Expert Systems with Applications 39 (2012) 7255–7261

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Assessing Intellectual Capital efficiency and productivity: An application to the Italian yacht manufacturing sector

Roberta Costa *

Department of Enterprise Engineering, University of Rome Tor Vergata, Via del Politecnico 1, 00133 Rome, Italy

ARTICLE INFO

Keywords:
Intellectual Capital
Intangible assets
Data Envelopment Analysis
Malmquist Productivity Index
Benchmarking

ABSTRACT

In this paper we evaluate the efficiency and productivity of Intellectual Capital (IC) through the assessment of Bests Practices, that have successfully implemented strategies of Intellectual Capital management. The techniques selected for appraising the productivity of intangibles are the Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI). This approach allows a direct comparison between firms of the same industry in the perspective of improvement through benchmarking. It overcomes one of the main limitations of the current intangibles metrics comparing enterprises on the basis their Intellectual Capital management.

The paper gives both academic and practical insights that could be used for the operational and strategic Intellectual Capital management. Actually, the outcome of the application gives to inefficient companies some directions for progress, that should constitute the basis for the formulation of future Intellectual Capital management strategies. Finally, we apply the analysis to the Italian yacht manufacturing sector in order to offer yachting companies guidelines for Intellectual Capital management.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Nowadays companies productivity and business performance depend in great measure on an efficient management of their Intellectual Capital, making the evaluation of the return on Intellectual Capital investments a critical obstacle to turning those investments into sources of competitive advantage. In fact, most firms are not able to assess how much they spend on Intellectual Capital, let alone how much they receive from those investments, and consequently many of them either under-invest or make ineffective investments (Zambon, 2003).

The analysis of intangibles as economic growth factors needs conceptual and analytical tools taking into account their unique characteristics and economic significance. This applies not only to the theoretical aspects, but also to the associated measurement and evaluation efforts. At firm level, the most relevant phenomenon, is the value of intangible assets increasingly outgrowing that of tangible assets, particularly, for knowledge intensive firms.

Actually, traditional accounting models of evaluation are not enough to determine the competitiveness of an organization and nothing can say about its strategic effectiveness in the Intellectual Capital management. There is the necessity of new approaches allowing to assess the factor over which the competition is currently played: Intellectual Capital management and exploitation (Lev, 2003a, 2003b). To answer this need, numerous and innovative methods of measure and management of intangibles have been elaborated. However, these methods are not widely adopted due both to their subjectivity and to the delay of the business culture into accepting these knowledge-based tools of management.

Above all, the analysis of the current methods for the measurement of intangible assets and Intellectual Capital put in evidence the lack of an explicit connection between Intellectual Capital investments and management, and their effects on business performance. This suggests a need for an investigation into the link between Intellectual Capital management and business performance (Carlucci & Schiuma, 2006; Chin, Lo, & Leung, 2010). The importance of such study is strengthened by contemporary economy being indeed a knowledge-based or knowledge economy. Moreover, an analysis of Intellectual Capital efficiency and productivity in terms of business performance should provide both academic and practical insights that could be used for Intellectual Capital operational and strategic management (Chen, Cheng, & Hwang, 2005; Cheung, Lee, Wang, Chu, & To, 2003; Meenakshi & Smith, 2002).

2. Intellectual Capital management and business performance

Intellectual Capital is described, in one of its numerous and most famous definitions, as the economic value of the combination of three categories of intangibles (Bontis, Dragonetti, Jacobsen, & Roos, 1999):

* Tel.: +39 0672597799; fax: +39 0672597951.
E-mail address: roberta.costa@uniroma2.it

0957-4174/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2012.01.099

- the "human capital" refers to the abilities, the competences, the know-how of human resources;
- the "structural capital" defines the organizational knowledge, mainly contained in business processes, procedures and systems;
- the "relational capital" takes account of the knowledge embedded in business networks, which includes connections outside the organization such as customer loyalty, goodwill, and supplier relations.

The necessity of companies to understand better the cause-effect relationship between investments in Intellectual Capital and business performance drove academics and practitioners to the creation of methodological approaches and tools to identify, classify and evaluate knowledge and intangible assets within a company. The interest on the topic has favoured, in the last years, the proliferation of models and methodologies studied for assessing all the factors, tangible and intangible, that have influence on business performance. In fact, traditional accounting practice partially overlook the identification and measurement of intangible assets Intellectual Capital in organizations. In particular, financial statements include some information on intangible assets as licenses, trademarks and patents, but there are no data on personnel competences, customer loyalty and satisfaction and many other intangible assets which have no formal place in traditional accounting statements (Zambon, 2003).

