Statistical Analysis for Strategic Innovation Decisions in Slovenian Mechanical Industry

Peter Fatur[*] - Borut Likar
University of Primorska, Faculty of Management, Slovenia

The objective of this study is to identify the main factors influencing the innovation and R&D performance of the machinery and equipment manufacturing industry in the Republic of Slovenia (RS). The research is based on statistical data from the Statistical Office of RS. Spearman's coefficient of correlation has been applied to the entire set of input and output variables in calculating the correlation coefficients. Results indicate the existence of two clusters of companies. Both are innovation followers but differ in their capabilities to produce breakthrough innovations and innovation-related turnover. For both of them, no correlation between the innovation outputs and business/financial performance is present.

Based on the empirical findings, we propose some organizational areas where additional managerial effort needs to be invested. Thus, the research also has a practical implication for the enterprises as well as for the national policy makers.

0 INTRODUCTION

The European Union's (EU) Lisbon goal of becoming the world's most competitive business environment by the year 2010 has not been met. According to the recent statistical indicators [1] the EU is still losing ground in business exploitation of knowledge and creativity to the United States (US) and Japan. Even though the innovation gap has decreased in the last years (towards US from 41 to 28%, and towards Japan form 42 to 38% in the 2004 to 2008 period) it remains significant.

The national innovation performances of European countries vary a lot. The European Innovation Scoreboard (EIS) classifies the countries into the following groups [1]: (i) the innovation leaders, including Denmark, Finland, Germany, Israel, Japan, Sweden, Switzerland, UK and USA. Sweden is the most innovative country, largely due to strong innovation inputs although it is less efficient than some other countries in transforming these into innovation outputs; (ii) the innovation followers include Austria, Belgium, Canada, France, Iceland, Ireland, Luxembourg and the Netherlands; (iii) the moderate innovators group includes Australia, Cyprus, Czech Republic, Estonia, Italy, Norway, Slovenia and Spain; (iv) the catching-up group

consists of Bulgaria, Croatia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania and Slovakia. These country groups appear to have been relatively stable over the last years.

An indicator of the innovation capability is a turnover of new or significantly improved products new to the market as a percentage of total turnover. For the year 2004, it counts 3.5% for medium and 8.5% for large companies for EU27. The relative turnover of new or significantly improved products new to the firm counts 5.1% for medium and 9.3% for large companies.

Pursuant to the national statistical data [2] only 35.1% of Slovenian companies prove to be innovative and 41.2% in the manufacturing sector. The machinery and equipment manufacturing industry [3] as the subject of our research performs better; however, no more than 47.3% of companies in this industry actively pursue innovation.

What is more, an in-depth analysis noticeably shows that the situation regarding innovation in Slovenian small and medium enterprises (SME) is even worse where the large companies record approximately 50% more innovativeness as the medium-sized ones while the small companies even threefold less than the

---

[*]Corr. Author's Address: University of Primorska, Faculty of Management, Cankarjeva 5, 6000 Koper, Slovenia, peter.fatur@fm-kp.si

large ones [2] (here it needs to be taken into consideration that an enterprise – regardless of its size – is classified in the statistical group of innovative enterprises by introducing at least one new product. The latter thus represents a "statistical benefit" for large companies.). Apparently, Slovenian manufacturing needs an innovation push to outrun the group of innovation followers and catch up with the group of innovation leaders.

Literature tackles different approaches to pursue innovation yet one of the fundamental ones proves to be an analysis of innovation processes based on input, process and output groups of indicators, either individual or composite.

Individual indicators [4] to [6] measure single influential factors (e.g. the amount of resources invested into the research and development (R&D), the annual number of days dedicated to training of management/employees). The problem of individual indicators remains their inability to deal with with the complexity of the innovation management field. Consequently, the composite indicators prove to be more appropriate since they regard the invention-innovation process with due complexity, as an intertwinement of related and correlated factors [7].

The input indicators (also referred to as "investment" indicators) include e.g. expenditure on R&D or employees training; [8] and [9]. The process indicators take into account the organisation or management of innovation processes, the use of appropriate management techniques (market research, problem analysis and idea creation techniques, forecasting techniques, etc.), and innovation environment within a company. The output indicators identify results, e.g. the number of patents and new products, market shares, revenues from the sales of innovations and innovative products etc.; [9] and [11]. Several studies have shown the correlations among the input, process and output variables. Hollenstein shows the correlations between the input (e.g. research input, development input) and the output-oriented indicators (e.g. number of patents, number of innovation projects) and the market-oriented measures (sales share of new products) – thus indicating the innovativeness of a firm [6]. Iansiti shows correlations among input (e.g. technology

from suppliers, technology from other groups) and process indicators (e.g. research groups, project management, communication) and technological potential and yield [8].

