuits (Grant, 1996; Turner and Makhija, 2006). Search breadth by its original definition has always been treated as the only metric to reflecting the whole scope of search. In that sense search breadth has encapsulated *range* and *diversity* of search (Chiang and Hung, 2010; Zhou and Li, 2012) without being able to provide any reflection on cooperation of these two elements. That is due to the fact that this metric cannot distinguish redundancy rates in knowledge acquired by firms when it is increased (see Figure 1 below). To fill that gap, an additional componential strategy is needed which can capture the diversity encapsulated in the knowledge that enterprises acquire from the outside world. By distinguishing between diversifying search and expanding search, '*Knowledge search diversity'* is introduced1. It acts as a metric for acquiring the heterogeneity in the network of knowledge sources firms explore, and is a supplementary strategy to search breadth. Knowledge search diversity is able to incorporate the role of 'complementarity' rather than 'substitutionality' inherent in the knowledge firms pursue to gain. Accessing to complementary knowledge gives firms better opportunity to avoid possible wordiness rates inherent in substitutional or rather general information that firms might encounter through merely broadening or deepening their search and thus increases search efficiency. This supplementary search scheme provides a

1 External search diversity is conceptualized and formulated for the first time by the authors of this article in a parallel study under review by another journal and it is accepted for publication due to minor revisions. Upon acceptance the parallel paper the related parts of this article will be referenced.

direction in search and contributes to optimization of firms' search policies. To be able to formulate that metric some steps are required to be taken. As an extension to the literature (Cassiman and Veuglers, 2002; Dong and Netten, 2017) a classification procedure -as a reference- among eleven possible sources of external knowledge is exerted: (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 embodies similar knowledge in nature but different classes supply differentiated knowledge. Based on this underlying reference, a search network (Sources which have been explored for knowledge by firms are categorized in different classes according to the classifying reference) is considered for each enterprise and then a '*knowledge diversity index'* as a search strategy is harmonized with the search network and in turn with the enterprise. Being moved by the diversity index applied in biology (Simpson index, 1949) and HHI index applied in economics (Hirschman, 1946; Herfindahl, 1950), the 'Knowledge diversity index' (KDI) which corresponds a heterogeneity metric to search networks of enterprises is introduced. If *N* is the total number of sources being explored (search breadth) by a firm and n_i is the number of sources in each of the four classes *i*, being explored by that specific firm (vertical, horizontal, societal and specialized) then P_i (for i=1... 4) is defined as below:

$$P_i = \frac{n_i}{N} \tag{1}$$

Knowledge diversity index for each specific firm (firm level) is captured through the underneath equation:

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

Some studies (Utterback and Suarez, 1993; Bogliacino and Pianta, 2013) including this article, perform empirical analysis in industry level. Therefore, a modification of KDI for industry level is also introduced. If *N* indicates the total percentages of firms having used all eleven sources (search breadth in each industry) and if u demonstrates the percentage of firms (in an industry) using a specific external source which lies in class *i* (e.g. *u*= suppliers, *u*= private clients and *u*= public clients in class 1) then U_i is formulated as follows for each of the four source classes (for i=1…4):

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

The knowledge diversity index in industry level is formulated as follows for (for i =1… 4):

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

Figure 1 below exemplifies computation of knowledge diversity using equation (2) above in case of two enterprises (1 and 2) by constructing explored source networks for each enterprise. It also demonstrates how search diversity differs from external search breadth as its supplementary search strategy.

