Intellectual Capital and Competitive Advantage: An Analysis of the Biotechnology Industry

Campisi Domenico, and Costa Roberta

Abstract**—**Intellectual capital measurement is a central aspect of knowledge management. The measurement and the evaluation of intangible assets play a key role in allowing an effective management of these assets as sources of competitiveness. For these reasons, managers and practitioners need conceptual and analytical tools taking into account the unique characteristics and economic significance of Intellectual Capital. Following this lead, we propose an efficiency and productivity analysis of Intellectual Capital, as a determinant factor of the company competitive advantage. The analysis is carried out by means of Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). These techniques identify Bests Practice companies that have accomplished competitive advantage implementing successful strategies of Intellectual Capital management, and offer to inefficient companies development paths by means of benchmarking. The proposed methodology is employed on the Biotechnology industry in the period 2007-2010.

Keywords**—**Data Envelopment Analysis, Innovation, Intangible assets, Intellectual Capital, Malmquist Productivity Index.

I. INTRODUCTION

THE aim of this paper is to develop a model for the measurement of the efficiency and productivity of the Intellectual Capital management and to analyze its implications in the Biotechnology industrial sector. In the modern business environment, Intellectual Capital management is increasingly recognized as a significant factor in becoming more and more competitive [1]. Moreover, Information and Communication Technology is connecting people at every level, creating a common knowledge that companies should foster and exploit for economic purposes [2]. For these reasons, managers and practitioners require conceptual and analytical tools taking into account the unique characteristics and economic significance of intangible assets [3]-[4]-[5].

Moreover, especially in knowledge intensive industries as the Biotechnology one, the value of intangible assets has been increasingly rising above the value of tangible assets. The tangible-intangible value gap is strictly correlated to the difference between a company book value and its market capitalization, underlining (above all for high-tech companies) the necessity to understand the impact of Intellectual Capital management on business performance [6].

This evidence underlines the necessity to explore the connection between intangible assets management and business performance. The understanding of the relationship between intangibles and business performance, such as efficiency and productivity [7]-[8], should provide both academic and practical insights that could be used for the operational and strategic management of Intellectual Capital [1].

Following this lead, we suggest a methodology to evaluate Intellectual Capital efficiency and productivity, searching for the Best Practices of an industrial sector. Then we analyze the Biotechnology industry in order to offer biotechnological companies guidelines for Intellectual Capital management.

This approach allows a direct comparison between companies belonging to the same industrial sector in the perspective of improvement through benchmarking. Moreover, it overcomes one of the main limitations of the current Intellectual Capital measurement methodologies, allowing to compare enterprises about their management of intangible assets [9].

The outcome of the methodology application to the Biotechnology industrial sector should give to inefficient companies guidelines to elaborate future Intellectual Capital management strategies.

II. LITERATURE REVIEW

Traditional accounting models are not adequate to determine the value of an organization because of its intangible assets [3]. Financial statements include some information on intangible assets as licenses, trademarks and patents, but they lack information on customer loyalty and satisfaction, corporate image, corporate social responsibility and many other valuable intangible assets which have no formal place in traditional accounting methodologies [12]-[13]-[14]-[15].

Nevertheless, also the current methods for the measurement of intangible assets do not fully address the issue inherent the connection among investments in Intellectual Capital intangibles, their management and their effects on business performance [10]. So far, the interest on the topic has boosted the creation of numerous intangibles-oriented form of corporate reporting and the creation of new models and methodologies studied for assessing all the factors, tangible and intangible, that have influence on a company value creation process [6].

Even though there are several noteworthy methods for Intellectual Capital measurement, their outcome about

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intangible values is not precise in an absolute way, but it is an excellent reference for benchmarking and a good measure of the evolution of a company in time [1]-[3].

Several studies have attempted to deal with the issue of how Intellectual Capital management improves business performance generating value in the organization. For example, the effects of Knowledge Management on the company value creation process, such as creativity improvement, have been analyzed focusing on the quantitative measures of this impact [16]. Moreover, the return of Intellectual Capital investments and management on knowledge productivity has been analyzed [1]-[17]-[18].