The results of Parthasarthy's study show that both, the innovation input and the innovation process have implications for innovation frequency, i.e. the number of new products introduced [12]. He realised that R&D intensity, by itself, positively influences the invented technologies; developing them into new products and marketing them frequently requires a corresponding level of functional integration. Developing a "marketable" product involves a transition form sequential to concurrent product and process development, using apposite product development techniques, e.g. design for assembly and pre-testing of processes by the process simulation tools [13] to [15].

Regardless of the fact that many approaches try to find the key influential factors for an effective management of innovation, an apposite method has thus far not been developed. The cited methods hold another limitation, namely they were all tested on somewhat small samples of companies and failed to focus on the machinery and equipment manufacturing industry which is the subject of our study.

Thus, the objective of this study is to identify the main influential factors and estimate their effects on the innovation and R&D performance in the machinery and equipment manufacturing industry in the RS.

1 METHODS

Pursuant to the official classification [3], our research encompassed companies headquartered in RS, belonging to the statistical class DK29: Manufacture of machinery and equipment. The sample size was 2500 companies while the subset of the statistical class DK29 comprised a total of 144 companies.

The Statistical Office of the RS (SURS) regularly collects the data on target industry pursuing standardized methodology, [16] to [18]. The statistical survey providing the core data for our research is the most recent Community Innovation Survey (CIS 2006) which in 2007 was carried out across Europe. The Slovenian CIS 2006 survey includes data from the years 2004 to 2006 on the enterprises' product (good or

service), organisational and process innovations, innovation activities and expenditures, co-operation in innovation and the effects of innovation. In addition, company's financial data (balance sheet, profit-and-loss account and some key financial ratios) was collected from the official statistical database on companies (Agency of the RS for Public Legal Records and Related Services), while the third statistical database (Statistical Register of Employment (SRDAP)) provided for data on the educational structure of employees. The employment data refer to the business year 2006 while the financial data comprise the period between 2003 (a year before the CIS survey) and 2007 (the subsequent year).

A group of relevant variables was selected from the statistical databases (Table 1). The two key variables that represent a measurable output from the innovation process have been defined as: RII ("Revenues from innovation index"), i.e. a share of turnover resulting from innovations, and RMI ("Revenues from market innovation index"), i.e. a ratio of turnover from innovations new to the market to turnover from innovations new to the company only. Furthermore, we defined the Lead index (LI) as a contemporary measure of the influence of both RII and RMI. A definition of indices is shown in Table 2.

Spearman's coefficient of correlation (*SCC*) was then applied to the entire set of input and output variables in calculating the correlation coefficients. Regardless of the fact that between the two associated variables the Spearman coefficient has less significance than the Pearson's coefficient, it is suitable for calculating correlations not only among the interval (associated) and ranked (discrete), but among combined variables used in a research.

2 RESULTS

We aimed to identify a relationship between the two key output variables from the innovation process, *RII* and *RMI*. Surprisingly, the Spearman correlation analysis showed no correlation (*SCC* = 0.01; *sig* = 0.94). Thus, there are a number of companies in the Slovenian machinery and equipment manufacturing industry with both, a high share of turnover from innovations and a high share of turnover from "radical" innovation in total innovation turnover

(high *RII* and high *RMI*). These companies are innovation leaders in the industry (Fig. 1).
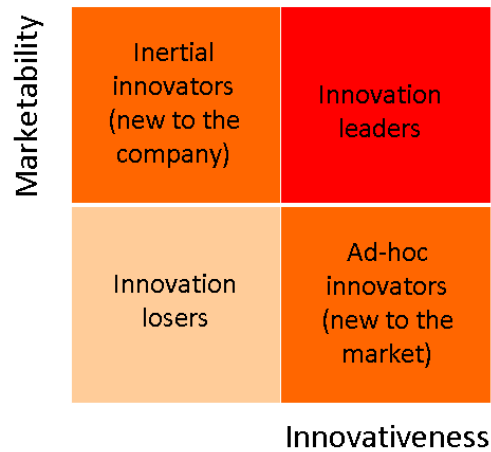

Fig. 1. *The Marketability/Inovativeness matrix*

On the other side of the matrix (low *RII* and low *RMI*), there are companies with little revenues from innovations and the latter are of minor impact (presumably of incremental type, e.g. incremental improvements to their existing products to follow the technology or market trends) – we call them "innovation losers".