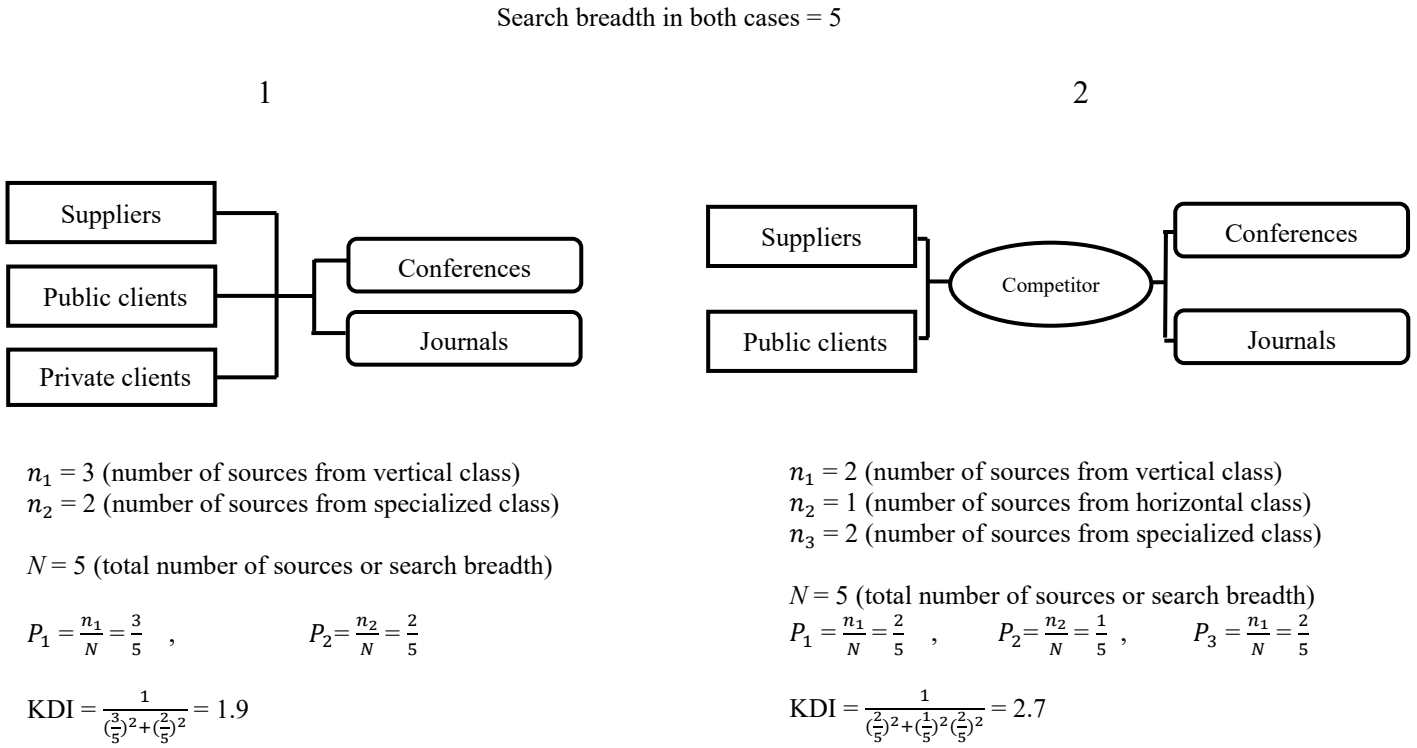

Figure 1. Verification of external search diversity

The computation above demonstrates that the knowledge acquired from source network by enterprise 2 is much more diverse (heterogenous) than in case of enterprise 1. This is the latent dimension in external search that search breadth is not able to reflect. It can be seen that search breadth in both cases is identical. The same procedure can be applied to industry level by utilizing equation (4) to capture the external search diversity in knowledge which is acquired by any individual industry.

3. Hypothesis Development

3.1. External Search Diversity and Logistics Innovation

The knowledge base of firm theory (Dosi, 1998) suggests that firms are particular storehouses of knowledge in the sense that each find distinguished ways to deal with their problems. Such organizationally-specific knowledge finds its route into the functional structure of the firms in two ways, either as organizational procedures or as rule-based supporting systems. Environmental changes necessitate firms to enrich and upgrade that knowledge base and consecutively the processing ecosystems of theirs to be able to catch up with the fast-changing market circumstances. Such consistent enrichment (in terms of acquisition, retrieval and manipulation of knowledge) cannot be effectively done for firms by merely relying on their internal sources of knowledge development. This is due to the highlighted fact that each agent passes specific roads to incorporating knowledge into problem solving procedures and those specificities could be sources of beneficial information for others.

As a result of competition, firms seek innovative attempts to sustain. When knowledge about customer choices and demand patterns as well as about supply side actors from one another's strategies is imperfect and biased then the consequence of competition for innovations in the market is based on the 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 and to pursue variety of innovations. However, the success of the latter is dependent on the efficiency of the former. Thus, firms seek innovation in different areas by looking for efficient and effective knowledge creation and acquisition strategies. Due to universal marketing trends such as globalization and low durability of technologies, logistics services have become an ignite domain for firms' innovative performance. 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 with each of these interacting service providing units contributes to firms' ability in beating innovation uncertainties. Logistics as part of supply chain, is a value-based mechanism in firms' strategic framework and by linking different channel partners (including customers) provides firms with opportunities of gaining versatile competitiveness advantage. As discussed in section 2, 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. This can be specifically the case in presence of redundancies and also potentially discovered (by competitors) idea creating knowledge. Rather, accessing to complementary knowledge especially in logistics as the intersecting functional area of the parties each of which could be addressed as a source of innovation promoting knowledge, benefits the efficiency in the whole industry. In fact, logistics services form a network throughout which knowledge reposited in different nodes (providers) as well as knowledge from clients and their corresponding end customers is flown. If any of the enterprises involved in such network (especially manufacturers of products and services) pursue knowledge strategies which facilitate gaining heterogenous knowledge from their external partners, innovation in logistics services will be favored. Such innovative outputs are results of incorporation of a knowledge base which supports complementary knowledge acquired from external sources and assimilated with the amount developed by internal sources into routines and rule-based supporting systems (Dosi, 1998). This is due to the fact that complimentary knowledge from outside, results in more efficient recombination outputs with internal knowledge gaps. Furthermore, accessing to diverse knowledge, trains firms' ability in absorbing valuable knowledge from outside which is referred to as absorptive capacity of firms (Cohen and Levinthal, 1990), therefore when providers of logistics services have advanced their absorptive capacity, this leads to reduction of inefficiencies in logistics and in turn higher values for customers are created. That reasoning leads us to hypothesize the following statement:

H1. External search diversity facilitates innovation in logistics services.

