Increasing bioethanol producers’ technological innovation capacity through r&d organisation

DARIUS SARGAUTIS
BA School of Business and Finance, Latvia
darius.sargautis@gmail.com
K.Valdemãra 161, Riga, LV-1013, Latvia
Phone +371 2921 4808

Increasing bioethanol producers' technological innovation capacity through r&d organisation

Abstract

The Research and Development (R&D) as company's structure unit is a key driver of technological innovation and is the most widely used in determining the technological innovation capacity of companies. The organization of R&D may be referred to as one of the key factors that have a direct effect on R&D's successful performance. Until now, there was no model allowing to estimate the effect of individual success factors on the R&D specific determinants of innovation The fresh look at the organizational factors identifying the R&D relationships with the determinants of innovation in certain industries, in this case bioethanol industry, reveals a deeper idea about the existing interactions between the objects of interdisciplinary research. The main findings of study describes interrelations between organizational factors and success of R&D activities which directly influence company' technological innovativeness in bioethanol industry.

The required data to determine R&D organisational factors as critical success factors (CSF) is collected through survey results in EU bioethanol industry. For claim verification and establishing the relationships between organizational critical success factors of R&D and determinants of technological innovation in the bio-ethanol industries study includes analyses of activities of European bioethanol producers, descriptive statistics methods, econometric analysis and data evaluation.

Keywords: *R&D, innovation, , bioethanol industry, critical success factors.*

Introduction

It is generally considered, that creating new products, processes and services is recognised as a major source of competitive advantage and technology is often the enabler of such innovations (Chiesa, 2001). The existing point of view that technological innovations are bringing the main input into industrial competitiveness, and has major support from scientific community (Zaltman et al., 1973; Tidd, 2001).

Traditionally it has been perceived that company, country or other object of study is innovative having Research and Development (R&D) activities and funds related to R&D activities. Amount of funds connected to R&D activities was the main indicator of ability to innovate. It was common to presume that R&D expenditures would lead to additional knowledge, and the dissemination of that knowledge base would result in innovations, especially products and processes (Kemp, et al., 2003). Eventually this point of view was criticized by time (Arnold & Thuriaux, 2001). It distinguishes between the input stage to the innovation process (e.g. R&D expenditures), the throughput stage (e.g. partner co-operation) and the output stage of the process (e.g. new products). Later others appeared, much more complex indicators, which define technological innovation capacity of the companies, but yet R&D is the most widely used in determining the technological innovation capacity of companies. Although, science already knows about existing positive correlations between R&D expenditure, value-added and turnover (Nadiri & Prucha, 1993) and (Mairesse & Mohnen, 2001), or that the R&D and innovation expenditures are highly correlated (Mohnen & Dagenais, 2002), it remains absolutely incomprehensible phenomenon the impact is making some direct relevance to the R&D factors, the determinants of technological innovation.

The organization of R&D may be referred to as one of the key factors that has a direct effect on R&D's successful performance. Increasing dynamism of competition is forcing R&D to change, adopt new/other forms of organizational structures. Currently the structural functions of R&D are multidimensional, with transforming, changing forms, dependent on the environmental conditions in which they are actively participating. It must be assumed that the different organizational forms, functions and other organizational aspects of R&D have a certain measurable direct impact on R&D's performance. Considering that R&D is a direct predictor of technological innovation, given conclusion allows us to assume, that certain R&D organizational factors become direct predictors of technological innovations that have dependence on environment. In this research by environment is meant the EU bioethanol industry, which currently is undergoing a change of generations in production technologies, accordingly is highly subjected to technological innovation. Since the generation of technological innovation in particular is a derivation of own R&D center, identification and evaluation of R&D organizational factors with predictable direct impact on technological innovation would increase the companies' technological innovation capacity.

This research article focuses on the identification of individual R&D organizational factors that have a direct impact on technological innovation. Therefore, determinants are set for technological innovation, characterized for EC bioethanol industry. Thus, we propose the hypothesis:

Hypothesis: Between organisational CSF of R&D activities and determinants of technological innovations in bioethanol industry the relationships are identifiable with a particular strength of impact and these relationships are not accidental.