On this account, the debate on intangible assets and Intellectual Capital is proceeding with developments both in practice and in theory and the traditional financial statement has shown its inadequacy dealing with the issue of intangibles, as testified by the increasing discrepancy between a firm market capitalization and its book value. This justify the rise of corporate intangible-oriented reporting systems and the creation of new methods for measuring Intellectual Capital (Sveiby, 2001–2010). These methods of measurement are based on different or even conflicting perspectives (monetary or not monetary, aggregate at firm level or not, etc.), but they all try to identify the essential contribution of intangible assets to the business competitiveness in the knowledge-economy (Lev, 2003b).

Although there are several methods for measuring Intellectual Capital, we must take into account that the measured value of intangible assets is not accurate in an absolute way. However, it is an excellent reference for benchmarking as a measure of the potential business evolution of a company over time (Lev, 2003a). Many of the existing methods are difficult to apply, require too much information or are not clearly described, while other ones are not numerical and they can only provide a reference to managers and decision-makers.

Even though several studies have attempted to deal with the issue of how Intellectual Capital investments can create value for the organization, current methodologies show a lack of an explicit identification of the effects of Intellectual Capital management on business performance. The effects of Knowledge Management projects on business performance have been analysed focusing on the quantitative measures of this impact (Firestone, 2001; Kingsley, 2002; Wen, 2009). Moreover, the return of Intellectual Capital investments is surely based on the analysis of the causal relationship between Intellectual Capital management strategies and the company business performance improvements that follow their implementation (Chen et al., 2005; McKeen, Zack, & Singh, 2006).

In this paper we want to emphasize the importance of measuring the results of Intellectual Capital management in order to test and to validate the effectiveness of Intellectual Capital management strategies, and to identify the most critical knowledge assets to be managed for achieving performance improvements. For these reasons, we apply a methodology based on the Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI). This analysis allows to estimate the cause-effect relationship between the efficient Intellectual Capital management and a successful business performance, while comparing companies that belong the same sector in the perspective of improvement through benchmarking.

3. The context of the analysis

This paper adopts a methodology that is based on the assessment of Bests Practices, that have successfully implemented strategies of Intellectual Capital management, and the comparison with other, less efficient, business realities. This approach can be applied both to companies of great dimensions, generally interested in the strategic importance of Knowledge Management, and to SMEs, typical of the Italian economic reality, that should not neglect the management of their Intellectual Capital (Campisi & Costa, 2008).

In order to evaluate the efficiency and the productivity of Intellectual Capital we combine Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI): both techniques are based on linear programming and estimates the efficiency of homogeneous operational unity (DMU – Decision Making Units), in this case the companies under study (Banker, Charnes, & Cooper, 1984; Charnes, Cooper, Golany, Seiford, & Stutz, 1985; Charnes, Cooper, & Rhodes, 1978; Coelli, Prasada Rao, & Battese, 1998). In this analysis, inputs and outputs must be correlated to the components of the Intellectual Capital, allowing to determine the relative efficiency and the productivity of the enterprises about their ability to manage their knowledge assets, compared to other enterprises and to the Bests Practices of the same business sector.

Moreover, this study adopt DEA and MPI to evaluate the impact of Intellectual Capital management on competitive advantage (Liu & Wang, 2008; Lu, Wang, Tung, & Lin, 2010; Wu, Tsai, Cheng, & Lai, 2006). The analytical results reveal if the enterprises under analysis achieve efficiency in Intellectual Capital management and, if not, how much they have to improve their Intellectual Capital management.

This approach offers the advantage of allowing a direct comparison between firms of the same industry, with the aim of achieving improvement through benchmarking. It overcomes one of the main limitations of the current intangible assets metrics allowing a comparison between enterprises regarding their management of intangibles.

In particular, in this paper we analyze the management of Intellectual Capital of a particular set of enterprises: Italian leisure boat manufacturers. We investigate the Italian yacht building sector because it is one of the most competitive in the Italian industry and it is constituted in great part by SME characterized by a high content of specialized knowledge. Moreover, Italy is one of the biggest world manufacturers of luxury yachts in the world.

4. The research models

4.1. The Data Envelopment Analysis

DEA is a method that allows management analysts to measure the relative productive efficiency of each member of a set of comparable organizational units based on a theoretical optimal performance for each organization (Banker et al., 1984; Charnest et al., 1978). For this purpose, the organizational units under analysis are designated as *Decision Making Units* (DMUs). These DMUs can be separate firms or institutions, or they can be separate sites or branches of a single firm or agency (Sexton, 1986). DEA evaluates relative efficiencies of DMUs without any assumption about the functional relationship between inputs and outputs. For all these reasons, the choice of the DEA is justified by the complexity of the processes that transform Intellectual Capital investments in value within a firm: they are hard to identify and harder to model, so that the properties of Data Envelopment Analysis makes this method particularly feasible to solve a problem of such nature.