3.2. Competition Intensity and Logistics Innovation

Environmental circumstances are one determinant of enterprises' policies and the directions they take in their corresponding marketplace. Competition intensity as one of the environmental forces creates incentives for firms to differentiate themselves. As Arrow (1962) suggests, competition creates incentives for firms to get engaged in inventive activities since replacement effect (Tirole and Aghion, 1997) does not exist for competing firms. Expectations of firms of the reactions of others (in terms of change in competition intensity) to innovation, are also explanators of incentives for investments in innovative activities (Baker, 2006). If after introduction of innovations, more fierce competition is expected the incentives for innovative investments decreases. In that case as long as firms' incentives to escape competition are bigger than their hesitance of being encountered with harsher competition, they would take the risk of innovative

investments. 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, 1994; Stapleton and Hanna, 2002). When firms are under competitive pressures, they look for diverse possibilities to escape competition and therefore to decrease uncertainties associated with inventive attempts. Logistics services are mostly competing in existing processes and services and their primary objective is to capture competitive advantage through creating higher customer values and satisfaction. Therefore, intensity of competition provides incentives for logistics services to look for innovative ways to either reduce the costs associated to their services (less costly routes down to the supply chain) or to find innovation by providing opportunities for value-added offerings. Logistics in that sense is a value-based area of firms' functionality and therefore when it is inherent with innovative outcomes not only it creates profitability but also it supports other strategies of firms (Sandberg et al., 2011). In other words, even competition in products and services increase competition intensity in logistics services and that in turn increases logistics innovation potencies. The reasoning above advances the following hypothesis:

H2. Competition intensity establishes a positive association with innovation in logistics services.

3.3. The Interaction Effect of Competition Intensity and Search Diversity on Logistics Innovation

Competition is the discovery process of the superior offerings evaluated by the market (Hayek, 1948) and it is the knowledge foundations of firms above all other explanatory factors which determines the ability of firms in dealing with uncertainties associated with market circumstances to capture competitive advantage. Competition implies firms to look for more problem-solving knowledge from supply and demand side (Kerber, 2006). As discussed in section 3.1, environmental forces imply firms to enrich their knowledge base accordingly to be able to establish procedures and functional systems (Dosi, 1998). The latter make them able to compete in their products, processes and services and subsequently to sustain and prosper in fast changing markets. Competition intensity is one of those highlighted forces being exerted on firms' policies and directions. Therefore, knowledge and competition interact in their relations with firms' differentiation and inventive policies. Thus, it is vital for firms to pursue knowledge acquisition strategies which contribute them in their innovative pursuits to beat competition.

Emergence of information and communication technology has raised the importance of knowledge management and strategies in logistics innovation (Shen et al., 2009; Durst and Evangelista, 2018). When competition in logistics is intense, then service providers pursue innovation through reducing price of their services or through increasing their service quality but universal trends and technology short life cycles makes it insufficient to flourish by only pursuing these two. It is speed to the market and flexibility of supply chains that form criteria to prosper. Logistics services as the interacting point of producers, suppliers, customers and other parties who provide knowledge to the supply chain (i.e., consultants, government, scientists) benefits from pursuing diversity in their search for knowledge in terms of speed and flexibility in three conducts; either by contributing to innovative organizational processes, establishment of external networks or cooperative policies and through improving absorptive capacity (see section 3.1). Thus, competition and diversifying search for knowledge interact on their way to logistics innovation. The two underlying conclusions from the discussion above are a) synergy paths (competition intensity) and knowledge-based paths (diversifying search for knowledge) have overlaps on their routes to logistics innovation b) knowledge-based paths can travel ways other than their intersecting routes with synergy paths to logistics innovation. Therefore, these two promoters of logistics innovation (synergy and knowledge-based) are partial substitutes rather than complements in their beneficial effects. That reasoning forms the following hypothesis:

H3. The individual promoting associations of competition intensity and search diversity on logistics service innovation are mitigated by their jointly manifestation

