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Financial performance and global start-ups: the impact of knowledge management practices

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ABSTRACT

This paper investigates how knowledge management (KM) practices improve the financial performance of global start-ups (GSs). Using a database of 114 global innovative Italian start-ups, this study is based on the principal component analysis – data envelopment analysis (PCA-DEA) method. In particular, a survey was conducted to investigate KM practices and secondary data was used to evaluate financial performance. This research highlights that the adoption of different knowledge management practices (i.e., acquisition, documentation, creation, transfer and application) has a positive impact on the financial performance of global start-ups. The study contributes to the literature on international entrepreneurship, shedding light on the consequences of KM practices for global start-ups' financial performance, and provides guidelines for business owners, enabling them to understand better how knowledge management can facilitate the achievement of high levels of financial efficiency.

1. Introduction

Knowledge, innovation and capabilities are central topics of study on the strategy and performance of firms (Knight and Cavusgil, 2004). Specifically, knowledge represents the most significant resource for innovative organizations (Papa et al., 2018) and is a key differentiating factor in the actual scenario (Del Giudice and Maggioni, 2014). Depending on an organization's purposes, knowledge can be used to improve different forms of value (Vrontis et al., 2021); consequently, its management is a practice established in organizational processes to ensure its effectiveness and to generate further value in a dynamic environment (Oliva et al., 2019). In particular, through knowledge formalization, organizational processes are constantly developed. Knowledge management (KM) is an organizational discipline that collects, develops, accumulates, uses and/or disposes of knowledge. It is fundamental for the organization as it generates value (Oliva, 2014), increases value (Nonaka, 1994) and contributes to the realization of the organizational purposes (Oliva et al., 2019; Santoro et al., 2019; Vrontis et al., 2019).

The utilization of knowledge management practices/processes (e.g., Del Giudice and Della Peruta, 2016; Fong and Choi, 2009; Seleim and Khalil, 2011; Shams et al., 2019; Turner et al., 2012; Xue, 2017) represents a significant driver of innovation (Inkinen, 2016) and can be considered as a company's performance measure. Knowledge management, therefore, impacts an organization's performance significantly and, by default, its financial performance, too (Zack et al., 2009). In this context, knowledge can be

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conceived as a resource that can be used to generate gains from the uncertainty facing companies (e.g., Battisti and Graziano, 2019; Buckley and Carter, 2002), for example for start-ups that by definition emerge and develop in uncertain and dynamic contexts. Start-ups play a central role in disrupting consolidated patterns in the market and generating innovations that create value for most of the society and destroy value for a lesser part (e.g., Oliva and Kotabe, 2019; Paoloni and Modaffari, 2021). In particular, in a highly uncertain global environment (Damilano et al., 2018), in which change is constant, the effectiveness of dispersed knowledge management represents a decisive factor for start-ups (Spender et al., 2017). In this context, in which the intricacy of the business environment has increased considerably over time (e.g., Miglietta et al., 2017; Miglietta et al., 2018), global start-ups (GSs) represent a type of international new venture (INV) that aims to derive a competitive advantage by managing several organizational activities across different countries (Oviatt et al., 1995) and that earns a proportion of its income from the sale of products in international markets (Knight and Cavusgil, 2004).

Specifically, GSs are new businesses that start taking advantage of opportunities anywhere in the world just as soon as their creator had their business idea (Englis et al., 2007). Therefore, global start-ups require different knowledge practices (e.g., Dalmarco et al., 2017; Seleim and Khalil, 2011; Xue, 2017), which can affect their performance. Furthermore, to be competitive in the actual knowledge economy, global start-ups should use the available knowledge effectively to implement their development strategies (Dalmarco et al., 2017). Consequently, it is necessary to know how the different knowledge management practices can improve the different types of performance (e.g., economic, financial and organizational) of start-ups in the context of international business. In this regard, in general terms, if knowledge management literature highlights how knowledge can enhance a company's competitiveness and thereby its performance, little is known about the effect on financial performance. Specifically, although the knowledge management literature investigates the different practices of knowledge management in start-ups (e.g., Oe and Mitsuhashi, 2013; Oliva and Kotabe, 2019) and the effects of knowledge management on start-ups' general performance (e.g., West and Noel, 2009; Wu, 2007), to the best of the authors' knowledge, no prior studies examine the ways in which the different types of practices (i.e., acquisition, documentation, creation, transfer and application) can improve the specific financial performance of start-ups in an international context (i.e., global start-ups). This because, the analysis of financial performance plays a key role in order to evaluate the capability of the start-ups to survive and growth (e.g., Cooper et al., 1994; Holtz-Eaking et al., 1994; Kerr et al., 2014).

Based on these considerations, the main purpose of this study is to fill that gap. Specifically, based on the assumption that knowledge management represents a key element in enhancing start-ups' general performance (e.g., Oe and Mitsuhashi, 2013; West and Noel, 2009), this paper aims to answer the following research question: *how do knowledge management practices improve the financial performance of global start-ups?*

To answer the research question, this paper reports an investigation of 114 global innovative Italian start-ups using the principal component analysis – data envelopment analysis (PCA-DEA) method (Adler and Golany, 2001, 2002; Ueda and Hoshiai, 1997). In particular, a survey was conducted to examine knowledge management practices and secondary data were used to estimate financial performance.

The results of our analysis indicate that the different knowledge management practices used by global start-ups influence their financial performance positively. Specifically, the contribution of this paper is manifold both from a theoretical and from a practical point of view. First, this study contributes to the literature on international entrepreneurship (IE), advancing the understanding of the impacts of knowledge management on global start-ups and extending the debate on the effects of knowledge management practices on the financial performance of start-ups in an international business context. Second, this paper investigates some specific aspects of knowledge management in relation to global start-ups' performance through a combined PCA-DEA approach in an unexplored market, namely the Italian one. Third, this research examines some critical factors in the development of global start-ups that can be useful for business owners to evaluate the financial effects of knowledge acquisition, creation, documentation, transfer and application.

The structure of this study is as follows. The first part presents the theoretical background of "global start-ups and knowledge management" and "knowledge management and financial performance". The second part explains the methodology (data, sample and research design) adopted in this study, followed by the results and the discussion. The last part contains the conclusions, theoretical and practical implications, limitations and future lines of research.

2. Theoretical background

2.1. Global start-ups and knowledge management

Studies on "born globals" (BGs), "global start-ups" (GSs) and "international new ventures" (INVs) have been ongoing since the mid-1990s (Oviatt and McDougall, 1994; Rennie, 1993). However, some authors suggest that the theory of born globals and international new ventures is incomplete and that significant lacunae remain in terms of knowledge about these companies (e.g., Zalan, 2018). In this regard, international new ventures are gaining popularity because it is less restrictive ("international") than global start-ups (implying "globalness") (Sikora and Baranowska-Prokop, 2018). However, Crick (2009) highlights that the terms BGs and INVs are both used to define businesses which are quickly becoming international "typically but not exclusively within three years of their business start-up". Furthermore, Cavusgil and Knight (2015) note that "international new ventures" is a similar concept also to born globals but are distinctive in some ways. For example, while the term "BGs" is more evocative, INVs is more correct because not many internationally focused start-ups actually develop "global" footprints (Cavusgil and Knight, 2015). In particular, although many efforts are made to define born globals, several definitions are applied (e.g., Bader and Mazzarol, 2009; Braunerhjelm and Halldin, 2019; Gabrielsson and Kirpalani, 2004; Øyna and Alon, 2018; Rennie, 1993) and, consequently, a harmonized definition is lacking (Ferguson et al., 2019). Knight and Cavusgil (2004) define BGs as *"entrepreneurial start-ups that, from or near their founding, seek to derive a*

substantial proportion of their revenue from the sale of products in international markets" (Knight and Cavusgil, 2004, p. 124). Likewise, a born global is a young company that is active in early export sales (Cavusgil and Knight, 2015). Most born globals are small and medium-sized enterprises due to their young age and limited resources. (Knight et al., 2004).