Actually, the Data Envelopment Analysis allows to focus on the "real" production frontier determined by the DMUs (Decision Making Units, in our case the firms). It is not necessary to be able to estimate "a priori" the best production function: this way the analyst has not to model the process of value-creation, but can determine the production frontier (value production) by means of the sample chosen for the analysis. In those terms, the choice of a sample of firms within the same business sector becomes essential: the firms have to be comparable for dimension and industry, in order to presume that the intangible processes of value-creation are similar. Moreover, the benchmarks obtained through the analysis are an example to follow for inefficient companies and it would be incongruous to imitate a firm belonging to another business sector. The same goes for the dimension variable: value-creation through intangibles is expected to be quite different between big firms and SMEs.

It's important to underline that DEA provides an aggregate measure of relative efficiency for each company: the analyst can realize a ranking system of the firms within their industry. In this way, the low-ranking companies, that DEA labels as inefficient in extracting value from their Intellectual Capital, will have a model to imitate in the high-ranking ones: the Best Practices of their sample. These results of DEA analysis offer a guideline to become efficient: it prescribes to inefficient firms specifically benchmarks to follow and what adjustments to the inputs and outputs should be made to reach the efficiency frontier. Another important key advantage of DEA over other methods of performance evaluation is that it allows to consider a number of outputs and inputs simultaneously, regardless of whether all the variables of interest are measured in common units (Sexton, 1986). In the problem of Intellectual Capital value-creation the DEA provides much needed flexibility to dial with the choice of inputs and outputs that may highly vary according to the business sector under study.

To make the model work, inputs have to be indicative of the enterprise efforts to create, capitalize and manage Intellectual Capital. In the literature on Knowledge Management there are plenty of such indicators: according to the peculiarities of the business sector to analyze, the analyst has to choose some rather than others. Outputs, on the other hand, have to be correlated to the economic-financial performance of the firm, but also to the Intellectual Capital productivity: also in this case literature offers an ample possibility of choice (for instance: number of recorded patents, number of product or process innovations, etc.). It's also important to choice inputs and outputs in such a way that all the components of the Intellectual Capital of the enterprise are considered in the analysis.

The efficiency concept of DEA is similar to classical production function. However, while the production function is determined by a specific equation, the DEA's envelope is made by a sample of data which corresponds to assigned decision making units. Therefore, in the DEA, the technical DMU efficiency is defined as regard to the other DMUs of the sample, using a benchmark equal to 1, which cannot be overstepped. DEA determines which DMU operates on the efficiency frontier. Inputs and outputs for every DMU are classified into efficient or not efficient combinations. In this way, the efficient combinations define implicitly a production function; the other combinations of inputs and outputs can be calculated as regard to them.

In particular, the generic DMU$_j$ consumes a quantity $x_j = \{x_{ij}\}$ of inputs ($i = 1,\ldots,m$) and produces a quantity $y_j = \{y_{rj}\}$ of outputs ($r = 1,\ldots,t$), which are set positives. In order to evaluate the efficiency through Data Envelopment Analysis, the analyst has to select the more appropriate DEA model. First of all, he has to recognize what kind of return to scale (constant or variable) describes the considered production process. Secondly, he has to identify the orientation of the problem: output oriented, input oriented, or input–output oriented (Coelli et al., 1998). An input-oriented DEA model aims at reducing the inputs amount at the present output level, whilst the output-oriented model, maximizes output level under at most the present input consumption. In the literature on Knowledge Management, all authors are in agreement that the return to scale of knowledge and Intellectual Capital is increasing. Basing on this assumption, the DEA model Constant Return to Scale (CRS) is not suitable to this study (Charnes et al., 1978). This leaves the model BBC (the name of the model is the acronym of the authors: Banker et al., 1984) that is characterized by variable return to scale (it is also indicated as VRS model). The model has to be clearly output oriented, in fact, a firm interested in improving the efficiency of intangible assets management or in increasing the return of investments in intangibles is focused on maximizing its outputs in terms of performance and not on minimizing its inputs in terms of costs.

In conclusion, the efficiency can be properly studied by a VRS model output oriented, which formulation is:

$$
\begin{aligned}
&\text{Max } \phi \\
&\text{s.t.} \\
&\sum_{j=1}^{n} \lambda_j x_i^j - x_i^o + s_i = 0 \quad \forall i \\
&\phi \cdot y_r^o - \sum_{j=1}^{n} \lambda_j y_r^j + s_r = 0 \quad \forall r \\
&\sum_{j=1}^{n} \lambda_j \geqslant 1 \\
&\lambda_j \geqslant 0 \quad \forall j \quad \phi \quad \mathit{free} \\
&s_i \geqslant 0 \quad s_r \geqslant 0 \quad \forall r\ \forall i
\end{aligned}
\tag{1}
$$

The first two constraints of the model (1) determine *a linear combination of the n DMU* of the sample (each weighted with λ_j), creating a *target DMU* that:

- produces at least ϕy°, a percentage ϕ of the outputs y° produced by the DMU under study;
- consumes at most x°: the inputs consumed by the target DMU must not exceed x° (the inputs consumed by the DMU under study).