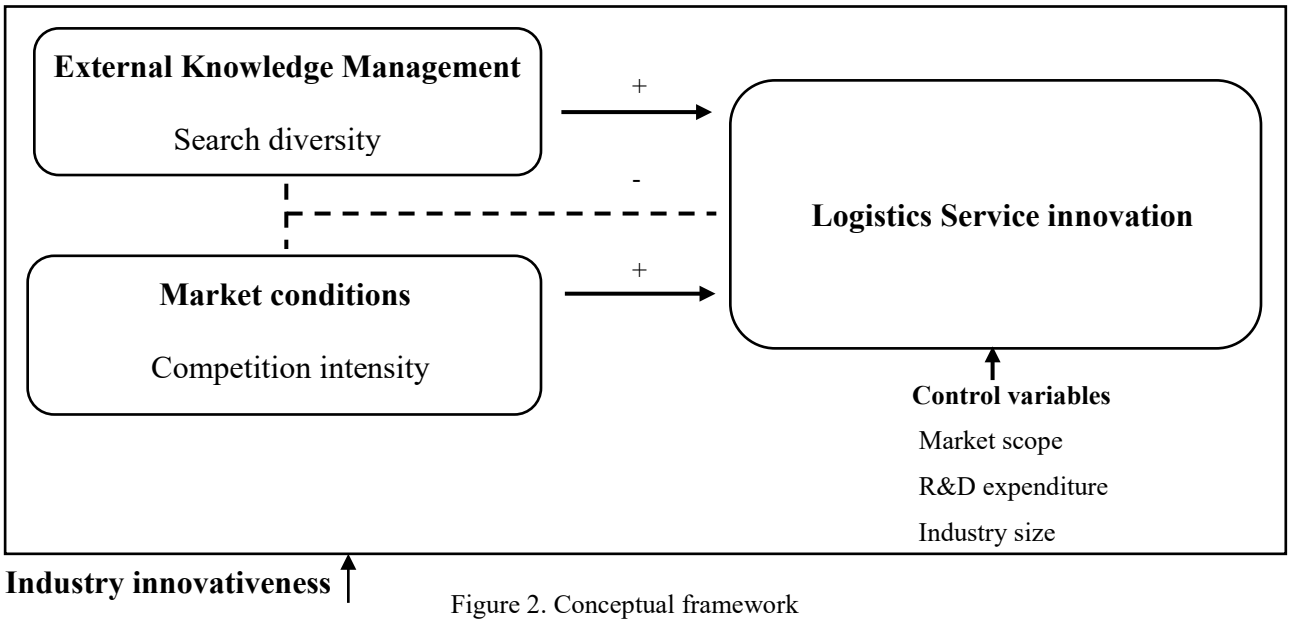

Figure 2. Conceptual framework

4. Data and Measures

4.1. Data

This study uses a Metadata set extracted from German Innovation Community Survey2. The dataset has been utilized in some other studies (Dong and Netten, 2017; Radicic, 2020) which analyze different factors related to innovation behaviors of German enterprises. German Innovation Community Survey is part of the European Commission's Community Innovation Survey (CIS). It embodies comprehensive innovation information of German industries both in firm and industry level. CIS has its parts from many other European countries.

The survey has been produced based on the methods advanced by the Organization for Economic Cooperation and Development (OECD). Many partners have been involved in producing the German Innovation Community Survey including Leibniz Center for European Economic Research (ZEW) who has been involved in gathering innovation related information of the German industry since 1993. The Federal Ministry of Education and Research (BMBF) is the authorized party for conduction of the survey. The metadata set contains annually supplied statistics. It encapsulates information from a series of enterprises including manufacturing service and retailing from food industries to mining to communication and information technology related firms. It supplies information about introduction of new products, services and processes or highly improved ones. A two-yearly modification is performed in order to eliminate information about enterprises which due to any reason (e.g., M&A) are not functioning as independent parties and also to add innovative activities and outcomes of entrants. For the purpose of this study CIS16 is utilized since it is the newest version of the dataset available in case of Germany. It contains self-evaluation innovative behavior of enterprises in German economy in the time frame of 2014-2016. It includes data about in-house and external R&D investments, technology acquisition, external sources of knowledge being exploited by firms and much more. More than one reference has filled in the designed questionnaire independently and that raises the reliability of the information obtained against the datasets which are provided based on answers from only one related reference. The data set includes 143,608 enterprises which make up to **85** industries which forms our analytical sample.

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

4.2.Variables and Measures

4.2.1. External Search Diversity

This study's objective is to investigate the association of external search diversity with logistics innovation in industry level, therefore the modified version of knowledge diversity index in equation (4) is utilized as one of the independent variables in our analysis. In the questionnaire enterprises were asked whether an external source (from eleven) has been highly important as an input to their innovative activities (rated by 1) or whether has not been important (rated by 0). Then the percentages of firms to whom any of the sources has been considered 'highly important' are used in calculation of industry external search diversity in our formulation (equation 4).

4.2.2. Competition Intensity

As measured in CIS16, percentage of firms in any industry who have perceived 'high competition intensity' in comparison to the ones who have not perceived competition to be intense in their market, is used as the proxy to industry competition intensity and is evaluated in our analysis as the second independent variable.

4.2.3. Logistics Innovation

Percentage of firms in each industry who have contributed to introduction or highly improvement of logistics innovation is utilized as the proxy to industry logistics service innovation and is evaluated as the dependent variable in our analysis.

4.3.Control Variables

4.3.1. Innovation Expenditure

The average of in-house R&D expenditure in each industry which has been allocated for innovative activities is utilized as the proxy to industry's R&D expenditure and is controlled as one of the associated factors to introduction of logistics innovation.

4.3.2. Market Scope

An important related factor to logistics innovation is the scope of the market each industry is active in. In order to have an estimation of such scope, percentage of firms in each industry which serve local markets, percentage of firms in each industry which serve national markets, percentage of firms in each industry which serve European markets and percentage of firms in each industry which serve international markets are considered and the score average of these percentages with

respective weights of 1,4,8,16 determine the proxy for market scope of each industry. The weights are used in order to distinct the relative territory of different geographical scopes.

4.3.3. Industry Size

The number of enterprises in each industry is used as the size of the industry. It has association with logistics performance in each industry.

Table 1 below illustrates description and range of variables being utilized in our evaluating models from independent to dependent and control variables. Table 2 presents the descriptive statistics of variables which are evaluated in the regression analysis.

Table 1. Summary of measures for search diversity, competition intensity and logistics innovation

Variable	Description	Range
Diversity	Inverse of the summation of fraction of classes divided by total sources squared $\frac{1}{\sum_{i=1}^{4}(\frac{U_i}{N})^2}$	0-4
Industry size	Total number of enterprises	29-74449
R&D expenditure	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%

Table 2. Descriptive statistics and variable correlations

	Mean	SD	(1)	(2)	(3)	(4)
Diversity	0.13	0.6	1			
Competition intensity	7.3	6.1	-0.07	1		
Total R&D	68.4	16.7	0.11	0.32	1	
Industry size	5407.7	10867	-0.07	0.9	0.35	1
Market scope	11.81	6.36	0.14	-0.12	0.39	-0.12