Adopting a different point of view, Oviatt and McDougall (1994) define born globals as an extreme version of INVs: "*business organizations that, from inception, seek to derive significant competitive advantage from the use of resources and the sale of outputs in multiple countries*" (p. 49). Specifically, an international new venture is an entrepreneurial start-up firm that has an international strategy (Scheela, 2016). From this point of view, born globals are start-ups by definition and thus are not recognized as a spin out of an existing company (Ferguson et al., 2019), and the defining characteristic of a born global is its accelerated internationalization (Weerawardena et al., 2007). This peculiarity is a significant difference from INVs, which begin life as spinouts. In this context, Oviatt et al. (1995) point out that global start-ups fall into four categories of INVs (i.e., Export Start-up, Multinational Trader, Geographically Focused Start-up and Global Start-up). From the beginning, their main aim is to build a competitive advantage by coordinating multiple organizational activities - not just exports. Unlike other types of INVs, global start-ups are more heavily involved internationally in both scale and scope (Baum et al., 2011). Based on this, GSs can be considered the most difficult INVs to develop because they need both skills for geographic and activity coordination (Oviatt and McDougall, 1994) and knowledge (Cavusgil and Knight, 2015). Regarding this last point, knowledge is considered to be the fundamental to survive (Wu et al., 2021) and it has always been an important asset for people and therefore for organizations (e.g., Papa et al., 2021; Oliva and Kotabe, 2019), both for large companies (Davies and Warren, 2011) and small-medium sized enterprises – SMEs (e.g., Beijerse, 2000; Fischer et al., 2021; Magni et al., 2021; Scuotto et al., 2017a, 2017b, 2020; Yew Wong, 2005), and for start-ups (Oe and Mitsuhashi, 2013), also in an international context-markets (Fletcher and Harris, 2012). Specifically, knowledge plays a key role in assistant companies' internationalization process (Del Giudice and Della Peruta, 2016) and it plays a key role in currently globalized world because it considerably contributes to create and maintain competitive advantages (Magni et al., 2021). Considering this last aspect, studies on global start-ups highlight that they represent a type of venture that follows opportunities from the moment they are discovered; the opportunities pursued by these ventures are global in nature and knowledge intensive (Englis et al., 2007). From this point of view, in the knowledge-intensive firms the fast international growth could be considered a necessity and not a strategic choice (Brennan and Garvey, 2009; Nummela et al., 2010).

At the beginning, knowledge-intensive start-ups generally operate and acquire core technology, financial resources and personnel locally. With time, their businesses will gradually expand globally (Taji, 2013). However, the founders of start-ups frequently begin their internationalization process before they have formally founded their venture even so the international activities develop concretely after their foundation both in scope and in geographic diversity (Englis et al., 2007). In this context, KM plays a key role in determining companies' innovation capability (e.g., Jiménez-Jiménez et al., 2014; Wang and Yang, 2016) whit impacts on overall organizational performance which, in turn, is straight connected to financial performance (e.g., Zack et al., 2009).

Specifically, knowledge management is relevant to start-ups, as well as to SMEs, because they tend to be relatively more dynamic and agile than larger companies and more ready to learn. Specifically, start-ups can be considered as agile organizations with dynamic capabilities (e.g., Teece, 2007; Teece et al., 2016) that take risks of a dissimilar nature because of their greater risk appetite and risk tolerance (Teberga et al., 2018). In this sense, on one side, KM represents one of the management practices that support start-ups and, on the other side, start-ups represent agile organizations that generate knowledge and are strongly dependent on it to play their transformative role (Oliva and Kotabe, 2019). In this regard, start-ups utilize the concept of open innovation (OI) to realize their expansion goals (Bereznoy et al., 2021); thus, the effectiveness of dispersed knowledge management is a crucial factor (Spender et al., 2017). For these reasons, the analysis of the impact of some specific critical factors on the development of start-ups may be important to guide companies' choices.

2.2. Knowledge management and financial performance

Start-ups require commitment, market knowledge and internal organization, all elements that can be improved through the use of knowledge management practices. Especially in a global context, full of challenges due to the typical environmental uncertainty in the international context markets (Nielsen, 2010), to the culture shock, to the different legal regimes and customer behaviours (Lin and Cheng, 2013), to the differences in distribution systems and sector profitability the firms, to secure their competitiveness, are necessary to improve knowledge-management capabilities.

The international context provides firms with superior access to new sources of knowledge and market information (Love and Ganotakis, 2013) and contributes, through learning-by-exporting, to increasing the innovation capacity and growth of firms (Wang and Tao, 2019). Increases in sales give firms economies of scale: the costs incurred can be spread over more production units, making them more profitable (Esteve-Pérez and Rodríguez, 2013; Golovko and Valentini, 2011; Azari et al., 2020). Therefore, knowledge management must feature efficient, effective and extensive implementation of different KM practices, which can be defined as "*observable organizational activities that are related to knowledge management*" (Zack et al., 2009, p. 394), to achieve the desired performance outcomes (Alavi and Leidner, 2001; Balasubramanian et al., 2019). Specifically, in the literature, there are many factors that may positively or negatively influence the adoption of knowledge management in general start-ups (Centobelli et al., 2017), and there are different knowledge management tools and knowledge management practices that support knowledge management's adoption (Xue, 2017). In this sense, Seleim and Khalil (2011) recognize five items used for measuring KM practices that do not have a particular order and in fact can be repeated and even overlap, specifically knowledge acquisition (KA), creation (KC), documentation (KD), transfer (KT) and application (KAPP). In detail, these practices can be defined as follows: KA refers to the selection and acquisition of knowledge from external sources; KC refers to activities that increase and generate insights, skills and relationships in the organization

and create internal knowledge; KD refers to actions that institutionalize knowledge in the form of an organizational memory to transfer and reuse it in the future; KT refers to activities that allow the exchange of knowledge between people, groups and organizational units at dissimilar levels; and KAPP involves the use of the existing knowledge to develop processes, products and services and enhance the organizational performance. An analysis of which knowledge management practices are used by start-ups and global start-ups may show how these companies deal with critical issues on their way to national and international markets. In other words, organizing knowledge management practices may influence the development of start-ups, for which not only the learning process but also its management are crucial to overcome critical factors (Dalmarco et al., 2017), with an impact on the performance.

Although, on the one hand, the literature explores the relationships between knowledge management and performance (e.g., Darroch, 2005; Zack et al., 2009), less is known about the general impacts on start-ups (e.g., Oe and Mitsuhashi, 2013; West and Noel, 2009; Wu, 2007) and even less about the effect of knowledge management on specific global start-ups' financial performance. In this regard, Oe and Mitsuhashi (2013) reveal that entrepreneurs' sharing of knowledge and experience in the same industry has a positive impact on the break-even point, considered as an indicator of start-ups' growth and performance. West and Noel (2009) observe how types of knowledge impact new venture performance during the start-up process. They examine three sources of new venture CEOs' knowledge namely industry and business, start-up and networking experiences; They do not find a link between a CEO's start-up performance and their industry knowledge. Furthermore, different financial and economic performance measures can be used at the start-up level. Some are based on balance sheet data (e.g., Jo and Lee, 1996; Reid and Smith, 2000; Wu, 2007) and others on subjective assessment, for example the responses obtained when implementing a survey (West and Noel, 2009). Specifically, following the approach linked to the balance sheet, Wu (2007) adopts the ROI (return on investment) as an indicator of financial performance. Davila et al. (2015) and Gilbert et al. (2006) suggest that sales (revenues) represent one of the most important measures of new venture/start-up growth and performance. Jo and Lee (1996) consider the ROA (return on assets) and ROS (return on sales) as indicators of performance. Finally, Reid and Smith (2000) adopt employment growth, ROCE (return on capital employed) and labour productivity as measures of performance. Based on the different indicators of economic-financial performance used in the various studies, it is useful to understand the impact of the different knowledge management practices on return on asset and revenues, i.e. two of the most used indicators in the international literature (e.g., Lin et al., 2011; Lu and Beamish, 2004; Sewak and Sharma, 2020).