In order to generate a complete analysis of the relative efficiencies (ϕ of all the organizational units under study, it is necessary to solve a separate linear program (1) for each DMU. Being this a maximization model, ϕ will be as high as possible, depending on y°, x° and the data sample. The constraint on the weights ($\Sigma\lambda$) determines the non decreasing return to scale.

The constructed target DMU dominates the DMU under study only if it is inefficient, while if it's efficient they coincide ($\phi = 1$, $\lambda_o = 1$, $\lambda_{j\neq 0} = 0$, all constraints satisfied with equality). Therefore, non-dominated and efficient DMUs are characterized by unitary efficiency ($\phi = 100\%$) and dominated-inefficient DMUs will be labeled by a ϕ larger than 100%.

In particular, a DMU is efficient if and only if the following conditions are simultaneously satisfied:

- $\phi^* = 1$,
- all slacks are zero.

The target DMU serves as a model of how the inefficient DMU might adjust its inputs and outputs so that it might also move to the efficiency frontier: at the optimum, slack variables determine surplus in inputs and defect in outputs for each inefficient DMU and they are used to indicate target values x_i', y_r' to each inefficient DMU.

Target inputs and outputs are expressed by the flowing expressions:

$$\begin{aligned} x_i' &= x_i^o - s_i^* \quad \forall i \\ y_r' &= \phi^* y_r^o + s_r^* \quad \forall r \end{aligned} \tag{2}$$

4.2. The Malmiquist Productivity Index

The Malmiquist Productivity Index (MPI) measures the total factor productivity change (TFP) between two data points over time by calculating the ratio of data point distances relative to a common technology (Fare, Grosskopf, Norris, & Zhang, 1994; Grosskopf, 1993). Malmquist analysis separates shifts in the frontier (technical change) from improvements in efficiency relative to the frontier (technical efficiency change).

Suppose that our hypothetical DMU has an input–output combination (x_i^t, y_i^t) in period t and (x_i^{t+1}, y_i^{t+1}) in period $t+1$. Two principal changes may have occurred between period t and period $t+1$. First, because of technical progress, the DMU could have produced more output per unit of input in period $t+1$ than in period t. In this case, its input–output combination in period $t+1$ would have been infeasible using period t technology. Thus, technical change has taken place. Second, the firm could also have experienced technical efficiency change if its operating point is closer (in relative terms) to the frontier in $t+1$ than it was in period t.

The Malmiquist Productivity Index measures both shifts in the frontier over time and changes in efficiency relative to the frontiers for different time periods. It requires the use of the distance function D^t (D^{t+1}) that represents the distance function relative to the production frontier at time t ($t+1$).

The output-orientated Malmquist productivity change index between period t and $t+1$ is:

$$MPI = \left[\frac{D_i^t(x_i^{t+1}, y_i^{t+1})}{D_i^t(x_i^t, y_i^t)} \frac{D_i^{t+1}(x_i^{t+1}, y_i^{t+1})}{D_i^{t+1}(x_i^t, y_i^t)} \right]^{1/2} \tag{3}$$

Eq. (3) represents the Malmquist Productivity Index, that uses period t technology and period $t+1$ technology. TFP growth is expressed as the geometric mean of two output-based indices from period t to period $t+1$. A MPI value greater than one indicates a TFP positive growth from period t to period $t+1$. This positive growth defines efficient firms operating on the production frontier. Thus, inefficient production units are those operating below the production frontier with a MPI value lesser than one indicating a decrease in TFP growth or performance relative to the previous year.

5. Efficiency and productivity of the Intellectual Capital management in the Italian yacht sector

The analysis explore the relationship between the Intellectual Capital management and the firm performance, evaluating the efficiency and productivity of the Intellectual Capital. The data analyzed were collected through interviews of executives and managers of the Italian luxury yacht sector and they refer to 17 companies in the years 2005 and 2008.

We investigate the Italian yacht building sector because it is one of the most competitive in the Italian industry and it is constituted in great part by SME characterized by a high content of specialized knowledge. Italy is one of the biggest world manufacturers of luxury yachts in the world. Italy is the world leader of the mega-yacht sector in terms of number of ongoing projects, which has recorded an increase of about 20% in the 4-years period 2005–2008. This sector is constantly growing and it is strategic for the Italian economy because it generates significant related economic profits in the downstream sectors of nautical tourism and services. The overall turnover of the boating sector (that takes into consideration both exports and production) for yacht building was more than 5 billion euros in 2008 (+40% in the 4-years period 2005–2008) and the contribution of the boating sector for the Italian GDP was equal to 5.5 billion euros in 2008. The number of employees working in the boat industry is estimated by UCINA equal to 25,300 (UCINA, Italian Marine Industry Association, 2010).