In this paper, we refer to Intellectual Capital choosing one of its most famous definitions, as the economic value of the combination of three categories of intangibles [11]:

• the "Human Capital" that refers to the abilities, the competences, the know-how of human resources;

• the "Structural Capital" that defines the organizational knowledge, mainly contained in business processes, procedures and systems;

• the "Relational Capital" that takes account of the knowledge embedded in business networks, which includes connections outside the organization such as customer loyalty, goodwill, and supplier relations.

The aim of the paper is to assess the effectiveness of Intellectual Capital management strategies, and to identify the most critical knowledge assets to be managed for achieving performance improvements. Following this lead, we propose a methodology that allows to estimate the efficiency and productivity of Intellectual Capital management.

III. The Methodology

A. The Data Envelopment Analysis

The Data Envelopment Analysis (DEA) is a technique that measures the relative efficiency of each member of a set of comparable units, called Decision Making Units (DMUs), on the basis of a theoretical optimal performance [20]-[21]. The organizational units under analysis can be companies and institutions, or branches of the same firm. DEA is a feasible technique to study the complexity of the processes that transform Intellectual Capital investments in business performance, because it evaluates the relative efficiencies of DMUs without any assumption about the functional relationship between inputs and outputs.

Indeed, DEA focuses on the "real" production frontier determined by the companies (DMUs) under analysis, without estimating "a priori" the best production function. For this reason, the analyzed firms have to belong to the same business sector: they have to be comparable for dimension and industry, in order to presume that the intangible processes of value-creation are similar.

Moreover, DEA provides an aggregate measure of relative efficiency for each company and it determines a ranking system of the firms within their industry. The high-ranking (efficient) companies are the Best Practices of their industry and they constitute a benchmark that low-ranking (inefficient) companies should imitate. Moreover, DEA prescribes to inefficient firms what adjustments to the inputs and outputs should be made to reach the efficiency frontier.

The choice of DEA inputs has to reflect the composition of the company Intellectual Capital [11], while outputs should be correlated to the economic-financial performance of the firm and the Intellectual Capital productivity.

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.

The generic DMU_j consumes a quantity $x_j = \{x_{ij}\}$ of inputs (i=1,..., m) and produces a quantity $y_j = \{y_{rj}\}$ of outputs (r=1,..., t). Knowledge Management researchers agree that the return to scale of Intellectual Capital is increasing. Basing on this assumption, the DEA model most suitable for the analysis of the intangible efficiency is the model BBC (the name of the model is the acronym of the authors[21]) that is characterized by variable return to scale (VRS model). The model has to be output oriented, because a company interested in improving the efficiency of Intellectual Capital management is focused on maximizing its outputs in terms of performance and not on minimizing its inputs in terms of costs [22]. The output-oriented model, maximizes output level under at most the present input consumption.

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

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

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 $\phi y°$, 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 =TE) 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 (Σλ) 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 (ϕ=1, λ_o=1, $\lambda_{j\neq 0}$=0, all constraints satisfied with equality). Non-dominated and efficient DMUs are characterized by unitary efficiency (ϕ=100%) and dominated-inefficient DMUs will be labeled by a ϕ smaller than 100%.

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

- ϕ^*=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:

$$x_i^{'} = x_i^o - s_i^* \quad \forall i$$
$$y_r^{'} = \phi^* y_r^o + s_r^* \quad \forall r \qquad (2)$$

B. 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 [23]-[24]. 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:

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

Equation 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.

IV. The Biotechnology Industry

The DEA and MPI methodologies put in evidence companies that have successfully implemented strategies of intangible assets management from less efficient ones and it can be applied to any industry and any typology of company [1]-[17]-[18]-[19]. The proposed approach offers the advantage of allowing a direct comparison between firms of the same industry regarding their management of intangibles.

In this paper, we apply the methodology to the "EU Industrial R&D Investment Scoreboard", an European Union's annual database containing the top 1000 worldwide companies in terms of investment in research and development [25]. We analyze data on intangibles from the EU database, companies' websites and reports. In particular, we analyze the 30 best worldwide innovative companies belonging to the Biotechnology industry in the four years period 2007-2010.