Our research focused on the companies in-between the two poles. Both groups are market/innovation followers.

The first cluster of companies (high *RII* and low *RMI*) makes a notable part of their revenues out of recently introduced products. However, these products usually act as substitutes to the company's existing products with no radical improvements incorporated. The result of such a strategy is no influence of new products over companies' financial performance. We named this type of companies "inertial innovators".

Companies from the second cluster ("ad hoc innovators") produce some market inventions, resulting in new products being introduced onto the market before competitors (low *RII* and high *RMI*). Such products incorporate a much higher degree of creativity. However, these companies somehow fail to make substantial revenues out of them. Therefore, the influence of innovation on the companies' financial performance is again very moderate, if there is any at all.

Table 1. *Definitions of variables under study*

Variable name	Definition
a1	The enterprise is part of an enterprise group
Intd_Good	The enterprise introduced new or significantly improved goods
Intd_Serv	The enterprise introduced new or significantly improved services
Intd_Proc	The enterprise introduced new or significantly improved processes
Intd_Org	The enterprise introduced new or significantly improved organizational methods
a3_1	Markets served: Local / regional within Slovenia
a3_2	Markets served: National
a3_3	Markets served: Other EU countries, EFTA, or EU candidate countries
e3_3	Enterprise received financial support for innovation activities from the EU
f31	Co-operation partner: Within your enterprise or enterprise group
f32	Co-operation partner: Suppliers of equipment, materials, components or software
f33	Co-operation partner: Clients or customers
f34	Co-operation partner: Competitors and other firms from the same industry
f35	Co-operation partner: Consultants, commercial labs, or private R&D institutes
f36	Co-operation partner: Universities or other higher education institutes
f37	Co-operation partner: Government or public research institutes
f3_slo	Partners for cooperation in innovation activities - Slovenia
f3_exp	Partners for cooperation in innovation activities - abroad
e1_2	The firm performed R&D continuously.
Exp_IntRD_Emp	Intramural (in-house) R&D expenditures / Total turnover 2006
Exp_ExtRD_Emp	Acquisition of R&D (extramural R&D) / Total turnover 2006
Exp_RD_Emp	Intramural + extramural R&D expenditures / Total turnover 2006
Exp_Tot_Emp	Total expenditures in innovation / Total turnover 2006
FA1_1	Factor Profit
FA2_1	Factor Labor cost
rev_0607	Total turnover growth 07/06 (%)
rev_exp_0607	Total turnover growth in foreign markets 07/06 (%)
emp_tech_all	Share of employees with an engineering degree
emp_edu_89	Share of employees with a masters or doctoral degree
emp_edu_6789	Share of employees with at least higher education

Table 2. *The key output variables of the innovation process*

RII	Revenues from innovation index	[Turnover from innovations introduced] / [Total turnover]
RMI	Revenues from market innovation index	[Turnover from innovations new to the market] / [Turnover from innovations new to the company]
LI	Lead index	{[Turnover new to the market] / ([Total turnover] – [Turnover new to the market])} * {([Turnover new to the market] + [Turnover new to the company] / [Total turnover]}

What are the specific characteristics of each group?

2.1 The "Inertial Innovators"

The "inertial innovators" are the ones with a high correlation between the share of turnover from innovations (*RII*) and a set of influential (input or process) factors which will be investigated in this section.

The output variable *RII* correlates with the introduction of new products, either goods (*Intd_Good*: $SCC = 0.866$; $sig = 0$) or services (*Intd_Serv*: $SCC = 0.513$; $sig = 0$) and new processes (*Intd_Proc*: $SCC = 0.535$; $sig = 0$), i.e. "techn(olog)ical" innovations, but much less with

the introduction of organizational innovations (*Intd_Org*: *SCC* = 0.193; *sig* = 0.021). Further, *RII* correlates with the extent of cooperation in innovation activities with other organizations (*f3_slo*: *SCC* = 0.774; *sig* = 0), (*f3_exp*: *SCC* = 0.733; *sig* = 0). Companies in this group collaborate intensively, in particular with the customers (*f33*: *SCC* = 0.787; *sig* = 0).