3. Methodology

3.1. Data and sample

To answer the research question, we utilized a database of innovative Italian start-ups (Italian Ministry of Economic Development, 2019). Innovative start-ups are defined as non-listed limited companies that meet the following requirements (art. 25 of Decree-Law no. 179/2012):

a) they have been recently created or are less than five years old; b) are headquartered in Italy or another EU/EEA Member State, but with manufacturing or a branch in Italy;

c) their annual turnover is under €5 million; d) they do not distribute their earnings and have never done so; e) fundamental to their mission are developing, producing and marketing innovative, technological products or services;

f) they are not the result of a merger or split-up or business transfer or a new branch; and g) they respect at least one of the following: 1) their R&D outlay corresponds to at least 15% of turnover and annual costs; 2) at least one-third of the total staff consists of doctoral employees, doctoral students, or researchers, or at least two-thirds of the team has a master's degree; and 3) the firm is the owner or licensee of a registered patent or owns original registered software. From the database of innovative Italian start-ups from the Italian business register, we selected all the start-ups available at the end of 2019, that is, 10,882 start-ups. As described in the next paragraph, starting with the questionnaires received online and after selecting the financial information on the global start-ups from the Bureau van Dijk AIDA database, our final sample was composed of 114 Italian global start-ups that, following McDougall's (1989) approach, we considered in this study as international new ventures that generate at least 10% of their total sales from foreign markets.

3.2. Research design

This research evaluates the performance of global start-ups using the integrated techniques of PCA and DEA. In particular, the study analyses the way in which KM practices effect the financial performance of global start-ups, following an explanatory approach.

We chose a non-parametric method to analyze the relationship between KM and financial performance because we could not predetermine the true functional form. From the analysis of several studies in the literature, it emerged that the PCA-DEA method can be applied to undertake performance evaluation. In these studies, a combined PCA-DEA approach is used to evaluate and rank manufacturing systems (Azadeh et al., 2007), to measure the performance of internet banking (Ho and Wu, 2009) or the productivity of distribution centres (Andrejić et al., 2013) or the energy sector (Fu and Ou, 2013), to measure, estimate and predict the quality of life (Poldaru and Roots, 2014), to evaluate organizational units' intellectual capital (Rahimpour et al., 2020; Tavakoli and Shirouyehzad, 2013) and to evaluate the effect of knowledge management on increasing safety management (Movahedi et al., 2015). These reviews show that a specific research on the effect of KM practices on financial performance using PCA-DEA is lacking.

In this method, the first step is to identify the DEA model's inputs and outputs. Next is the collection of data on KM practices through a structured questionnaire that forms the basis for the input variables and the extraction of financial variables for the outputs. Then, due to the necessity of reducing the number of variables and eliminating the correlation between input components, PCA is used to transform inputs into independent variables to improve the DEA's discriminatory power. After this step, an output-oriented DEA

model is applied to obtain the efficiency of each unit. Finally, a ranking and sensitivity analysis is performed to provide further information on how input and output variables affect efficiency. The following figure summarizes the different steps of our research. The following figure shows the research design (Fig. 1).

3.2.1. Selection of input and output variables

To assess knowledge management, the five practices previously introduced, namely KA, KC, KD, KT and KAPP, were taken into consideration as DEA inputs and sales revenues and ROA as outputs. The following figure shows the DEA model (Fig. 2).

3.2.2. Structured questionnaire

Data for this study were collected using a structured questionnaire to gain a comprehensive insight into people's experiences, opinions and practices (e.g., Bethlehem, 2009; Marsden and Wright, 2010; May, 2001). The questionnaire was created in February 2020 following different studies in the field of knowledge management practices. As previously introduced, our sample contains innovative Italian start-ups, which were contacted by e-mail. After the initial preparation, in line with the study by Panzeri et al. (2013), ten Italian business owners took part in the pre-testing by answering the questionnaire during one-hour long meetings. The pre-test was used to assess the measures, make sure the instructions and questions were clear and make minor changes. (Tanriverdi, 2005).

The survey was initially conducted for approximately 1 month in March 2020. Due to the Covid-19 situation, we decided to extend the questionnaire for another 15 days in April 2020.

After a short presentation of the research project, in the initial part of the questionnaire informing the business owners about the main objective of the survey, research method, procedure and anonymity in terms of data analysis (Sarra et al., 2015), the questionnaire was structured into six sections with closed questions and seven-point Likert scale items (ranking from one = very low practice to seven = very high practice).

The first section requested some general information about the start-ups (denomination, region and sector) and two main pieces of information for which the start-ups had to indicate whether they are considered to be global (based on a definition of global start-ups) and state the percentage of their total sales that come from foreign markets. The other five sections concerned the five KM processes. To measure the five KM practices, a modified version of the survey by Filius et al. (2000) and Seleim and Khalil (2011) was adopted, and for each process, a six-item scale was used. The second section investigated knowledge acquisition to understand how knowledge is acquired from external sources. The third part focused on knowledge creation to determine how knowledge is generated using internal insights and skills. The fourth section of the survey analysed knowledge documentation to discover how knowledge is stored. The fifth section investigated knowledge transfer to ascertain how knowledge is shifted between the different levels of the organizational units. Finally, the last part of the questionnaire examined knowledge applications to illustrate how knowledge is used to develop products, services and processes and requested some general information about the respondents (see the survey of Filius et al. (2000) and Seleim and Khalil (2011) for the general description of the items of these constructs).

At the end of the survey period, a total of 548 questionnaires had been received. Of these, only 126 responding companies defined themselves as global start-ups and indicated that they derived at least 10% of their total sales from foreign markets. We excluded 2 global start-ups because their answers were incomplete. After the first phase of our research, the 124 valid questionnaires obtained formed the basis for the input variables. The questionnaire had a Cronbach's alpha of 0.8456, which is acceptable according to Nunally and Bernstein's (1994) guidelines.

We checked the "Composite Reliability" (CR) and the "Average Variance Extracted" (AVE) to assess the internal consistency and convergent validity of the variables. All variables reach the recommended cut-off value (0.70 the cut-off value for CR and 0.50 for AVE) (Hair et al., 2017). Table 1 shows the Cronbach's alpha, internal consistency and convergent validity of all the variables.

3.2.3. Secondary data

As previously introduced, following the main studies in the literature (Lin et al., 2011; Lu and Beamish, 2004; Sewak and Sharma, 2020), we used start-ups' sales revenues and return on assets (ROA) for the year 2018 as indicators of financial performance. We operationalized the ROA as the profit before taxes as a proportion of the total assets. All the financial variables, which represent the outputs of the DEA model, were extracted from the Bureau van Dijk AIDA database. Missing data and a lack of the going-concern requirement led to the exclusion of 10 companies from the analysis sample.

Our final sample comprised data on 114 Italian global start-ups once incomplete observations had been removed. As the input and output data had to be non-negative in order to be compatible with the DEA method, the ROA negative values were converted into positive data like this: (Pastor, 1996).

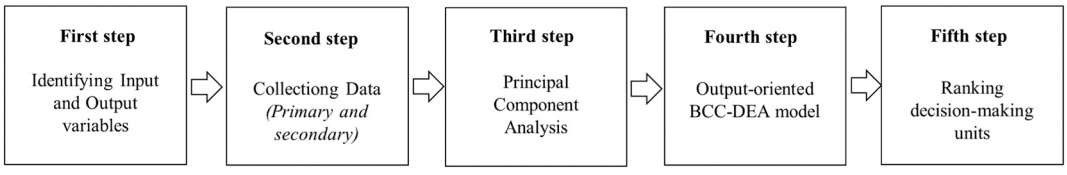

Fig. 1. Research design.

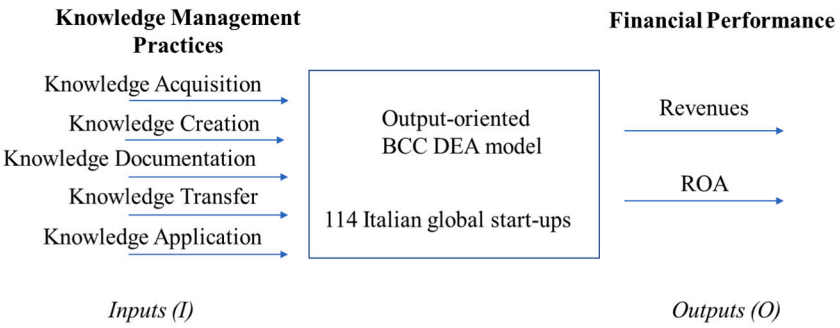

Fig. 2. DEA model.