The inputs and outputs chosen for the analysis are correlated to the components of the Intellectual Capital (Human Capital, Relationship Capital, Structural Capital). This choice allows us to determine the relative efficiency and productivity of the enterprises about their ability to manage their knowledge assets, compared to other enterprises of the Biotechnology industrial sector. The analytical results reveal if the business sectors under analysis achieve efficiency and productivity growth in knowledge management and, if not, how much they have to improve their Intellectual Capital management.

V. Results

Several studies analyze how to transform Intellectual Capital investments in a competitive advantage [1]-[17]-[18]-[19]-[26]-[27]. This paper investigates the impact of Intellectual Capital management on business performance through a quantitative approach.

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

- first input (I1): R&D Investments (Innovation Capital, Structural Capital) [1]-[17]-[18];
- second input (I2): Employees (Human Capital) [16]- [19]-[26]-[27]-[28];
- third input (I3): patents [1]-[9]-[17]-[18];
- first output (O1): net sales. The net sales are operating revenues earned by a company when it sells its products. It is a financial indicator that quantifies the competiveness of a company in its business sector;

- second output (O2): market capitalization. The market capitalization captures the value that the market attributes to an organization beyond its tangible assets, considering the added value generated by the organization intangibles.

We matched the results obtained through the application of DEA with those relating to the calculation of MPI. For this purpose we realize a clustering in 6 categories segmenting the values of the MPI and the technical efficiency (Table I).

The 6 categories are characterized as follows:

I. High competitiveness and rapid growth: from 2007 to 2010 the companies in this category have improved rapidly. They are applying excellent strategies of Intellectual Capital management and should maintain their competitive advantage by maintaining current strategies.

II. High competitiveness and slow growth: the companies in this category still benefit from good efficiency in managing their Intellectual Capital, but their competitiveness is declining. They have achieved no further progress in the 4 years period under analysis. If they do not want to lose their competitive advantage in the market they need to implement new innovative strategies.

III. Medium competitiveness and rapid growth: in 2007-2010 the companies in this category have medium efficiency in managing their Intellectual Capital, but they are also characterized by a rapid efficiency growth. These companies must continue their current strategies of Intellectual Capital management in order to catch up with their competitors. Companies are gradually reaching efficiency and a good productivity of their intangibles. The improvements in efficiency are gradual but not as rapid as those of the firms belonging to Group I;

IV. Medium competitiveness and slow growth: in 2007-2010 the companies in this category have medium efficiency in managing their Intellectual Capital. Moreover, they register a decline in efficiency from 2007 to 2010. For these reasons, these firms have to improve their Intellectual Capital management strategies. Gradually they are losing their competitiveness and the possibility to seize their competitors is rapidly declining. The decline of competitiveness is more severe than in Group II;

V. Low competitiveness and rapid growth: in 2007-2010 the companies in this category have low efficiency in Intellectual Capital management, but they are also characterized by a rapid efficiency growth within the four years period. These companies must continue their current strategies of efficiency improvement in order to catch up with their competitors. These companies can rapidly reach efficiency and a good productivity of their Intellectual Capital, but they have more distance to cover than the firms in Group III;

VI. Low competitiveness and slow growth: in 2007-2010 the companies in this category have low efficiency in managing their Intellectual Capital. Moreover, they register a decline in efficiency in the same period. 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 decline of competitiveness is more severe than in Group III, since their current efficiency in managing Intellectual Capital is lower.

TABLE I
CLASSIFICATION BASED ON RELATIVE EFFICIENCY AND MPI

Category	Malmquist Index	Relative efficiency	Description
I	MPI ≥ 1	TE ≥ 0,8	High competitiveness Rapid growth
II	MPI < 1	TE ≥ 0,8	High competitiveness Slow growth
III	MPI ≥ 1	0,5 < TE < 0,8	Medium competitiveness Rapid growth
IV	MPI < 1	0,5 < TE < 0,8	Medium competitiveness Slow growth
V	MPI ≥ 1	TE ≤ 0,5	Low competitiveness Rapid growth
VI	MPI < 1	TE ≤ 0,5	Low competitiveness Slow growth

Table II summarizes the results obtained from the study of the Biotechnology industrial sector. The percentage of efficient companies is very high (33%) and the Best Practices of the sector are clearly identifiable: they are the American Incyte (group I) and Celgene (group II), and the Danish Topotarget (group I). From Fig. 2 we can see that a considerable part of the sample (43%) is classified in Group I (high competitiveness and rapid growth). Nevertheless, many other companies (33%) belong to the less performing groups IV, V and VI, affecting negatively the overall performance of the sector. We note however that about two-thirds of the sample present significant progress in terms of productivity in the four-year period. In the light of the results obtained, with an average efficiency of 0.602 and MPI index equal to 1.128, the sector is classified in Group III (average competitiveness and rapid growth).