Further, there is a correlation of the above output index with the level of education of the employees (share of employees with at least higher education (*emp_edu_6789*: *SCC* = 0.424; *sig* = 0); share of employees with a masters or doctoral degree (*emp_edu_89*: *SCC* = 0.300; *sig* = 0)). These companies do not serve the local or regional markets (*a3_1*: *SCC* = 0.063; *sig* = 0.454) but rather the national (*a3_2*: *SCC* = 0.348; *sig* = 0) and export (*a3_3*: *SCC* = 0.290; *sig* = 0) markets, where their revenues are slightly growing (*rev_exp_0607*: *SCC* = 0.249; *sig* = 0.017). A high *RII* shows no correlation with the financial result (*FA1_1*: *SCC* = 0.025; *sig* = 0.776).

It seems that this type of innovation followers represents relatively rigid, well established organizations which have traditionally performed the innovation activities but have done them somehow by inertia. We may define their attitude towards innovation as "we always did it this way" – which is not far from routine (in its negative sense) and which results in no breakthrough innovation but rather a continual improvement of existing products and processes to follow the technical/technological developments in the market. The internal organization can (and has to) remain unchanged for long periods. These companies manage to keep their market positions but are condemned to stagnation and vulnerable to new competition with innovative substitutes for their existing products.

This profile of companies intensively cooperates with customers in the field of innovation. The cooperation goes along with the up-to-date concept of open innovation, [19] and [20]. However, it may also imply the company's position "the customer is a king" which relies on the customer's demands but very often pushes the company in a defensive position. Namely, customers usually request products already seen at the competition, not products solving their in-depth problems, problems they may not even be aware of. A company following the customer's requirements without a critical assessment and without a creative insight into deep customer needs may quickly be mislead in the direction of copying existing market solutions and becoming an innovation follower.

2.2 The "Ad Hoc Innovators"

The "ad hoc innovators" are the ones with a high correlation between the *RMI* and some of the influential factors (input or process indices). This is a less defined group than the group of inertial innovators – the correlations are lower – yet it shows some interesting characteristics.

As shown above, the output indices *RMI* and *RII* have no mutual correlation. Furthermore, *RMI* has none or very little correlation with the indices that correlate high with *RII*.

Data on company size was not available. However, since there is no correlation in this cluster with the introduction of products (*Intd_Good*: *SCC* = 0.026; *sig* = 0.857), (*Intd_Serv*: *SCC* = 0.085; *sig* = 0.551) and new processes (*Intd_Proc*: *SCC* = 0.141; *sig* = 0.323) (the three indices being a logical consequence of company size, as discussed in Introduction), it can be assumed that this cluster consists of smaller companies than the cluster of inertial innovators. These types of companies are often a part of an enterprise company group (*a1*: *SCC* = 0.397; *sig* = 0.004); other enterprises in the group are their major cooperation partner in innovation (*f31*: *SCC* = 0.394; *sig* = 0.046).

RMI correlates with the question whether the company performed R&D continuously of occasionally (*e1_2*: *SCC* = 0.366; *sig* = 0.011). Obviously, there is a systematic R&D ongoing in companies with a high share of turnover from "radical" innovation in total innovation turnover. To perform R&D, these companies more often make use of public funding from the EU (*e3_3*: *SCC* = 0.362; *sig* = 0.009).

Further, there is a correlation with labour costs per employee (*FA2_1*: *SCC* = 0.336; *sig* = 0.024) and a negative correlation with the share of employees with a technical background of high school level and higher (*emp_tech_all*: *SCC* = -0.335; *sig* = 0.016) (this may indicate lower salaries of engineering staff in comparison to other profiles (!)).

The output index *RMI* also correlates with the growth of revenues in export (*rev_exp_0607*: $SCC = 0.314$; *sig* $= 0.050$). However, as in the former case, it shows no correlation with the company financial results (*FA1_1*: $SCC = -0.152$; *sig* $= 0.319$).

At first glance, these companies seem to have a better profile for innovation success. They produce "real" market inventions, resulting in new products being introduced onto the market before competitors. By exploiting knowledge from various sources they manage to incorporate a higher degree of creativity in their products than in the case of inertial innovators. However, these companies somehow fail to make substantial revenues out of their new products. Therefore, the influence of innovation on the companies' financial performance is again very moderate, if any at all. It looks as they put more effort in knowledge creation than in marketing it effectively.