Table 1
Measurement validity of inputs variables.

Variables/constructs	Cronbach's alpha	CR	AVE
Knowledge acquisition	0.8529	0.891	0.577
Knowledge creation	0.7293	0.782	0.508
Knowledge documentation	0.7418	0.768	0.505
Knowledge transfer	0.8224	0.864	0.521
Knowledge application	0.8112	0.869	0.526

Table 2
Descriptive statistics of primary values of input and output variables.

Variables	Obs	I/O	Mean	Std. Dev.	Min	Max
Knowledge acquisition						
ka1	114	I	4.95614	1.352745	2	7
ka2	114	I	5.570175	1.349987	2	7
ka3	114	I	5.236842	1.541764	1	7
ka4	114	I	4.807018	1.595775	1	7
ka5	114	I	4.350877	1.867194	1	7
ka6	114	I	4.640351	1.928488	1	7
Knowledge creation						
kc1	114	I	5.719298	1.565721	1	7
kc2	114	I	5.377193	1.155137	2	7
kc3	114	I	4.631579	1.27788	1	7
kc4	114	I	5.359649	1.476226	1	7
kc5	114	I	5.27193	1.409733	2	7
kc6	114	I	4.45614	1.505978	1	7
Knowledge documentation						
kd1	114	I	5.210526	1.484276	1	7
kd2	114	I	5.210526	1.874249	1	7
kd3	114	I	5.72807	1.786305	1	7
kd4	114	I	5.587719	1.295406	1	7
kd5	114	I	4.701754	1.407501	1	7
kd6	114	I	5.482456	1.256716	2	7
Knowledge transfer						
kt1	114	I	5.385965	1.279579	2	7
kt2	114	I	4.754386	1.398871	1	7
kt3	114	I	4.596491	1.686591	1	7
kt4	114	I	4.622807	1.811421	1	7
kt5	114	I	5.157895	1.520241	1	7
kt6	114	I	5.394737	1.632732	1	7
Knowledge application						
kapp1	114	I	4.140351	1.847635	1	7
kapp2	114	I	4.394737	1.782999	1	7
kapp3	114	I	5.087719	1.47283	1	7
kapp4	114	I	5.280702	1.680227	1	7
kapp5	114	I	5.605263	1.430505	1	7
kapp6	114	I	5.508772	0.9144428	4	7
Sales revenues	114	O	204.437163	361.99426	0.0002	1705.181
ROA	114		−6.774298	36.791345	−190.66	64.65
ROA(positivevalues)	114	O	185.4306	36.7503	1	256.31

Table 3
Correlation matrix of values of input variables.

	ka1	ka2	ka3	ka4	ka5	ka6	kc1	kc2	kc3	kc4	kc5	kc6	kd1	kd2	kd3	kd4	kd5	kd6	kt1	kt2	kt3	kt4	kt5	kt6	kapp1	kapp2	kapp3	kapp4	kapp5	kapp6
ka1	1.0000																													
ka2	0.5129	1.0000																												
ka3	0.4887	0.6233	1.0000																											
ka4	0.6151	0.4623	0.3317	1.0000																										
ka5	0.4336	0.3412	0.3060	0.6140	1.0000																									
ka6	0.5401	0.4500	0.5349	0.6128	0.6326	1.0000																								
kc1	0.1153	0.1518	0.0974	0.0631	0.1187	0.1245	1.0000																							
kc2	0.0900	0.0879	0.1382	0.0158	0.0530	0.1488	0.6071	1.0000																						
kc3	0.0725	-0.0977	0.0896	0.0603	-0.0121	0.1576	-0.0477	0.0050	1.0000																					
kc4	0.1143	-0.0061	0.0789	0.0861	0.0983	0.0614	-0.0019	-0.0076	0.4274	1.0000																				
kc5	0.0991	0.0341	0.1208	0.0983	0.0710	0.2283	0.0028	0.0506	0.5719	0.7265	1.0000																			
kc6	0.0186	-0.0594	-0.0126	-0.0183	0.0433	0.1271	-0.0728	-0.0489	0.5158	0.3873	0.5705	1.0000																		
kd1	0.5071	0.4386	0.2642	0.6450	0.5223	0.5152	0.1247	0.0772	-0.1127	-0.0389	-0.0445	-0.1542	1.0000																	
kd2	0.4121	0.3054	0.1388	0.4990	0.4364	0.4741	0.0475	-0.0656	0.0068	-0.0756	-0.0219	-0.0625	0.7251	1.0000																
kd3	0.3393	0.2484	0.1682	0.3322	0.2942	0.3105	0.0800	-0.0356	0.0100	-0.0196	-0.0442	-0.1377	0.6159	0.7732	1.0000															
kd4	0.4946	0.3583	0.2000	0.5049	0.3786	0.3900	0.0428	-0.0607	-0.0338	-0.0190	-0.0786	-0.1160	0.6025	0.6120	0.6319	1.0000														
kd5	0.0674	0.2393	0.1429	0.0766	0.1749	0.1231	0.2428	0.4726	-0.0124	0.0010	-0.0167	-0.0563	0.0303	-0.0531	0.0062	0.1698	1.0000													
kd6	0.0698	0.0972	0.0364	0.0733	0.0366	0.0722	0.2268	0.2759	0.0180	0.1060	0.1701	0.1305	-0.0075	-0.0134	-0.0199	0.0961	0.4473	1.0000												
kt1	-0.0208	0.0764	-0.0153	-0.1019	-0.1164	-0.0616	0.2975	0.3437	0.0390	0.0617	0.1572	0.0043	-0.1177	-0.0674	0.0115	-0.1007	0.4527	0.5491	1.0000											
kt2	0.2234	0.2623	0.2324	0.0499	0.1790	0.1999	0.3521	0.5014	0.0182	0.1589	0.1598	0.0242	0.0251	-0.1320	-0.0801	-0.0271	0.5018	0.4204	0.3649	1.0000										
kt3	0.2482	0.2846	0.0745	0.1286	0.1297	0.0801	0.4494	0.5648	-0.1271	0.0588	-0.0353	-0.1150	0.1509	0.0131	0.0778	0.1298	0.5080	0.2764	0.3475	0.5390	1.0000									
kt4	0.0979	0.1864	0.0956	0.0634	0.1886	0.1534	0.4772	0.3773	-0.1753	-0.0150	-0.0323	-0.1051	0.1351	0.0731	0.0255	0.0538	0.3616	0.4227	0.3764	0.5463	0.5493	1.0000								
kt5	0.0206	0.0894	-0.0388	0.0455	-0.0446	0.0135	0.3943	0.4496	0.0120	0.0928	0.0582	-0.0974	-0.0149	-0.0677	0.0127	-0.0071	0.3200	0.3025	0.2914	0.4886	0.3978	0.2789	1.0000							
kt6	0.0880	0.2142	0.0750	0.1042	0.0674	0.1888	0.6841	0.7180	-0.0866	-0.0080	-0.0086	-0.0811	0.1918	0.1143	0.1221	0.1111	0.4368	0.2385	0.3542	0.4574	0.5693	0.4817	0.4916	1.0000						
kapp1	0.0521	-0.0288	0.0193	0.0633	0.1600	0.2055	-0.0230	0.0040	0.5019	0.3934	0.5390	0.7051	-0.0980	0.0016	0.0412	-0.0754	0.0469	0.1230	0.0929	0.0511	-0.0470	-0.0528	-0.0521	0.0049	1.0000					
kapp2	0.0256	0.0196	0.0880	-0.0041	0.1149	0.1884	-0.1121	-0.0386	0.3984	0.3625	0.4428	0.5684	-0.1554	-0.1151	-0.0855	-0.1282	-0.0197	0.0920	0.0374	0.0357	-0.1320	-0.0960	0.0225	-0.0844	0.6063	1.0000				
kapp3	0.0686	0.0058	-0.0248	0.0487	0.1206	0.0611	-0.0506	-0.0872	0.3135	0.1400	0.2612	0.4326	-0.0409	0.1119	-0.0615	-0.1154	-0.0940	0.1251	0.0476	0.0406	-0.0854	-0.0107	-0.1090	-0.0624	0.4182	0.3203	1.0000			
kapp4	0.1456	0.0420	0.0219	0.1458	0.2391	0.1543	0.0067	0.0453	0.2712	0.2301	0.3149	0.4281	0.1145	0.1272	0.0227	-0.0033	-0.0391	0.1616	0.0521	0.1200	0.0122	0.0642	-0.0591	-0.0246	0.4433	0.3762	0.7123	1.0000		
kapp5	0.1785	0.0168	0.0829	0.1563	0.1086	0.1694	-0.0934	-0.0430	0.3264	0.1726	0.2336	0.4088	0.1604	0.1138	0.0200	0.1359	-0.1645	0.0576	-0.0031	-0.0135	-0.0886	-0.0921	-0.1827	-0.1866	0.2890	0.2421	0.3988	0.5804	1.0000	
kapp6	0.1613	0.0138	0.0519	0.0618	0.0915	0.0545	-0.0910	-0.0325	0.2678	0.2173	0.2624	0.4469	0.0051	-0.0734	-0.0662	-0.0828	-0.1423	0.1464	0.0273	0.0709	-0.0436	-0.1235	-0.0456	-0.1416	0.2978	0.3968	0.4199	0.5974	0.4593	1.0000