We select three inputs and two outputs suitably correlated to the components of the Intellectual Capital and to performance, with the aim to analyze productivity and efficiency of Intellectual Capital and the relationship between Intellectual Capital management and business performance:

- first input (I1): specialized personnel expressed as percentage of total personnel (here we consider designers, project planners, engineers, R&D personnel, etc.),
- second input (I2): investments in Relational Capital (expressed in thousands of euros). As investments in Relational Capital we intend all investments carried out for the acquisition of new clients, such as advertising, marketing initiatives and technical reports published on specialized journals. In particular, yacht builder invest significantly in International Boat Shows participation as the main way to achieve new contacts, partners, clients, etc.
- third input (I3): investments in R&D (expressed in thousands of euros).
- first output (O1): number of product/process innovations,
- second output (O2): yearly revenue (expressed in thousands of euros).

We appositely choose inputs and outputs that take into account business performance (O2) and that are balanced on all the three component of the Intellectual Capital: Human Capital (I1), Relational Capital (I2), Structural Capital (I3 and O1). In this way we can guarantee a better assessment of the effect of a correct management of intangible assets on the firm's performance.

In Table 1 we can observe that, under the hypothesis of a variable return to scale and an output oriented DEA model, only eight companies are efficient. The results of the study (Table 2) puts in evidence that they are all benchmarks that inefficient companies should follow: for example DMU10 (Inò Group) has to imitate the IC management of DMU12 (Manò Marine) and DMU17 (Versilmarina) in order to improve its business performance and efficiency. The ranking of Table 2 shows that DMU12 is a benchmark for nine inefficient enterprises: it is the Best Practice of the sample and it provides an example to follow for more than half of the companies of the sample analyzed.

It is useful to classify companies in a ranking system within their industry, discriminating efficient (score 100% and slacks equal to zero) from inefficient ones (score over 100%). Inefficient enterprises are ranked in order of increasing score because the higher the score the more inefficient is an enterprise. A further analysis of the benchmarks allows to discriminate between efficient enterprises: the more times an enterprise occurs as a benchmark the higher it ranks. The number of times that an enterprise is a benchmark (see Table 2) represents without doubt an indicator of an excellent performance: if the frequency is very high the enterprise can be considered the Best Practice in its business sector (see for example Manò Marine – DMU12 in Table 2). If the frequency is lower the firm is not regarded as a Best Practice because even though efficient it lesser imitable.

Table 1
Relative efficiency (score) of companies in the year 2008. In the benchmarks column values in brackets are the lambdas of the VRS (BCC) DEA model. Efficient companies are indicated with a boldfaced score.

Companies	DMU	Score (%)	Benchmarks	Slacks				
				I1	I2	I3	O1	O2
Airon Marine	DMU1	221	DMU5 (0.01) DMU11 (0.25) DMU12 (0.74)	3.47	0	135.93	0	0
Canados Group	DMU2	564	DMU5 (0.04) DMU7 (0.22) DMU12 (0.74)	0.39	14.05	0	0	0
Cantiere F.lli Rossi	DMU3	109	DMU12 (0.16) DMU16 (0.47) DMU17 (0.37)	0	376	0	0	786.44
Cantiere Mariotti	DMU4	262	DMU7 (0.16) DMU12 (0.84)	10.2	0	483.51	0	2890.32
Ferretti Spa	DMU5	**100**	5	0	0	0	0	0
Fiart Mare	DMU6	185	DMU5 (0.01) DMU11 (0.19) DMU12 (0.81)	0.12	0	1579.85	0	0
Flag Marine	DMU7	**100**	3	0	0	0	0	0
Franchini International	DMU8	511	DMU5 (0.01) DMU7 (0.03) DMU12 (0.96)	16.67	0	539	0	0
Innovazioni e Progetti	DMU9	**100**	0	0	0	0	0	0
Inò Group	DMU10	174	DMU12 (0.68) DMU17 (0.32)	56.72	0	370	0	21359.22
InRizzardi	DMU11	**100**	3	0	0	0	0	0
Manò Marine	DMU12	**100**	9	0	0	0	0	0
Officine San Giorgio	DMU13	**100**	0	0	0	0	0	0
Salpa	DMU14	188	DMU12 (0.38) DMU17 (0.62)	17.51	0	527.83	0	8920.39
San Lorenzo	DMU15	244	DMU5 (0.18) DMU11 (0.63) DMU12 (0.18)	1.11	749.74	0	0	0
Saver	DMU16	**100**	1	0	0	0	0	0
Versilmarina	DMU17	**100**	2	0	0	0	0	0

Table 2
Relative efficiency, benchmarks and ranking of the companies (year 2008).