2.3 The Lead Index

There is no correlation between the share of turnover from innovations in total turnover (*RII*) and the ratio of turnover from innovations new to the market to turnover from innovations new to the company (*RMI*). Thus, companies with high quality innovations not (necessarily) make a lot of sales out of them (and vice versa). In order to determine the factors that may contemporary influence both output indices *RII* and *RMI* we have defined a third output index called the Lead index (*LI*). Since *RMI* shows very little correlation with inputs, it is apparent that *LI* is somehow biased towards *RII* but is still a good estimate to determine the factors that a company needs to focus upon when trying to improve the innovation system. The findings will be discussed in the subsequent section.

3 DISCUSSION

As shown in the Results section, the correlations among groups of influencing indicators and companies' economic/financial results are not significant, either for the group of inertial innovators or for the ad hoc innovators. As it is difficult to explain precisely the reason(s), some possible options will be discussed.

First, some relevant EU findings need to be investigated. Innovation performance in the EIS is measured as the average performance on both innovation inputs and innovation outputs. Efficiency analyses among the input and output dimensions show that for most countries there are efficiency gains to be reached. This applies to countries of all levels of performance: many of the innovation leaders (see Introduction) have relatively low innovation efficiency while several of the moderate innovators and catching-up countries have a relatively high efficiency. Slovenia, besides being ranked in the group of moderate innovators (third out of four groups), combines low efficiency in transforming innovation inputs both in Intellectual property and in Applications (Intellectual property measures the achieved results in terms of successful know-how; Applications measures the performance in terms of labour and business activities and their value added in innovative sectors) [1].

The same might be the case of the companies from the "ad hoc innovators" cluster. They produce some market inventions, resulting in new products being introduced onto the market before competitors. Such products incorporate a high degree of creativity. However, these companies are inefficient in exploiting them on the market and thus fail to make substantial revenues out of them. Therefore, the influence of innovation on the companies' financial performance is very moderate.

Another reason for poor economic performance might be a small share of break-through innovations in the companies' innovation portfolio. Companies are not primarily focused on products which are new to the market but on those which are new to the company only, e.g. a development of the improved products but not completely new ones; an orientation on costs reduction; a reduced time to respond to customer or supplier needs; an improved communication or information sharing etc. Such an approach is a characteristic of the innovation followers, not the leaders. This thesis can be supported by the authors' several years of experience in the National commission for Innovation rewards at the Chamber of Commerce of RS. The most common patterns/types of best Slovenian innovation projects are improvements of existing products, new products/services connected with relatively unimportant incremental innovations,

Fatur, P. – Likar, B.

cost-cutting innovations and other types, which are not connected with break-through ideas – neither via completely new products nor new, highly efficient business models. Such products only lead to little added value. Only a small proportion is the break-through innovations.

Such a situation is prevailing in our first cluster of companies ("inertial innovators") that invest considerable amounts in innovation and make a notable part of their revenues out of recently introduced products. However, these products usually act as regular substitutes of their existing products with no radical improvements incorporated. The result of such a strategy, as it is clear from the correlation matrix, is no influence of these new products to companies' financial performance.

Given the complexity of innovation management science, there is evidently no recipe to improve the efficiency of innovation inputs. However, the Lead Index that contemporarily measures the influence of both the (i) share of turnover resulting from innovations and (ii) share of turnover from innovation new to market in total turnover from innovation indicates some suggestions.

Having creative work undertaken within the enterprise to increase the stock of knowledge and using it to devise new and improved products and processes – in particular in form of the internal R&D process – running continuously and not just occasionally, seems to be one of decisive factors. There is an indication that innovations need to be developed by the company itself and not purchased from outside. However, a well established partnership is required with multiple partners used either for co-creation of innovations or as a source of information (in particular customers, consultants and external research institutions). A share of employees with a masters or doctoral degree has a positive correlation as well. The companies' marketing activities (the introduction of the innovations to the market) needs to be enforced. Finally, the organizational innovations – in particular innovative business models – that proved to be a weak point in our sample – should receive more attention of the managers.