$$\begin{aligned} Z_j &= ROA_j + Q \\ Q &= min\{ROA_j\} + 1 \end{aligned} \tag{1}$$

The following table summarizes the descriptive statistics of the primary values of the input and output variables (I/O) (Table 2).

3.2.4. Principal component analysis and data envelopment analysis

To evaluate the performance of Italian global start-ups, in terms of relative efficiency, we applied the DEA linear programming technique (Cooper et al., 2011). The measurement of efficiency helps managers to improve the existing business model and provide a better working process. Optimizing the efficiency of knowledge management assets can substantially improve the performance and thereby create a competitive advantage for the start-ups. DEA, as proposed by Charnes et al. (1978), utilizes multiple inputs and outputs to measure how well a firm (a decision-making unit – DMU) performs relative to the best units by converting multiple inputs and outputs of each DMU or unit into measurable units.

Measuring performance in absolute terms is often less valuable than making comparisons with other companies and providing examples of good practices that underperforming start-ups should follow to improve their performance in terms of knowledge management processes. DEA benchmarks DMU performance by setting best practice targets (Cook et al., 2019).

The efficiency level is achieved with a minimum number of inputs to produce a definite number of outputs, or the maximum production of outputs with a definite number of inputs (Fethi and Pasiouras, 2010).

Efficiency scores range from 0 to 1 (100%) and a DMU is fully efficient at (100%). This is only based on evidence available when other DMUs do not show that some input or output could be enriched on without negatively impacting some of its other inputs or outputs.

We applied an output-oriented model with variable returns to scale (VRS – BCC) (Banker et al., 1984), which means taking into account the pure technical efficiency (Alfiero et al., 2017). The model was calculated as follows:

$$Max\ P_o = \sum_{r=1}^{s} u_r y_{ro} - u_o \tag{2}$$

subject to

$$\sum_{r=1}^{s} u_r y_{ri} - \sum_{i=1}^{m} v_i x_{ij} - u \le 0; j = 1, .., n$$

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$v_i \ge \varepsilon; u_r \ge \varepsilon,\ \ u_o\ free\ in\ sign$$

where y_{rj} is the *rth* output for the *jth* start-up, x_{ij} is the *ith* input for the *jth* start-up, s is the number of outputs, m is the number of inputs and u_r and v_i are the variable weights estimated and used to calculate the relative efficiency of o. Five inputs and two outputs were selected for the application of the method DEA, taking into account as much as possible the variables used in previous studies.

The inputs are five knowledge management processes (Seleim and Khalil, 2011), which we obtained from the questionnaire (with six items for each practice), while we identified revenues and ROA as financial performance indicators for the output variable. The results of the DEA model were calculated using DEA Solver.

DEA also works with a small number of observations (Thanassoulis et al., 1996), but, to improve its discriminatory power, it is necessary to limit the number of variables and eliminate the correlation between them. Table 3 shows the correlation matrix.

We used the PCA (e.g., Beltrami, 1873; Jordan, 1874; Pearson, 1901) method to extrapolate the important information from the knowledge management data for each process (KA, KC, KD, KT and KAPP) and to incorporate this information into a set of new variables, called PCs, that generally express 70–90% of the variance in the data (Sharma, 1996).

Adler and Golany (2001, 2002) and Ueda and Hoshiai (1997) independently developed the idea of melding DEA and PCA methods. PCA is computed to replace the original m inputs with a smaller set of PCs in the PCA-DEA model and this describes the variance structure of a data matrix through linear combinations of variables.

If the first few components contain most of the variance of the population, the PCs can replace the original variables with a small loss of information.

The PCA is based on correlation rather than covariance as different measurement units are often used when quantifying variables used in DEA. The following equations are used for computing PC scores for the input variables:

$$\begin{aligned} X_{PC_i} &= l_{1i}X_1 + l_{2i}X_2 + \ldots + l_{pi}X_p,\ \ i = 1, 2, \ldots, p \\ Var(X_{PC_l}) &= l_i' C l_{i,}\ i = 1, 2, \ldots, p \end{aligned} \tag{3}$$

Some values found by the PCA method were negative, and these data were converted into positive data with formula (1). The STATA 16 software was applied. Table 3 shows the values of the converted independent variables using the PCA method. In determining the number of factors, the latent root criterion was employed (Leonidou, 2000). The latent root criterion, with a cut-off value of 1.0 for the eigenvalue, indicates that one factor is retained for each knowledge management practice.

Table 4
Values of the independent positive variables for inputs for each DMUs.