5. Methodology and Results

5.1. Methodology

Although normality assumption of the residuals for linearity is fulfilled but this study selects to utilize Quantile regression in this study to evaluate the explanatory coefficients of independent variables in different quantiles of the response (logistics innovation). Unlike regular linear regression which utilizes least squares to calculate the conditional mean of the response, Quantile regression estimates the conditional quantiles of the response and conditional median in particular. That is one out of the two reasons why this study selects to utilize this method. Given our aim to perform the analysis in industry level (rather than firm level), Quantile regression due to its ability in estimating conditional quantiles of the dependent variable, produces us interesting results about status of logistics innovation in different industries. Meaning that it gives us the opportunity to obtain different regressions (different relationships) between independent and dependent variables in low percentiles, medium percentiles (median) and high percentiles of the response. Low, medium and high percentiles of the response are representatives of industries with low, medium and high rate of contemporary logistics innovation. Therefore, Quantile regression provides a powerful instrument to obtain results which present interesting insights about dynamics of logistics innovation in different industries. The second reason for our choice is the flexibility of Quantile regression in generation of robust estimation in the absence of fulfillment of linearity assumptions and treating the outliers. None-parametric *bootstrapping* method with 1,000 iterations based on Green (2008), is utilized to perform weighted least squares Quantile regression according to LeSage (1999) and Mohammadi (2008). The evaluating models are performed in four quantiles (t= 0.2, t=0.5 or median, t=0.7, t=0.8). The underlying regression model is equated as follows:

(5)

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

Where Y estimates the rate of the introduction of innovations in logistics services in four levels.

5.2. Results

Table 3 below demonstrates the findings of the analysis of the associations of external search diversity, market competition intensity and their interaction with innovations in logistics services. The scope of the market demonstrates positive relation with logistics innovation. This is due to

possessing possibly more resources for industries which serve bigger markets to appropriate their innovative investments in better timing and with higher quality. This can also relate to higher market shares for bigger serving industries. The positive relation between market share and innovation performance in general has been indicated in the literature (Blundell et al., 1999; Giroud and Müller, 2010). Also, industries with firms which serve bigger markets have possibly larger networks of external relations which in turn enables them to improve their supply chain and logistics services. Such improvement can take place for instance in form of outsourcing or by broadening competencies of external suppliers. Industry size (number of enterprises in each industry) demonstrates a negative trend with innovation in logistics. This can be interpreted by difficulty of finding innovative ways leading to cost reductions and new value creation in cases of existence of high number of suppliers and competitors in large industries in comparison to smaller ones in presence of competition intensity. Thus, the results suggest that industries which possess lower number of active firms but are able to serve bigger market scopes are more likely to realize innovations in logistics services. Total R&D expenditure illustrates a positive relationship with logistics innovations and that means such investments facilitate innovation in logistics services. This result is consistent with literature when such relationship is examined between R&D investment and innovation performance in general (Love and Mansury, 2007).

In line with the direction of the analysis in sections 3.1 and 3.2, search diversity establishes a positive trend with innovation in logistics services. Competition intensity also generates positive incentives for logistics services to engage in innovation activities. Based on the reasoning in section 3.3 their joint occurrence on the other hand, partially diminishes their individual positive relations due to the overlaps in their paths towards logistics innovation.

Table 3. Standardized Quantile regression models for analysis of logistics innovation

	(1)	(2)	(3)	(4)
	t = 0.2	t = 0.5	t = 0.7	t = 0.8
Diversity	0.93***	0.7**	0.61*	0.33
	(0.02)	(0.03)	(0.03)	(0.04)
Competition intensity	0.53**	0.91***	1.4***	0.91***
	(0.14)	(0.2)	(0.25)	(0.3)
Market scope	0.5***	0.54***	0.65***	0.61***
	(0.08)	(0.06)	(0.07)	(0.1)

Total R&D	0.4***	0.28***	0.24***	0.27**
expenditure	(0.08)	(0.09)	(0.07)	(0.1)
Industry size	-0.38*	-0.7***	-0.71***	-0.71***
	(0.02)	(0.02)	(0.01)	(0.01)
Competition* diversity	-0.67***	-0.48**	-0.47**	-0.3
	(0.2)	(0.02)	(0.21)	(0.3)
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

As already discussed in section 5.1, different percentiles of the response for which different estimating models are generated, are representatives of industries with low (t=0.2), medium (t=0.5), high (t=0.7) and very high (t=0.8) intensity of innovative outcomes in logistics services during the time span of 2014-2016. This basis provides opportunity for extensive interpretations and insights for theory and practice.

The positive relationship of search diversity with logistics innovation is characterized with volatility among industries with different intensities of logistics innovation. It indicates to establish a higher positive pattern with logistics innovation in industries which are less innovative in logistics in comparison to more innovative ones. Therefore, when enterprises initiate to pursue innovative campaigns in logistics services, searching for diverse external knowledge helps achieving their goals dependent of how innovative the industry they are active in is in terms of logistics. This can be seen in Table 3 where search diversity contributes logistics innovation better in industries which are less innovative (t=0.2) where the coefficient is 0.93 comparing to industries which are medium in logistics innovation (t=0.5) with the coefficient equal to 0.7. For high and very high innovative industries (t=0.7 and t=0.8) this coefficient is 0.61 and 0.33 respectively. It is also worth considering that searching diversely for external knowledge does not establish a statistically significant association with logistics innovation in industries with very high intensity of logistics innovation (t=0.8). While synergies to get engaged in logistics related innovation activities which are created by competition intensity illustrate dynamic trends among industries with different rates of logistics innovation as well, their facilitating role is indicated to be the highest in highly innovative industries (t=0.7). This can be seen in Table 3 which illustrates the coefficient related to competition intensity at t=0.7 to be 1.4. Less innovative industries are indicated to be pushed by competition intensity to introduce logistics innovation less than others

(see Table 3, at t=0.2 the coefficient is 0.53) which is in contrast with the role of search diversity in less innovative industries. Competition's synergically positive relations are similar in medium level innovative industries (See Table 3, at t=0.5 the coefficient is 0.91) and in very highly innovative ones (at t=0.8 the coefficient is 0.91).