Rank	Companies	DMU	Score (%)	Benchmarks
1	Manò Marine	DMU12	100	9 times
2	Ferretti Spa	DMU5	100	5 times
3	Flag Marine	DMU7	100	3 times
3	InRizzardi	DMU11	100	3 times
4	Versilmarina	DMU17	100	2 times
5	Saver	DMU16	100	1 time
6	Innovazioni e Progetti	DMU9	100	0 times
6	Officine San Giorgio	DMU13	100	0 times
7	Cantiere F.lli Rossi	DMU3	109	DMU12 DMU16 DMU17
8	Inò Group	DMU10	174	DMU12 DMU17
9	Fiart Mare	DMU6	185	DMU5 DMU11 DMU12
10	Salpa	DMU14	188	DMU12 DMU17
11	Airon Marine	DMU1	221	DMU5 DMU11 DMU12
12	San Lorenzo	DMU15	244	DMU5 DMU11 DMU12
13	Cantiere Mariotti	DMU4	262	DMU7 DMU12
14	Franchini International	DMU8	511	DMU5 DMU7 DMU12
15	Canados Group	DMU2	564	DMU5 DMU7 DMU12

DEA results defines target inputs and outputs that inefficient firms have to adopt in order to reach the efficiency frontier: slack variables determine surplus in inputs and defect in outputs for each inefficient DMU and they are used to indicate target values (see Eq. (2)) to each inefficient DMU. Naturally, target values of efficient enterprises coincide with their current outputs and inputs. From the analysis of the inputs and outputs slacks (see Table 1) it is possible to notice that in order to become efficient some enterprises should reduce inputs and simultaneously increase outputs in terms of performance: for instance, DMU14 (Salpa) should reduce investments in personnel and R&D and, at the same time, increase its revenue.

Inefficient companies have to read these results in the following way: the enterprise that invests more in their Intellectual Capital does not always obtain a better business performance, because there is a cause-effect relationship between the two variables only in presence of an adequate management of the Intellectual Capital. Actually, the proposed method points out Best Practices to imitate for their capacity of management of Intellectual Capital. In fact, DEA highlights the presence of enterprises that have an efficient management of their Intellectual Capital and knowledge creation processes: they succeed in maximizing their own results in terms of performance without investing more than the other ones (Campisi & Costa, 2008).

The analysis is further extended introducing the Malmquist Productivity Index (applied between the years 2005 and 2008) in order to determine the productivity of the Intellectual Capital of the 17 companies (Fig. 1). The introduction of the MPI allows to compare shift in technology and catching-up in efficiency with company efficiency (previously measured by means of DEA) and it represents the potential competitiveness of the company within its industry: the capacity of the company to constantly increase the efficiency and productivity of its Intellectual Capital (Liu & Wang, 2008; Wu et al., 2006).

Table 3 shows four categories that classify the yacht builder companies on the basis of their relative efficiency in the year 2008 (score in the Table 1) and the results of the MPI analysis on the sample (Fig. 1).

The four categories are characterized as follows:

- High competitiveness and rapid growth: from 2005 to 2008 the companies in this category have improved rapidly. They are applying excellent strategies of Intellectual Capital management and should maintain their competitive advantages by continuing current strategies.
- High competitiveness and slow growth: in 2008 the companies in this category still benefit from good efficiency in managing their Intellectual Capital, but their competitiveness is continuously

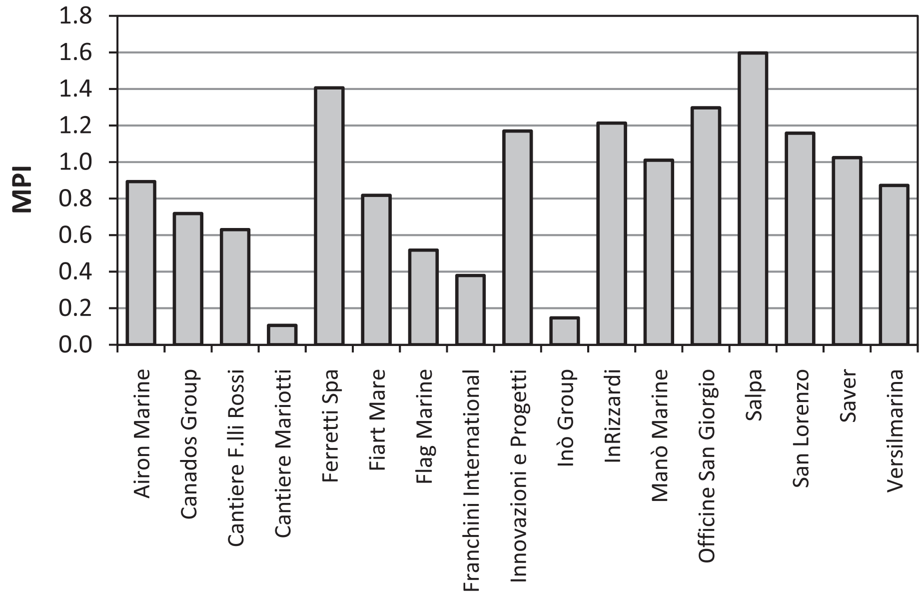

Fig. 1. Total factor productivity expressed by MPI in the 4 years period 2005–2008.