	KA	KC	KD	KT	KAPP
DMU	PC1	PC2	PC3	PC4	PC5
DMU1	3.453637	4.627547	4.511125	8.105856	1.363990
DMU2	7.657796	8.320225	7.562193	6.662508	5.374601
DMU3	4.775603	7.345146	6.200012	7.624501	7.015875
DMU4	6.094027	7.924187	6.526743	6.865255	5.275466
DMU5	7.020099	7.517533	3.558334	4.431845	2.460809
DMU6	5.807163	7.924187	5.904655	7.633860	6.762717
DMU7	6.290080	8.199088	2.879565	1.658130	1.986749
DMU8	5.750718	5.343905	6.368713	7.348480	4.627658
DMU9	7.637078	7.203141	2.855600	5.630755	6.458187
DMU10	6.835190	7.204501	2.831568	5.857094	6.812468
DMU11	4.270178	2.750142	7.055474	4.732825	5.588090
DMU12	4.693833	5.365786	6.790101	5.568588	6.103441
DMU13	3.134639	5.035945	1.652114	5.593055	4.479588
DMU14	6.602122	7.510893	7.264855	6.726922	5.641894
DMU15	6.784748	3.142560	4.210455	4.473290	5.788133
DMU16	2.513265	4.554354	8.629669	4.421108	3.599757
DMU17	5.957598	2.754529	6.607406	6.860011	2.836222
DMU18	7.865446	7.389023	8.366976	7.535120	7.339849
DMU19	7.634283	7.867441	3.915049	7.286574	7.085580
DMU20	6.790188	6.194179	8.106937	5.812775	4.993323
DMU21	1	5.437379	4.729840	6.237707	4.211715
DMU22	8.917963	8.291349	6.264023	4.477404	3.572530
DMU23	7.672629	6.165304	1.654773	8.853368	8.073301
DMU24	3.834520	3.262177	4.635762	6.652278	6.400047
DMU25	5.321924	7.243637	3.404957	5.634368	2.638820
DMU26	8.502662	6.520846	8.629669	5.884545	5.933748
DMU27	5.397037	6.958475	6.264016	6.913688	7.013073
DMU28	6.871957	7.635496	4.545133	7.466948	5.965728
DMU29	5.839025	5.355171	6.001331	5.974298	4.154990
DMU30	6.680392	8.291349	5.754617	2.821210	3.777005
DMU31	7.220560	8.349100	8.398968	7.265721	6.076214
DMU32	6.628585	8.291349	6.508049	4.442833	5.256978
DMU33	3.158152	3.014791	7.524868	5.235272	2.784435
DMU34	2.988847	6.501337	5.001185	7.783276	3.000727
DMU35	6.204810	6.486336	4.457114	4.100033	4.857441
DMU36	5.737996	6.964110	6.511403	4.723592	4.309895
DMU37	3.425637	4.595058	6.294028	5.889789	5.391399
DMU38	5.566135	4.214253	5.789289	5.178478	3.067882
DMU39	7.881496	6.129788	5.274557	4.824821	6.933034
DMU40	6.983305	7.235013	7.562193	5.241017	2.537445
DMU41	5.397844	7.367143	5.183887	2.021025	4.934419
DMU42	2.547683	5.414936	4.845178	4.170931	2.987843
DMU43	5.870269	6.461197	4.660461	5.515660	4.078013
DMU44	5.671298	8.274094	4.373104	5.592051	4.507447
DMU45	4.346716	7.128762	7.497515	3.362512	2.961683
DMU46	4.825625	3.247182	7.738889	6.497116	7.136442
DMU47	6.524606	6.995797	6.510730	5.158258	2.872266
DMU48	8.050355	7.431534	5.513278	5.266355	4.270576
DMU49	5.553533	7.028501	5.389922	4.493510	4.273378
DMU50	6.931466	7.638670	5.281248	5.833367	4.889206
DMU51	2.630705	5.105971	3.899044	5.572960	5.727538
DMU52	8.917963	8.291349	5.559262	7.267351	8.073301
DMU53	4.137640	6.623654	4.172409	8.045314	6.809665
DMU54	6.658457	8.279729	6.116030	5.179983	3.854026
DMU55	8.917963	8.285714	6.302042	3.788316	2.877010
DMU56	6.057647	4.913596	5.405928	5.194459	3.141360
DMU57	8.236310	7.646670	6.211324	5.272106	3.697217
DMU58	3.680873	1	1.839448	7.379569	5.413645
DMU59	6.374322	7.285142	5.773949	7.296804	5.438487
DMU60	5.484004	6.012480	6.792781	6.539062	5.473269
DMU61	7.902214	6.070793	4.982499	6.207124	4.027248
DMU62	6.620883	7.019692	3.351646	6.212242	5.910391
DMU63	3.164217	4.450026	5.440573	6.187030	5.185188
DMU64	5.819440	5.972335	4.333124	8.694086	8.073301
DMU65	5.114273	5.885708	2.844900	4.932923	4.921186
DMU66	2.834049	3.887501	5.917987	3.102344	1
DMU67	6.002238	5.815396	7.052127	7.333377	7.219283

(*continued on next page*)

Table 4 (*continued*)

	KA	KC	KD	KT	KAPP
DMU68	3.930736	7.505258	5.145195	1	2.469572
DMU69	6.144530	6.018465	5.247871	4.451193	3.848695
DMU70	4.944968	6.285367	3.993087	6.693597	6.320008
DMU71	3.185023	1.826586	5.475919	4.385539	5.968531
DMU72	4.255500	7.424267	5.481252	5.121184	6.555396
DMU73	2.490798	6.813743	6.982803	4.462928	2.646722
DMU74	3.868938	5.466494	6.050002	4.099161	5.143690
DMU75	6.210660	6.343325	5.290563	5.959822	2.964736
DMU76	4.619107	6.512331	2.153502	4.433229	3.683363
DMU77	4.580761	2.885919	6.283355	7.140770	6.472695
DMU78	7.368702	6.984177	5.795275	5.996763	3.934436
DMU79	8.110635	7.621415	6.494724	7.098303	4.768432
DMU80	3.024843	6.230435	6.725417	3.414187	3.889877
DMU81	7.495354	8.245219	2.628220	6.191149	6.777685
DMU82	7.991892	7.438413	7.103445	7.889280	6.927429
DMU83	5.114273	6.669785	4.939222	8.357031	7.663683
DMU84	7.679730	6.989812	8.109590	6.559654	5.679479
DMU85	7.058118	7.076438	8.125603	5.095845	4.849399
DMU86	5.338780	7.652305	2.641552	5.317539	3.200984
DMU87	8.917963	8.349100	8.315625	6.622192	5.235079
DMU88	5.204929	7.656930	5.405928	5.972422	3.251846
DMU89	4.431041	6.024100	2.558216	3.888673	6.836040
DMU90	4.032684	5.957903	5.207920	7.333005	5.127396
DMU91	7.081631	6.949666	4.737792	3.473350	1.613722
DMU92	6.280188	6.394075	1.992139	5.888791	1.837708
DMU93	8.339449	7.243637	7.248156	5.880431	5.558913
DMU94	3.884217	6.042715	6.516070	2.271327	1.327473
DMU95	7.139562	3.988741	5.497931	5.987399	2.362141
DMU96	7.582683	7.414517	7.653564	3.745999	4.270576
DMU97	1.066165	2.382386	4.239745	8.443909	7.867091
DMU98	5.774764	5.926651	1	4.293397	3.151717
DMU99	2.780425	1.376772	3.848392	5.956948	4.273378
DMU100	4.842539	7.955077	3.351646	7.058494	7.666486
DMU101	6.211467	7.407284	8.369629	6.653276	1.284299
DMU102	8.673546	7.867441	3.392325	7.660829	6.848361
DMU103	5.219762	5.194967	4.987164	7.681922	7.374632
DMU104	7.628191	7.150371	4.169728	6.682734	5.537014
DMU105	6.678813	6.500332	8.141616	2.011160	2.862666
DMU106	7.863868	7.001432	4.955867	8.704949	8.073301
DMU107	5.352480	4.428152	8.629669	7.971913	5.333606
DMU108	3.294265	7.703061	4.835818	4.360200	1.452784
DMU109	8.917963	8.337480	5.253238	5.532513	6.028155
DMU110	5.471282	6.895536	4.869170	8.668747	5.978612
DMU111	2.647887	5.825943	1.514732	6.336321	5.175107
DMU112	3.826079	1.826586	5.979984	7.011430	6.904419
DMU113	8.710313	8.005833	6.039322	5.983285	4.366093
DMU114	7.638590	8.041703	7.862911	7.214171	7.050657
Eigenvalues	3.51003	3.92622	4.46356	3.20348	4.21169
Variance Explained	0.7404	0.7144	0.7439	0.5339	0.7353
Cronbach alpha	0.85	0.68	0.76	0.82	0.81

4. Findings

The performance evaluation results, detailed in Table 5, show that 32 global start-ups (28% of the sample) can be considered efficient, with the optimum efficiency value of 1. The average efficiency score is 0.7671, and over 70% of the sample reached a higher efficiency level than the average, while the standard deviation is 0.2693. Of the start-ups, 17 have a score between 0.5 and 0.75 and are marginally inefficient units while just 14 (12% of the sample) are distinctly inefficient units with a score of less than 0.5. The last technically inefficient start-up is DMU 89 with an efficiency score of 0.0001. In the following table, the ranking position is based on the efficiency levels from the DEA analysis in BCC model.

To highlight the characteristics that inefficient DMUs need to improve to reach the efficiency frontier, we analysed the characteristics of the 32 companies that achieved a score of 1 with those that achieved a score lower than 0.5. We only focused on inputs (KM practices) here because the achievement of optimal levels of financial performance is dependent on many contingent factors that cannot be controlled by the manager. In particular, Table 6 compares the geometric averages of the results of the responses to the questionnaire from the start-ups that were found to be efficient with those that were not, showing how effectively they must increase the use of knowledge management practices.

In addition to an overall analysis, a detailed analysis was carried out on each DMU, highlighting the benchmark start-ups. For

Table 5
Performance evaluation results.