The friction between the effects of search diversity and competition intensity demonstrates some volatility among different industries. This can be seen in Table 3 illustrating the coefficients for the interaction effect to be -0.67, -0.48, -0.47, -0.3. The interaction effect of competition intensity and search diversity indicates a similar pattern to the one established between search diversity and logistics innovation in different industries in terms of its magnitude. This effect is maximized in industries with low intensity of logistics innovations (t=0.2, -0.67) and decreases (in magnitude) when industries are highly innovative in terms of logistics (t=0.5, t=0.7). Finally (similar to the pattern of search diversity) it loses a statistically significant relation with logistics innovation and is thus neutralized in industries with very high intensity of logistics innovations.

5.3. Robustness Check

Linearity assumptions were checked and all except for skewness assumption for some variables were supported. Most importantly quantile-quantile plot for approval of the normality distribution of the residuals was directed (Bai and Ng, 2005) and normality assumption was approved. Although Quantile regression is a robust substitute for regular linear regression when linearity assumptions are not supported but since performance of that method in this study is based on weighted least squares, fulfillment of normality assumption for residuals improves the reliability of the results.

Correlations between two of the explanatory variables (competition intensity and industry size, see Table 2) demonstrated potentials for concern (in terms of existence of problematic multicollinearity). Therefore, Belsley diagnostics was performed which is based on calculation of conditional indices and variance decomposition proportions. The test results recognized no critically affecting multicollinearity in need of treatment thus the findings are not affected by correlations between regressors. Those verifications suggest evidence for robustness in findings.

6. Discussion and Conclusion

6.1. Theoretical and Practical Inferences

This article distinguishes between diversifying search and expanding search both of which has been previously reflecting in one metric namely search breadth. The full spectrum of search (including extent and diversity) has been always treated in terms of search breadth while the interaction of those two elements could not be reflected by definition in that one metric. Thus, this study utilizes a novel and dynamic element of external knowledge search which generates an analytical metric for diversity in search for external knowledge as a supplement to search breadth. External search diversity captures that dynamic by introducing a scale for covering heterogeneity aspect in search in a way that can be measured and traced.

Since innovation is an outcome to interaction of many interdependent factors, analysis of their relations in presence of one another and under influence of one another provides insightful results for theoretical extensions in literature and practical conducts. Therefore, this study analyzes knowledge-based explanators and synergy explanators of innovation in logistics services in interaction with one another. Logistics services as the intersection of functional areas of many supply chain actors merits potentials for innovative outcomes. It is the area of competition for creating higher customer values. The winners are the ones who possess criteria for accessing superior knowledge base which is in turn the result of the assimilation of internally developed knowledge with complementary knowledge gained from outside which gives optimal recombination for filling gaps in the internal stock. Acquisition of knowledge attributing such feature is the result of a well-founded external knowledge strategy. External knowledge diversity can provide a direction when firms intend to expand their search. It is further demonstrated that diversifying search facilitates innovation outcomes in logistics services and that provides a horizon for practitioners how to improve their innovation campaigns when they incorporate knowledge as an input to innovation processes. Competition intensity demonstrated synergy producing potentials for innovations in logistics in line with theories of competition and innovation which frame this relationship for innovation in general term (Arrow, 1962; Aghion and Tirole, 1994; Tirole and Aghion, 1997; Baker, 2006). It is demonstrated that such synergy path and knowledge-based path indicate some friction on their roads to logistics innovation. That improves enterprises' decision making processes and contributes them in optimizing their knowledge acquisition strategies towards logistics innovation in accordance with competition intensity in their markets. The further

implication of this paper lies in uncovering the fact that association of the synergy path and knowledge-based path of the focus with logistics innovation is dependent on how *'innovative'* their corresponding market is in terms of introduction of logistics innovation. Such intensity in different industries can interact with the magnitude of the relations that antecedents of logistics innovations establish with it. That introduces an insightful consideration for decision makers where and how to diversify their search for knowledge in accordance with competition intensity in their markets when pursuing innovation in logistics.

6.2. Limitations and Future Research

This study utilizes CIS16 from German economy for the sake of its analysis. It embodies information about innovative behaviors of enterprises and industries in the time frame of 2014-2016. The intention existed to make the analysis based on a more recent survey but up to this date no more recent dataset of that kind for Germany is available. It would also be an interesting avenue for research to perform the analysis in prior time frames and to make comparisons. The rate of logistics innovation which is addressed in this study is related to finalized logistics innovations. An interesting research opportunity could be to include all preceding innovative activities as well and make comparisons in results. And finally, since the metadata extracted from German industry is the basis of analysis in this paper, the results are applicable to Germany and other industrialized European countries with similar socio-economic structures. It is also likely to interpret the results for industrialized countries in other parts of the world but it could be an interesting complementing attempt to research about developing jurisdictions to authenticate the generality of the findings.

References

Aghion, P. and Tirole, J. (1994), "The management of innovation", *The Quarterly Journal of Economics*, Vol.109 No. 4, pp.1185-1209.

Arrow, K.J. (1962), "Economic welfare and the allocation of resources for invention", NBER Chapters, in: *The Rate and Direction of Inventive Activity: Economic and Social Factors*, National Bureau of Economic Research, Inc., pp.609-626.