Identified variables subjects to statistical processing of data by using the linear regression, which is capable to determine the force influence of each identified R&D organizational factors on separate determinant of technological innovation. The article represent a model that evaluates the impact of organizational factors on the innovative capacity of the company within the bioethanol industry.

Identification of organisational CSF of R&D

Scientific literature which researches R&D activities, generally concentrates only on one or several factors separately, which are having an effect on certain phenomena, particular on the productivity or degree of innovativeness of companies expressed a certain specific determinant. Apart from the lack of an integrated approach to the factors influencing the activity of R&D, the importance of power / influence (whether this factor is generally some effect on the activity of R&D) factors individually on certain phenomenon, established only in some cases. The specifics of the industry in which R&D is active remains unrecorded.

Depending on the task set, in certain case the types of organizational structures that are being used can bring more positive effect comparing with other existing organizational structures. Brown's et. al. (2002) analysis shows that the structure of an organization can be as a major driver of R&D success. For example, those Organizational structures that are less hierarchic and less rigid comparing to the ones traditionally found in the industry are more supportive for R&D success. Or in case of considering the structure for responsibility – then both the decentralized and the centralized structures can be effective, but under different conditions (Allen, 1977; Marquis and Straight, 1965). Authors shows, that decentralized structure is effective when the flow of knowledge has to be relatively fast and the projects are of long duration. Jain et al. (2010) noted that decentralized structure is better when a lot of new information comes in and out of the project area, requiring a flexible system of organizing as well as a great deal of communication and cooperation among people participating in the project. Rothwell (1976) complements the research by indicating that when the management structure is horizontal and decentralized the main performers in R&D - the innovative individuals, are particularly effective.

The centralized structure is more effective when the projects are short-term and the flow of knowledge is not especially rapid (Jain, et al., 2010). Chiesa (2001) in his study suggests the centralization of R&D is more favourable for these determinants: 1) secrecy of technological knowledge (Rugman, 1981; Terpstra, 1977)., 2) lowering costs of coordination and control (De Meyer and Mizushima, 1989); 3) achieving economies of scale and achieving critical mass; iv) exploiting company-specific technological advantages, emerging from home market conditions, on other markets (as the international product life cycle model suggests) (Vernon, 1966).

Some of the authors notice, that there is a point to combine structures. As an example, Peters and Waterman (1988) in their research they are pointing out that excellent companies are having combined centralized and decentralized structures.

Katz and Allen (1985) researched matrix structure and proved that in cases when project managers are perceived to be controlling organizational rewards, and functional managers determine the technical content of projects more positive effects were achieved.

Chiesa (2001) puts, that in recent times there is a tendency, when companies try to concentrate on the management of technology and management level of the corporation is becoming more centralized view. By the way, research designed by Roberts (1995), confirms that corporate R&D is more research oriented and that divisions are more development oriented. Brown et. al. (2002) points out that the specific systems, such as ones that are focused on the project (project-oriented structures) may correlate with the success of R&D. Need to pay attention to the orientation of the R&D structures proposed by Chiesa (2001). Chiesa (2001) divided R&D structures in input oriented and output oriented. Input oriented should be successful practice if R&D unit is oriented by scientific discipline, technical area or activity. Output oriented should fit product line or project. The organization structures for product line helps to focus on goals such as customer focus, innovation generation, business activities integration, managerial flexibility.

As a structural form of an R&D organization in the multinationals there is geographic distribution of activities. It was noted, internationalisation, can be a key factor in accelerating company' ability to accumulate knowledge and the acquisition of unique opportunities (Prahalad&Hamel, 1990; De Meyer, 1993; Hamel&Prahalad, 1993). On the other hand Brown's et. al. (2002) research shows that it is not possible to refuse the in-house structure and, that in certain cases this system can guarantee success.

There is a suggestion to group the activities of decentralized R&D into two groups: demand factors and supply factors. It is suggested that factors like: i) technology transfer between headquarters and subsidiaries ii) need to access foreign markets; iii) need to improve a company' ability to respond to specific requirements of local markets, and iv) need to increase the proximity of product development activities to key customers (Hirschey and Caves, 1981; Granstrand et al. 1992) bring to demand factors. As for supply factors, it is invited to enrol i) increasing acceleration of technological progress, ii) the increasing costs of technology development and the international specialisation of knowledge sources (Perrino and Tipping, 1989; Howells, 1990; Sakakibara and Westney, 1992; De Meyer, 1992)

Other factors indicated political motivations and image as reasons for decentralizing R&D (Hakanson, 1992), or enhance a company' competitive image (Granstrand et al. 1992).