Table 3
Four categories classification based on relative efficiency (2008) and MPI (2005–2008).

	MPI ⩾ 1 Rapid growth	MPI < 1 Slow growth
Efficient companies	Ferretti Spa	
High competitiveness	Innovazioni e Progetti	
	InRizzardi	Flag Marine
	Manò Marine	Versilmarina
	Officine San Giorgio	
	Saver	
Inefficient companies		Airon Marine
Low competitiveness		Canados Group
	San Lorenzo	Cantiere F.lli Rossi
	Salpa	Cantiere Mariotti
		Fiart Mare
		Franchini International
		Inò Group

declining. They have achieved no further progress in the 4 years period 2005–2008. If they do not want to lose their competitive advantage in the market they need to implement new innovative strategies.

- Low competitiveness and rapid growth: in 2008 the companies in this category have low-medium efficiency in managing their Intellectual Capital, but they are also characterized by a rapid efficiency growth within the 4 years period 2005–2008. These companies must continue their current strategies of efficiency improvement of their Intellectual Capital management in order to catch up with their competitors. Companies in this categories could rapidly reach efficiency and a good productivity of their Intellectual Capital.
- Low competitiveness and slow growth: in 2008 the companies in this category have low-medium efficiency in managing their Intellectual Capital. Moreover, they register a decline in efficiency from 2005 to 2008. This group need urgently a change of Intellectual Capital management strategies. They are losing their competitiveness and the possibility to seize their competitors is rapidly declining.

The introduction of the MPI allows a better interpretation of the results previously acquired by means of the DEA analysis. If we compare the performances obtained by the companies in Tables 1–3, we can elaborate better conclusions on their management of Intellectual Capital, on the basis of the efficiency and the productivity of their Intellectual Capital. For example, some of the Best Practises of the sector in the year 2008, Flag Marine and Versilmarina (ranked second and fourth in Table 2) risk to lose competitiveness in the long run. They are still benchmark to imitate by inefficient companies, but they were more competitive in the past. On the other hand, inefficient companies as San Lorenzo and Salpa have still a long way to go in order to close the gap with the other ones, but their MPI show that their current strategies of efficiency improvement may be the right ones. The comparison between the results of DEA and MPI gives a more insightful reading of the ability of a company in the exploitation of its Intellectual Capital, offering a dynamic measurement of the changing in the efficiency and productivity, where the solely DEA analysis is a static one.

This makes clear that DEA and MPI are not to be used ex-ante for the elaboration of possible strategies, but they has to be employed ex-post for assessing the efficiency of actions already undertaken. It is clear that the evaluation ex-post constitutes the essential basis for the formulation of future Intellectual Capital management strategies.

6. Conclusions

The paper analyse the relationship between Intellectual Capital management and firm performance of Italian yachting companies using DEA and MPI as empirical instruments. Moreover, it describes the strategic importance of the organization Intellectual Capital as a source of achievement of competitive advantage.

On the basis on an efficiency and productivity analysis of Italian yachting companies in the 4 years period 2005–2008, the study reveals that about half of the sample achieve efficiency, while the remaining companies have to improve in the management of their Intellectual Capital in order to catch up with their competitors.

The results of the study classify the companies analyzed in a ranking that reflect their ability in managing their own Intellectual Capital, identifying the Best Practises of the sector. The firms that want to improve their performance have to follow the example of these Best Practices: enterprises of the same industry that share the same processes of exploitation of the Intellectual Capital. This is the main reason that impose a choice of a sample belonging to the same industry: otherwise DEA benchmarks would lose any meaning for inefficient enterprises, because the value-creation process of intangible assets is surely very different depending on industrial sectors.

Then input and output slacks are measured in order to give to inefficient companies a direction for progress. In fact, input and output targets are extremely important to understand major organizational and structural problems within a company. The results show that enterprises that invest more in Intellectual Capital are not automatically the ones that get better business performance but there is a cause-effect relation only if an enterprise is excellent in the management of its Intellectual Capital.

The application of MPI shows that less than half of the companies of the sample improved their efficiency in the period of time considered and the comparison with the DEA results allows to deepen the conclusions on Intellectual Capital management.