Bagshaw, K.B. (2019), "Logistics management from firms' performance perspective", *European Journal of Logistics, Purchasing and Supply Chain Management*, Vol. 7 No. 1, pp.12-28.

Bai, J. and Ng, S. (2005), "Tests for skewness, kurtosis, and normality for time series data", *Journal of Business & Economic Statistics*, Vol. 23 No. 1, pp.49–60.

Baker , J. (2007), "Beyond Schumpeter vs. Arrow: How Antitrust Fosters Innovation", *Antitrust Law Journal*, Vol. 74 No. 2007, pp.575– 602.

Blundell, R., Griffith, R. and Van Reenen, J. (1999), "Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms", *The Review of Economic Studies*, Vol. 66 No. 3, pp.529-554.

Bogliacino, F. and Pianta, M. (2013), "Profits, R&D and innovation- A model and a test", *Industrial and Corporate Change*, Vol. 22 No. 3, pp.649-678.

Busse, C. (2010), "A procedure for secondary data analysis: Innovation by logistics service providers", Journal *of Supply Chain Management*, Vol. 46 No. 4, pp.44-58.

Cassiman, B. and Veugelers, R. (2002), "R&D cooperation and spillovers: some empirical evidence from Belgium", *American Economic Review*, Vol. 92 No. 4, pp.1169–1184.

Chesbrough, H. (2002), "Graceful exits and foregone opportunities: Xerox's management of its technology spinoff Organizations", *Business History Review*, Vol. 76 No. 4, pp.803–8.

Chesbrough, H. (2003), *Open Innovation*, Harvard University Press: Cambridge, MA.

Chesbrough, H. and Bogers, M. (2014), "Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation", In Henry Chesbrough, Wim Vanhaverbeke and Joel West, eds., *Open Innovation: New Frontiers and Applications*, Oxford: Oxford University Press. pp.3-28.

Chiang, Y.H. and Hung, K.P. (2010), "Exploring search and perceived innovation performance from the perspective of inter-organizational knowledge flows", *R&D Management*, Vol. 40 No. 3, pp.292-299.

Chow, H.K.H., Choy,K.L., Lee,W.B. and Chan, F.T.S. (2005), "Design of a knowledge-based logistics strategy system", *Expert Systems with Applications*, Vol. 29 No. 2005, pp.272-290.

Cohen, W.M. and Levinthal, D.A. (1990), "Absorptive capacity: A new perspective on learning and innovation", *Administrative Science Quarterly*, Vol. 35 No. 1, pp.128–152.

De Carvalho, C.J. and Malaquias, R.F. (2012), "Internal logistics, external communication, information processing and financial control: An analysis with Brazilian micro and small enterprises", *Journal of Operation and Supply Chain Management*, Vol. 5 No. 1, pp.31-44.

Dong, J.Q. and Netten, J. (2017), "Information Technology and external search in the open innovation age: new findings from Germany", *Journal of Technological Forecasting & Social Change*, Vol. 120 No. 2017, pp.223-231.

Dosi, G. (1998), "The contribution of economic theory to the understanding of a knowledge-based economy", IIASA, Laxenburg, Austria, Working Paper, pp.95-56.

Durst, S. and Evangelista, P. (2018), "Logistics knowledge management: State of the art and future perspectives", *Knowledge Management Research & Practice*, Vol. 16 No. 4, pp.427–434.

Felin, T. and Zenger, T.R. (2017), "The theory-based view: Economic actors as theorists", *Strategy Science*, Vol. 2 No. 4, pp.258-271.

Flint, D.J., Larsson, E., Gammelgaard, B. and Mentzer, J.T. (2005), "Logistics innovation: a customer value-oriented social process", *Journal of Business Logistics*, Vol. 26 No. 1, pp.113-47.