			Benchmarks										
DMUs	Score	Rank	Input										Output
DMU1	0.7866	67	DMU23	0.273	DMU31	0.069	DMU43	0.442	DMU99	0.216			
DMU2	0.5401	100	DMU40	1									
DMU3	0.6658	92	DMU99	1									
DMU4	0.6874	90	DMU99	1									
DMU5	0.8276	53	DMU43	0.517	DMU58	0.228	DMU98	0.066	DMU99	0.19			
DMU6	0.8717	45	DMU99	1									
DMU7	0.9705	37	DMU50	0.159	DMU66	0.133	DMU79	0.515	DMU93	0.192			
DMU8	0.7671	73	DMU99	1									
DMU9	0.7851	68	DMU98	0.258	DMU99	0.742							
DMU10	0.067	112	DMU43	0.406	DMU76	0.027	DMU92	0.268	DMU93	0.299			
DMU11	0.7942	62	DMU99	0.794	DMU112	0.206							
DMU12	0.9747	36	DMU23	0.149	DMU98	0.739	DMU99	0.113					
DMU13	1	1											
DMU14	0.829	52	DMU86	0.98	DMU92	0.02							
DMU15	0.7556	80	DMU58	0.044	DMU99	0.745	DMU112	0.211					
DMU16	0.853	47	DMU45	0.203	DMU94	0.068	DMU99	0.601	DMU112	0.127			
DMU17	1	1											
DMU18	0.619	95	DMU99	1									
DMU19	0.707	88	DMU99	1									
DMU20	0.7665	74	DMU99	0.976	DMU112	0.024							
DMU21	1	1											
DMU22	0.9981	35	DMU22	1									
DMU23	1	1											
DMU24	0.7676	72	DMU99	1									
DMU25	0.7773	69	DMU43	0.367	DMU98	0.193	DMU99	0.44					
DMU26	0.0694	110	DMU86	0.385	DMU99	0.615							
DMU27	0.5564	98	DMU98	0.837	DMU99	0.163							
DMU28	1	1											
DMU29	0.9185	42	DMU47	0.085	DMU99	0.915							
DMU30	0.7926	63	DMU43	0.423	DMU47	0.094	DMU112	0.483					
DMU31	1	1											
DMU32	1	1											
DMU33	0.2949	103	DMU31	0.155	DMU38	0.292	DMU58	0.137	DMU63	0.087	DMU99	0.329	
DMU34	0.2773	104	DMU23	0.169	DMU43	0.178	DMU99	0.653					
DMU35	0.5416	99	DMU43	0.052	DMU58	0.023	DMU99	0.637	DMU112	0.288			
DMU36	0.0605	113	DMU47	0.278	DMU94	0.004	DMU99	0.55	DMU112	0.167			
DMU37	0.7559	79	DMU99	0.989	DMU112	0.011							
DMU38	0.9998	34	DMU38	1									
DMU39	0.8364	49	DMU99	0.81	DMU112	0.19							
DMU40	1	1											
DMU41	0.759	77	DMU28	0.14	DMU58	0.048	DMU94	0.205	DMU99	0.237	DMU112	0.37	
DMU42	0.9999	33	DMU42	0.999									
DMU43	1	1											
DMU44	0.3287	102	DMU28	0.137	DMU58	0.682	DMU99	0.181					
DMU45	1	1											
DMU46	0.7508	83	DMU99	1									
DMU47	1	1											

(*continued on next page*)

Table 5 (*continued*)

			Benchmarks											
DMUs	Score	Rank	Input										Output	
DMU48	0.0821	108	DMU47	0.176	DMU99	0.732	DMU112	0.092						
DMU49	0.4003	101	DMU47	0.369	DMU99	0.435	DMU112	0.196						
DMU50	1	1												
DMU51	0.8723	44	DMU13	0.016	DMU23	0.37	DMU43	0.168	DMU58	0.028	DMU66	0.405	DMU79	0.012
DMU52	1	1												
DMU53	0.8062	58	DMU28	0.661	DMU58	0.193	DMU99	0.028	DMU112	0.118				
DMU54	0.9423	39	DMU28	0.056	DMU86	0.756	DMU99	0.188						
DMU55	0.7974	61	DMU43	0.061	DMU47	0.547	DMU94	0.251	DMU99	0.01	DMU112	0.131		
DMU56	0.7882	66	DMU43	0.542	DMU66	0.238	DMU87	0.173	DMU93	0.047				
DMU57	0.0678	111	DMU43	0.091	DMU58	0.136	DMU87	0.101	DMU99	0.671				
DMU58	1	1												
DMU59	0.7084	87	DMU99	1										
DMU60	1	1												
DMU61	0.6461	93	DMU47	0.176	DMU99	0.824								
DMU62	0.7981	60	DMU58	0.058	DMU98	0.099	DMU99	0.843						
DMU63	1	1												
DMU64	0.0855	107	DMU43	0.712	DMU76	0.073	DMU92	0.173	DMU99	0.042				
DMU65	1	1												
DMU66	1	1												
DMU67	0.7259	86	DMU99	1										
DMU68	1	1												
DMU69	0.8031	59	DMU76	0.632	DMU94	0.183	DMU112	0.185						
DMU70	0.6818	91	DMU23	0.169	DMU43	0.781	DMU98	0.031	DMU99	0.019				
DMU71	1	1												
DMU72	0.7624	76	DMU99	0.86	DMU112	0.14								
DMU73	1	1												
DMU74	0.7905	65	DMU99	0.688	DMU112	0.312								
DMU75	0.9275	40	DMU43	0.16	DMU47	0.493	DMU99	0.347						
DMU76	1	1												
DMU77	1	1												
DMU78	0.7697	71	DMU47	0.242	DMU99	0.758								
DMU79	0.7275	85	DMU99	1										
DMU80	0.6924	89	DMU45	0.107	DMU94	0.21	DMU99	0.433	DMU112	0.251				
DMU81	0.7765	70	DMU23	0.662	DMU28	0.333	DMU99	0.004						
DMU82	0.7476	84	DMU99	1										
DMU83	0.0904	106	DMU21	0.283	DMU23	0.234	DMU28	0.483						
DMU84	0.8299	51	DMU99	1										
DMU85	0.9263	41	DMU43	0.861	DMU66	0.038	DMU94	0.101						
DMU86	1	1												
DMU87	1	1												
DMU88	0.7519	82	DMU43	0.189	DMU47	0.207	DMU99	0.604						
DMU89	0.0001	114	DMU23	0.087	DMU58	0.061	DMU98	0.717						
DMU90	0.8254	54	DMU99	1										
DMU91	0.8312	50	DMU43	0.224	DMU79	0.119	DMU92	0.16	DMU94	0.453	DMU99	0.044		
DMU92	1	1												
DMU93	1	1												
DMU94	1	1												
DMU95	0.9699	38	DMU43	0.437	DMU47	0.159	DMU99	0.404						

(*continued on next page*)

Table 5 (*continued*)

			Benchmarks										
DMUs	Score	Rank	Input										Output
DMU96	0.8677	46	DMU28	0.038	DMU79	0.563	DMU94	0.141	DMU112	0.258			
DMU97	0.7923	64	DMU23	0.378	DMU63	0.347	DMU99	0.275					
DMU98	1	1											
DMU99	1	1											
DMU100	0.8093	56	DMU98	0.129	DMU99	0.871							
DMU101	0.8786	43	DMU43	0.714	DMU47	0.164	DMU99	0.122					
DMU102	0.8083	57	DMU98	0.119	DMU99	0.881							
DMU103	0.5728	97	DMU99	1									
DMU104	0.844	48	DMU43	0.065	DMU58	0.261	DMU79	0.158	DMU99	0.018	DMU112	0.498	
DMU105	0.6251	94	DMU17	0.131	DMU73	0.502	DMU79	0.325	DMU94	0.043			
DMU106	0.6035	96	DMU43	0.839	DMU47	0.16	DMU99	0.001					
DMU107	0.7631	75	DMU43	0.053	DMU94	0.22	DMU112	0.727					
DMU108	1	1											
DMU109	0.7571	78	DMU99	0.929	DMU112	0.071							
DMU110	0.0787	109	DMU43	0.071	DMU58	0.219	DMU99	0.052	DMU112	0.658			
DMU111	0.0943	105	DMU23	0.502	DMU58	0.124	DMU98	0.256	DMU99	0.119			
DMU112	1	1											
DMU113	0.8221	55	DMU99	1									
DMU114	0.7544	81	DMU43	0.911	DMU76	0.012	DMU99	0.077					

example, DMU23, DMU31, DMU43 and DMU99 were identified as the benchmarks for DMU1 in Table 4. In fact, DMU1, with an increase of 0.273 in its first input (KA), will be an efficient unit in relation to the DMU23 unit (as a benchmark). Additional alternative for DMU1 is to increase its second input (KC), taking into consideration the performance of DMU31. In other words, with a gain of 0.0069 in the KC, DMU1 will be an efficient unit regarding the start-up unit (as a benchmark) and so on. Any alternative can be chosen as a benchmark because they would all produce a more efficient production unit. Likewise, an analogous procedure would mean all inefficient units would increase their efficiency regardless of the benchmark set.