The results give both academic and practical insights that could be used for the operational and strategic management of an organization Intellectual Capital.

Finally, DEA and MPI have long been used as excellent analytical tools for studying efficiency and productivity in profit and nonprofit organizations, but little has been mentioned about the applicability of them on knowledge-based companies to evaluate the efficiency Intellectual Capital management.

References

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science, 30*, 1078–1092.

Bontis, N., Dragonetti, N. C., Jacobsen, K., & Roos, G. (1999). The knowledge toolbox: A review of the tools, available to measure and manage intangible resources. *European Management Journal, 17*(4), 391–402.

Campisi, D., & Costa, R. (2008). A DEA based method to enhance intellectual capital management. *Knowledge and Process Management, 15*(3), 170–183.

Carlucci, D., & Schiuma, G. (2006). Knowledge asset value spiral: Linking knowledge assets to company's performance. *Knowledge and Process Management, 13*(1), 35–46.

Charnes, A., Cooper, W. W., Golany, B., Seiford, L. M., & Stutz, J. (1985). Foundation of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. *Journal of Econometrics, 30*(1–2), 91–107.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*, 429–444.

Chen, M. C., Cheng, S. J., & Hwang, Y. C. (2005). An empirical investigation of the relationship between intellectual and firms' market value and financial performance. *Journal of Intellectual Capital, 6*(2), 159–176.

Cheung, C. F., Lee, W. B., Wang, W. M., Chu, K. F., & To, S. (2003). A multi-perspective knowledge-based system for customer service management. *Expert Systems with Applications, 24*, 457–470.

Chin, K. S., Lo, K. C., & Leung, J. P. F. (2010). Development of user-satisfaction-based knowledge management performance measurement system with evidential reasoning approach. *Expert Systems with Applications, 37*, 366–382.

Coelli, T. J., Prasada Rao, D. S., & Battese, G. E. (1998). *An introduction to efficiency and productivity analysis*. Boston: Kluwer.

Fare, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical change and efficiency change in industrialized countries. *American Economic Review, 84*(1), 66–83.

Firestone, J. M. (2001). Estimating benefits of knowledge management initiatives: Concepts, methodology, and tools. *Journal of the KMCI, 1*(3), 110–129.

Grosskopf, S. (1993). Efficiency and productivity. In H. O. Fried, C. A. K. Lovell, & S. S. Schmidt (Eds.), *The measurement of productive efficiency: Techniques and applications* (pp. 160–194). New York: Oxford University Press.

Kingsley, M. (2002). Show me the money – measuring the return on knowledge management. <http://www.llrx.com/features/kmroi.htm>.

Lev, B. (2003a). *Intangible assets: Values, measures and risk*. Oxford: Oxford Management Readers.

Lev, B. (2003b). *Intangibles*. Milan: Etas.

Liu, F. H., & Wang, P. H. (2008). DEA Malmquist productivity measure: Taiwanese semiconductor companies. *International Journal of Production Economics, 112*, 367–379.

Lu, W. M., Wang, W. K., Tung, W. T., & Lin, F. (2010). Capability and efficiency of intellectual capital: The case of fabless companies in Taiwan. *Expert Systems with Applications, 37*, 546–555.

McKeen, J. D., Zack, M. H., & Singh, S. (2006). Knowledge management and organizational performance: An exploratory survey. In *Proceedings of the 39th Hawaii International Conference on System Sciences (HICSS'06)*.

Meenakshi, S., & Smith, P. (2002). A performance-based approach to knowledge management. *Journal of Knowledge Management Practice*. <http://www.tlainc.com/articl32.htm>.

Sexton, T. R. (1986). The methodology of data envelopment analysis in measuring efficiency: An assessment of data envelopment analysis. In R. H. Silkman (Ed.), *New directions for program evaluation* (pp. 7–299). San Francisco: Jossey-Bass.

Sveiby, K. E. (2001–2010). Methods for measuring intangible assets. <http://www.sveiby.com/articles/IntangibleMethods.htm>.

UCINA (Italian Marine Industry Association) (2010). UCINA for boating: a year of activity. Genoa. Italy: UCINA publications.

Wen, Y. F. (2009). An effectiveness measurement model for knowledge management. *Knowledge-Based Systems, 22*, 363–367.

Wu, T., Tsai, H., Cheng, K., & Lai, M. (2006). Assessment of intellectual capital management in Taiwanese IC design companies: Using DEA and the Malmquist productivity index. *R&D Management, 3*(5), 531–545.

Zambon, S. (2003). Study on the measurement of intangible assets and associated reporting practices. In *Official study for the directorate general "Enterprise" of the European Commission*. Luxembourg: Office for Official Publications of the European Communities. <http://ec.europa.eu/internal_market/services/docs/brs/competitiveness/2003study-intangassets-full_en.pdf>.