4 CONCLUSION

Despite some encouraging indicators and at times somewhat misleading statistical data, it is obvious that only a moderate portion of the innovative potential of enterprises in the Slovenian mechanical industry is exploited. The incontestable fact remains that the influence of innovation on the companies' revenues and profit remains too low. A clear strategy of innovation and appropriate further activities are the crucial factors leading to an increase of this influence [21]. The strategy should consistently support the innovation process and strongly focus on most important activities leading to the best innovation performance. Since the innovation introduced to the market is only the last of the links in the invention-innovation chain, a comprehensive and systematic approach is required. In order to asure such an approach, the "innovation of management" [22] in the way that it would be able to manage the innovation process effectively remains a prerequisite.

5 REFERENCES

[1] *European Innovation Scoreboard 2007 - Comparative analysis of innovation performance.* (2008). Luxembourg: Office for Official Publications of the European Communities.

[2] Statistical Office of the Republic of Slovenia (2008). *Rapid reports - research and development, science and technology 2004-06*, no. 49.

[3] Hlavaty, M. (2002). *SKD - standard classification as per activities (NACE Rev.1)*. Official Gazette of the Republic of Slovenia, (in Slovenian).

[4] Coombs, R., Narandren, P., Richards, A. (1996). A literature-based innovation output indicator. *Research Policy*, vol. 25, no. 3, p. 403-414.

[5] Freel, M.S. (2005). Patterns of innovation and skills in small firms. *Technovation*, vol. 25, no. 2, p. 123-134.

[6] Hollenstein, H. (1996). A composite indicator of a firm's innovativeness. An empirical analysis based on survey data for Swiss manufacturing. *Research Policy*, vol. 25, p. 633-645.

[7] Hagedoorn, J., Cloodt, M. (2003). Measuring innovative performance: is there an advantage in using multiple indicators? *Research Policy*, vol. 32, no. 8, p. 1365-1379.

[8] Iansiti, M. (1997). From technological potential to product performance: An empirical analysis. *Research Policy*, vol. 26, no. 3, p. 345-366.

[9] Carayannis, E., Gonzalez, E., Wetter, J. (2003). The nature and dynamics of discontinuous and disruptive innovations from a learning and knowledge management perspective. *International Handbook on Innovation*, p. 115-138.

[10] Michalisin, M. (2001). Validity of annual report assertions about innovativeness: an empirical investigation, *Journal of Business Research*, vol. 53, p. 151-161.

[11] Fatur, P., Likar, B. (2009). Development of performance measurement methodology for idea management. *International Journal of Innovation and Learning*, vol. 4, p. 422-437.

[12] Parthasarthy, R., Hammond, J. (2002). Product innovation input and outcome: moderating effects of the innovation process. *Journal of Engineering and Technology Management*, vol. 19, no. 1, p. 75-91.

[13] Žargi, U., Kušar, J., Berlec, T., Starbek, M. (2009). A company's readiness for concurrent product and process development. *Strojniški vestnik - Journal of mechanical engineering*, vol. 55, no. 7/8, p. 427-437.

[14] Anišić Z., Krsmanović, C. (2008). Assembly initiated production as a prerequisite for mass customization and effective manufacturing. *Strojniški vestnik - Journal of mechanical engineering*, vol. 54, no. 9, p. 607-618.

[15] Perme, T. (2009). Translation of extended Petri net model into ladder diagram and simulation with PLC. *Strojniški vestnik - Journal of mechanical engineering*, vol. 55, no. 10, p. 609-622.

[16] The Community Innovation Survey 2006. Retrieved on 14. 9. 2009, from *http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.*

[17] Eurostat 2008. (2008). *Science, technology and innovation in Europe*. European Commission-Statistical Books, p. 83-154.

[18] Fifth Community Innovation Survey: Statistical Office of the Republic of Slovenia. Retrieved on 14. 9. 2009, from *http://www.stat.si/doc/vprasalniki/INOV-P-S_2006.pdf.*

[19] Chesbrough, H.W. (2003). *Open innovation. The new imperative for creating and profiting from technology*. Boston, Harvard Business School Press.

[20] Chesbrough, H., Vanhaverbeke, W., West, J. (2006). *Open innovation: researching a new paradigm*. Oxford, New York: Oxford University Press Inc.

[21] Collins, J.C. (2001). *Good to Great. Why some companies make the leap... and others don't.* Random House Business Books, London.

[22] Mulej, M., Ženko, Z. (2004). *Introduction to systems thinking with application to invention and innovation management.* Management Forum, Maribor.

Fatur, P. – Likar, B.