Fugate, B.S., Autry, C.W., Davis-Sramek, B. and Germain, R.N. (2012), "Does knowledge management facilitate logistics-based differentiation? the effect of global manufacturing reach", *International Journal of Production Economics*, Vol. 139 No. 2, pp.496-509.
Gellman, A.J. (1986), "Barriers to innovation in the railroad industry", *Transportation Journal*, Vol. 25 No. 4, pp.4-11.
Giroud.,X. and Mueller, H.M. (2010), "Does corporate governance matter in competitive industries?" *Journal of Financial Economics*, Vol. 95 No. 3, pp.312-331.
Grant, R.M. (1996), "Toward a knowledge-based theory of the firm", *Strategic Management Journal*, Vol. 17 No. 1996, pp.109– 122.
Grawe, S.J. (2009), "Logistics innovation: a literature-based conceptual framework", *The International Journal of Logistics Management*, Vol. 20 No. 3, pp.360 – 377.
Greene, W.H. (2008), *Econometric Analysis*, Sixth Edition. Pearson Prentice Hall: Upper Saddle River.
Hayek, F.A. von. (1948), "The Meaning of Competition", in: Hayek, F. A. von (ed.): *Individualism and Economic Order*, Chicago: University of Chicago Press, pp.92- 106.
Herfindahl, Orris C. (1950), *Concentration in the steel industry*, PhD diss., Columbia University, OCLC 5732189.
Hirschman, A.O. (1946), "National power and the structure of foreign trade", *American Political Science Review*, Vol. 40 No. 1, pp.146-147.
Kerber, W. (2006), "Competition, knowledge, and institutions", *Journal of Economic Issues*, XL (2), pp.1–7.
Kline, S. and Rosenberg, N. (1986), "An Overview of innovation", In R. Landau, & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington, DC: National Academy of Sciences, pp.275–306.
Laursen, K. and Salter, A. (2006), "Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms", *Strategic Management journal*, Vol. 43 No. 5, pp.867–878.
Lee, E.S. and Song, D.W. (2015), "Competition and co-operation in maritime logistics operations", In *Handbook of Ocean Container Transport Logistics*, Springer, pp.477–496.
LeSage, J. P. (1999), *Applied Econometrics Using MATLAB*, University of Toledo.
Love, J.H. and Mansury, M.A. (2007), "External linkages, R&D and innovation performance in US business services", *Industry and Innovation*, Vol. 14 No. 5, pp.477-496.
Lundvall, B. A. (2007), "National innovation systems – Analytical concept and development tool", *Industry and Innovation*, Vol. 14 No. 1, pp.95–119.
Mannheim Innovation Panel, https://www.zew.de/en/publications/zew-expertises-research-reports/research-reports/innovations/mannheim-innovation-panel-the-annual-german-innovation-survey.
Marra, M., Ho, W. and Lee, C.K.M. (2016), "Managing supply chain knowledge-based linkages for improving operational performance", *Knowledge Management Research and Practice*, Vol. 14 No. 3, pp.1-14.
Mohammadi, S. (2008), *QUANTILEREG: MATLAB function to estimate quantile regression*, University of Tehran.
Neumann, G. and Tome, E. (2009), "Empirical impact study on the role of knowledge management in logistics", *International Journal of Electronic Customer Relationship Management*, Vol. 3 No. 4, pp.344-359.
Novack, R.A., Rinehart, L.M. and Langley, C.J. Jr. (1996), "A comparative assessment of senior and logistics executives' perceptions of logistics value", *Journal of Business Logistics*, Vol. 17 No. 1, pp.135-78.
OECD. (2005), "The measurement of scientific and technological activities", In Oslo Manual. *Guidelines for collecting and interpreting innovation data (3rd ed.)*. Paris: OECD EUROSTAT.
Radicic, D. (2020), "Breadth of external knowledge search in service sector", *Business Process Management Journal*, Vol. 27 No. 1, pp.230- 252.
Richey, R.G., Adams, F.G. and Dalela,V. (2012), "Technology and flexibility: enablers of collaboration and time-based logistics quality", *Journal of Business Logistics*, Vol. 33 No. 1, pp.34-49.
Rogers, E.M. (2003), *Diffusion of innovations* (5th ed.), New York: Free Press.
Rosenkopf, L. and Nerkar, A. (2001), "Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry", *Strategic Management Journal*, Vol. 22 No. 4, pp.287–306.

Sandberg, E., Abrahamsson, M. and Kihlen, T. (2011), "Characteristics of a logistics-based business model", *Journal of Marketing Channels*, Vol. 18 No. 2, pp.123-145.
Shen, H., Wang, L., Xu, Q., Li, Y. and Liu, X. (2009), "Toward a framework of innovation management in logistics firms: A systems perspective", *Systems Research and Behavioral Science*, Vol. 26 No. 2, pp.297-309.
Simpson, E. (1947), "Measurement of diversity", *Nature*. 163,688 (1949).
Stank, T.P., Daugherty, P.J. and Ellinger, A.E. (1998), "Pulling customers closer through logistics service", *Business Horizons*, Vol. 41 No. 5, pp.74-80.
Stapleton, A. and Hanna, J.B. (2002), "Technological innovation adoption: an empirical investigation of steamship line sales force integration", *Transportation Journal*, Vol. 41 No. 4, pp.5-22.
Tether, B.S. and Tajar, A. (2008), "The organizational-cooperation mode of innovation and its prominence amongst European service firms", *Research Policy*, Vol. 37 No. 4, pp.720- 739.
Tirole, J. and Aghion, P. (1997), "Formal and real authority", *Journal of Political Economy*, Vol. 105 No. 1, pp.1-29.
Turner, K. L. and Makhija, M.V. (2006), "The role of organizational controls in managing knowledge", *Academy of Management Review*, Vol. 31 No. 1, pp.198-217.
Utterback, J.M. and Suarez, F.F. (1993), "Innovation, competition and industry structure", *Research Policy*, Vol. 22 No. 1, pp.1-21.
von Hippel,E. and von Krogh, G. (2016), "Crossroads—Identifying viable "need–solution pairs": Problem solving without problem formulation", *Organization Science*. Vol. 27 No. 1, pp.207–221.
Wagner, S.M. (2008), "Innovation management in the German transportation industry", *Journal of Business Logistics*, Vol. 29 No. 2, pp.215-32.
Xu, X. and Ma, H. (2010), "Application in logistics enterprises for knowledge management", in 'E-Business and E-Government (ICEE), International Conference on, pp.3343–3346.
Zhou, K.Z. and Li, C.B. (2012), "How knowledge affects radical innovation: knowledge base, market knowledge acquisition, and internal knowledge sharing", *Strategic Management Journal*, Vol. 33 No. 9, pp.1090-1102.
Zinn, J.S. (1994), "Market competition and quality of nursing home care", *Journal of Health Politics, Policy and Law*, Vol. 19 No. 3, pp.555- 582.
Zinn, W. (1996), "The new logistics in Latin America: an overview of current status and opportunities", *The International Journal of Logistics Management*, Vol. 7 No. 1, pp.61-71.