Brown et. al. (2002) pointing a bureaucracy as a factor that has a negative effect when operating R&D.

An important part which is dealing with organizational work of R&D centre is controlling its activities. Achieved results are often connected with control method and result monitoring. Katz and Allen noticed (1985) that effectiveness of the scientists often depends on the balance between the influence of the two supervisors. Researchers noticed that in cases like that, when the project manager was performing work related to the project, connection of which were outside the organization (i.e., the organization, the suppliers, the customers,) was mostly concerned while the functional manager was doing the inside work.

At the same time Pelz and Andrews (1966) are claiming that the best work occurred in environments that were not too tightly controlled. Individual autonomy with the condition that work will be coordinated moderately, by using individual autonomy, usually resulted in finding the best solution. Other additional types of organizational structures are for example independent, accountable substructures, such as internal entrepreneurship teams, and were shown to correlate with success (Brown, et al., 2002).

Jain et. al., (2010) noticed that in some cases there is a necessity to create other types of structures, as for example dual or even a triple hierarchy within the organization. That necessity can appear when it is required to improve the position of technical personnel. In some cases technical personnel may not want management responsibilities at higher levels, since they are losing direct connection with R&D (Jain, et al., 2010). At the same time Schriesheim and others (1977) are not agreeing with that, stating that double hierarchy generally is not bringing the desired effect, when it is necessary to resolve conflict situation between management of the organization and working professionals.

Triple hierarchy which was studied by Baumgartel (1957) and Pelz (1956) where they had noticed that in cases when management positions, in scientific and administrative practice, were taken by a person with professional or scientific education, the researchers felt safer under such management which gave organization an opportunity to achieve higher productivity and morale. Additional work that was done by other researchers (for example, Lawrence and Lorsch, 1967, Likert, 1967, Mintzberg, 1973) are complementing these researches.

It is important to mention that organization of work is playing an important role in assimilation of information. For instance, Kellers research (1994) on R&D project groups showed that the effective teams were capable of processing large amounts of information if the tasks the team had to do were non-routine.

As one of the crucial factors determining the success within the organization is organizational culture. Researchers are agreeing that certain factors of a culture can affect the success. For example Scott and Bruce (1994) identified that organizational culture supporting innovative behaviour of an individual, will be more successful comparing with other culture which is not supporting innovations. Brown et. al.(2002) research is supporting this statement. It is crucial to pay attention to the factors like tolerance of failure Brown et. al.(2002), high-quality supervisor–subordinate relations Scott and Bruce (1994), which are contributing to the development and maintenance of that culture. Jabri (1992) additionally opens elements which help to promote innovation culture. He has noticed that scientists who perceived that the tasks assigned to them were appropriate collaborated more with team members, expended more effort on the tasks.

It is important to underline that tasks must be reasonable, because satisfaction and performance of the scientists depend on it (Jain, et al., 2010). Jain et. al., (2010) also notices that cultures that are reward frequently are more effective than cultures that are not.

In each organization, in addition to routine work there must be a time when important decisions are taken. Then usually people often seek others who agree with them. Employees who are entrusted with the responsibility of deciding avoid or reject those who disagree with them. Janis (1982) believes that these tendencies result in groupthink and in major mistakes and correspondingly to poor performance.

Some organizations have seen the culture in which initially dominated the competition between employees. But some research, (see for example Rosenbaum et. al, 1980), suggests that competitiveness is often not desirable. A better result can be achieved in the cooperative conditions (Rosenbaum, et al., 1980).

R&D management has a strategy as well as the corporation. R&D strategy should be well balanced and rigged to achieve outcomes consistent with the corporation's mission and goals (Wright et al., 1996), and to fully maximize the long term gain of R&D investments (Larsson, 2004).