5. Discussion

Relying a PCA-DEA, we developed a model to uncover the link between knowledge management practices and financial performance, and we highlighted empirical evidence on the impact of KM on global start-ups financial performance.

Building on the assumption that the pursue of a positive financial performance is relevant for the survival and growing of the global start-ups (Oe and Mitsuhashi, 2013; Markham, 2002), this empirical research highlights that the design and adoption of appropriate KM practices are important for the financial performance of global start-ups.

In particular, our results show that there is a relationship between the input (knowledge management practices) and the output (financial performance) values, which is underlined by the differences in the average BCC efficiency values, indicating different returns to scale in the data set. The high percentage of start-ups with an efficiency value above 0.7 demonstrates that the business owners are already geared toward optimizing their knowledge management practices and recognize them as added value to improve their financial performance.

In line with previous studies (e.g., Del Giudice and Della Peruta, 2016; Wu et al., 2021), our research confirms that KM is a process that generates value and the majority of start-ups owners have already recognized the importance of implement KM practices. At the same time, the start-ups with a low rank need considerable improvement to enhance the productivity and efficiency of their KM practices and to achieve the optimal scale for their financial performance. In particular, KD, KAPP and KA are the KM practices that need to be further increased to reach a satisfying level of efficiency.

The investigation of the summary of the returns to scale presents that 54 start-ups operate under decreasing returns to scale (DRSs), 51 under constant returns to scale (CRSs) and 9 under increasing returns to scale (IRSs).

DRS occur when the proportional growth in all inputs is less than the proportional rise in outputs, while under CRS, units operate when an increase in inputs leads to a proportional increase in outputs. This demonstrates that significant work is still necessary to improve the KM process and reach efficient levels.

6. Conclusions and implications

Even if the literature on knowledge management is wide, it is nevertheless constantly expanding, always opening up new possibilities for study, also in a context of international business. Specifically, although the literature examines the knowledge management practices in start-ups and the effects of knowledge management on general start-ups, to the best of our knowledge, no prior studies explore the ways in which the different types of knowledge management practices can increase the financial performance of specific global start-ups.

Based on a database of Italian start-ups at the end of 2019, this study developed a survey (structured questionnaire) to investigate the different knowledge management practices and used secondary data (financial statements available from the BvD AIDA database) with the aim of selecting start-ups and exploring their financial performance. Through the combined use of PCA and DEA (Adler and Golany, 2001), with the purpose of reducing the curse of dimensionality and the correlation between variables that occurs in DEA when there is a high number of inputs and outputs in relation to the number of decision-making units (Adler and Golany, 2007), this study highlighted that the different knowledge management practices used by global start-ups influence their financial performance positively. Moreover, the high efficiency scores achieved by 70% of the global start-ups analysed demonstrate that business owners are already recognizing the role of knowledge management as a key factor in improving their performance. In detail, 32 global start-ups can be considered to be efficient with the optimum efficiency value (1) and over 70% of the sample were shown to be marginally efficient units (>0.75). Based on considerations described in the previous two paragraphs, our research leads to several theoretical and managerial implications.

6.1. Theoretical implications

The theoretical contributions of this research are manifold.

Table 6
Geometric averages of the results.

	Geometric mean				
	ka	kc	kd	kt	kapp
Efficiency start-ups	4.5072	4.9544	5.2787	4.4666	4.8588
Inefficiency start-ups	3.9778	4.5971	4.4520	4.2462	4.2334

In general terms, this research enriches the existing literature both on managerial issues connected to knowledge and on corporate finance topics connected to performance. Through a combined PCA-DEA method, this research suggested a positive impact of the different practices of knowledge management (i.e., acquisition, documentation, creation, transfer and application) on financial performance (measured in terms of revenues and return on assets) in the specific case of innovative Italian start-ups, i.e. of international new ventures that generate at least 10% of their total sales from foreign markets. By exploring financial performance, this study advances our understanding of the impact of different knowledge management practices by global start-ups. Based on this, our research provides new insights to shed light on the consequences of KM practices on global start-ups' financial performance. It fills a gap between the general results of previous research, focused on the effect of KM on start-ups' general performance (e.g., Oe and Mitsuhashi, 2013; Oliva and Kotabe, 2019), and new specific results, based on the analysis of financial performance in an international context. In more detail, our study contributes to the literature on international entrepreneurship, advancing the understanding of the impacts of knowledge management on start-ups definable as global and extending the international debate on the consequences of knowledge management practices on financial performance (e.g., Darroch, 2005; Oe and Mitsuhashi, 2013; West and Noel, 2009; Wu, 2007; Zack et al., 2009). Specifically, our paper contributes to the knowledge management and entrepreneurial finance literature by assessing the relationship between the different practices of KM and financial performance in the context of global innovative Italian start-ups. Establishing KM practices offers a strategic way for global start-ups to increase financial performance also providing signs of these processes' importance in generating and sustaining competitive advantages (Santoro et al., 2018).

6.2. *Practical implications*

The results of our research allow us to develop implications also of a practical nature.

The positive relationship between KM practices and financial performance provides an important signal for business owners. In particular, the high efficiency scores achieved by 70% of the global start-ups analysed demonstrate that business owners are already recognizing the role of knowledge management as a key factor in improving performance. From this point of view, many global start-ups operate in sectors that are characterized by high levels of knowledge intensity (Englis et al., 2007) and that require the implementation of practices that favour its development. In an international and dynamic context, global start-ups, like other new ventures, have little time and few resources to achieve their scalability objectives, but they are able to overcome the barriers preventing the spread of knowledge management (Centobelli et al., 2017). More competitive start-ups perform better and are more likely to access finance, for example from banks and venture capital, to grow in the market and overcome the so-called "valley of death" (Markham, 2002). Therefore, business owners need to develop practices of knowledge management that enable them to obtain a positive financial performance. Specifically, managing knowledge in global start-ups involves capturing and documenting the specifics related to innovative technical, process and organizational strategies. Furthermore, for business owners who want to adopt knowledge management practices, choosing the processes that may influence the financial performance can positively represent a strategic competitive advantage (e.g., Magni et al., 2021; Santoro et al., 2018).

7. Limitations and future lines of research

Limitations in our research results (below) mean there is still a lot of space for future research.

First, the study focuses on Italian global start-ups that present specific characteristics that enable them to be defined as innovative (art. 25 of Decree-Law no. 179/2012). However, these results cannot be applied to other countries, so future researchers could focus on other developed and/or emerging countries and compare the results and find parameters to use across the board.

Second, linking knowledge management practices directly to financial results can be difficult since many intertwining variables can influence the performance of a firm at the same time. For this reason, we do not claim to have identified a pure causal relationship (Yew Wong, 2005).

Third, this study is based on intelligence which might be impartial due to the selected analysis approach used. So, any future research could be carried out by employing other statistical analyses (e.g., Podsakoff et al., 2012; Vrontis et al., 2021).

Fourth, although combined PCA-DEA is used in several studies on management (e.g., Adler and Golany, 2001; Andrejić et al., 2013; Ho and Wu, 2009), it is uncertain if this type of analysis gives a reliable and comprehensive representation. Other methods could also be combined in the future (i.e., neural networks and DEA, analytical hierarchy process (AHP) and DEA, and fuzzy AHP and DEA) to assess knowledge management impact on financial performance and determine if results using the approach in this paper could be improved.

Fifth, future studies could expand the set of variables considered regarding the practices/processes of knowledge management; for example, they could take into consideration not only practices but also methods and tools and the different types of financial measures that can be used to investigate the different impacts on global start-ups.

Finally, future research could investigate how potential innovative start-ups from under-developed economies could grow quickly internationally and start competing with competitors in more developed countries.

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