VI. CONCLUSION

Today, Intellectual Capital is widely considered the most important competitive factor for a modern organization. In this paper, we analyze the importance of intangible assets and the role of knowledge management in the new economy. The “knowledge-based” company views its Intellectual Capital as a real asset that has to maximize the organizational productivity. Following this lead, we investigate the relationship between Intellectual Capital management and firm performance in the Biotechnology industry using DEA and MPI. Moreover, we describe the strategic importance of

TABLE II
THE RESULTS OF THE ANALYSIS

Country	Company	TE SCORE 2010	MPI 2007-20010	GRUPPO	FREQUENZA BENCHMARK
USA	Amgen	1	1.084	I	0
UK	Ark Therapeutics	0.103	0.58	VI	0
USA	Biogen Idec	0.852	1.096	I	0
Sweden	Biovitrum	0.431	0.971	VI	0
USA	Celgene	1	0.82	II	**17**
USA	Cell Genesys	1	2.182	I	1
USA	Cubist Pharmaceuticals	0.876	1.242	I	0
Belgium	Devgen	0.617	1.261	III	0
Denmark	Genmab	0.39	0.485	VI	0
USA	Geron	0.578	0.946	IV	0
USA	Gilead Sciences	1	0.918	II	5
USA	Idenix Pharmaceuticals	0.416	1.274	V	0
USA	Incyte	1	1.772	I	**13**
Austria	Intercell	0.357	0.624	VI	0
USA	InterMune	0.988	1.413	I	0
USA	Lexicon Pharmaceuticals	0.525	1.327	III	0
USA	Medarex	0.719	1.303	III	0
Germany	MediGene	1	1.051	I	5
USA	Nektar Therapeutics	0.502	1.068	III	0
USA	Neurocrine Biosciences	0.116	0.705	VI	0
Denmark	NeuroSearch	0.309	0.696	VI	0
USA	OSI Pharmaceuticals	0.554	0.849	IV	0
USA	PDL BioPharma	1	2.962	I	8
The Netherlands	Pharming	0.199	0.85	VI	0
Denmark	Topotarget	1	2.144	I	**14**
USA	United Therapeutics	0.846	1.074	I	0
UK	Vernalis	1	1.421	I	0
USA	Vertex Pharmaceuticals	0.973	1.146	I	0
USA	XOMA	1	2.288	I	1
USA	Zymogenetics	0.603	1.356	III	0
	Average	**0.602**	**1.128**	**III**	

the organizational Intellectual Capital as a source of competitive advantage.

On the basis on an efficiency and productivity analysis of the worldwide biotechnological companies in the four years period 2007-2010, the study reveals that one-third 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.

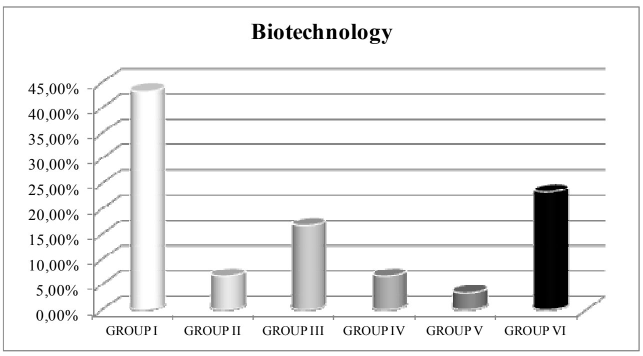

Fig. 1 Classification of the Biotechnology industry companies

The study classifies the companies in six categories depending on their ability in Intellectual Capital management, and identifies the Best Practices 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. The application of MPI shows that about two third 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.

Finally, the combination of DEA and MPI gives guidelines to decision makers and offers academic insights that could be used for the operational and strategic management of Intellectual Capital.

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