R&D organizations that are able to adapt elements of the strategy objectives, policies, programs to unique situation in which they are located has the opportunity to become more innovative (Jain, et al., 2010). Researches Rheem (1995) confirmed that the companies which have had long-term strategic planning are more productive than those who don't have such a plan existing. According to Jain et. al. (2010) to achieve their goals, depending on the current situation, the R&D organization , division , or other structural unit to which belongs the R&D, must think deeply about long-term objectives and the methods of their reach . Attention must be paid to different emerging situations - from demand partners, owners that adjust to the important purposes, until there is a change in the head of the organization.

Researchers have noticed that often in research organizations horizontal strategic integration is not done well (see Jain et. al., 2010). It is assumed that this is due to the individual interests of disciplinary researchers which had arisen because of the segmentation research projects within the department. But Hax and Majluf (1996) noticed that clearly executed and the corresponding horizontal strategy may be one of the most critical ways to establish a superior competitive position.

When choosing a strategy associated with the technology Chiesa (2001) suggests paying attention to categories such as selection, timing and acquisition mode.

Possession of information has always given the advantage of companies. After all decisions are made on the basis of the available information whether a future form of competition or technological change or shape the evolution of the company. Therefore, the collection of information according to Chiesa (2001), must bear on the basis of strategy formulation.

It is necessary to emphasize the importance of factors such as portfolio diversity. Research by Henderson (1994) on 120 programmes over thirty years shows that portfolio diversity is the key to success for the research organizations. Henderson revealed that the highest productivity occurred when there were between six and ten programms. Baker et al. (1988) found that projects that disposed of additional strategies were more successful than others. At the same time was worth noting that the R&D projects must be closed before the technical implementation of technology, as well as changes occurring during implementation of the project more often lead to a negative result (Baker, et al., 1988).

Presented and grouped according to their belonging to particular activity in this section CSF of R&D related to organizational factors are listed in Annex I.

Innovation capacity measurement of bioethanol company and research methodology

Although in the last chapter the organisational critical success factors were given the systemic belonging to certain groups that have similar features, yet it is obvious that the membership is interdisciplinary in nature, represents different areas of activity in which the factors are active. Therefore organizational CSF in R&D allocated without considering the relationship between a beginning or a particular group or the medium in which they have a certain importance. The author's assumptions about the existence of certain relationships between the individual CSF and technological innovation capacity of a company raises a number of open issue for this type of research.

First, there is a need to identify methods by which determinants of innovation to be measured and determining the ability of companies to innovate. The need to focus on bio-ethanol industry and the specifics of the industry, which are the active subjects of bio-ethanol, determine the choice of the determinants of innovation. Initially, in this case, we should focus on the fact that at this point in the scientific community there is no standardized method of evaluation of companies, according to which measures the ability to innovate. This issue is described in more detail in chapter Innovation measurement.

Secondly, the received database covers a spacious list of potentially useful explanatory variables. The existing situation limits the number of possible methods of analysis that allow to determine the effect of individual independent variables on the response variable. This case forces to reject modeling using multiple regression covering certain/all number of independent variables, or their groups, thereby limiting the understanding of the influence of individual variables simultaneously. To improve the quality of the results obtained a simple regression analysis is used in this paper, which allows to evaluate the influence of each variable separately mounted on the determinants of innovation in the bioethanol industries.

Innovation measurement

First of all, the variables must be measured in order to assess the degree in which the chosen variables influence the technological innovation. However, as noted by researches (Dodgson, et al., 2008, Smith, 2005) one of the greatest challenges to managing innovation is its measurement. According to Souitaris (2003) nowadays there is no such approach, which would allow to measure the innovation. Furthermore, there are known to be controversies about the correlation of variables and their relation to the rate of innovation (Downs & Mohr, 1976; Wolfe, 1994). Innovation is difficult to measure for a number of reasons. Dodgson, et al. (2008) points out the 4 main reasons: 1) some time is necessary for benefits appearing, 2) term of innovation, 3) some measurement systems measure inputs to the innovation, while others only measure outputs the benefits of an innovation often do not appear until sometime after its introduction, 4) ascertaining the source of an innovation may be complex.

This situation of emerging issues in the measurement of the determinants of innovation in the research described Souitaris (2003). The researcher argues that due to the difficulty in measuring the parameters of innovation we should pay attention to the factors that affect the discrepancy between the determinants of innovation and the degree of innovation, respectively. This situation can be subject to the origin, definition and measurement of innovation itself. In the studio, the researcher draws attention to items such as the differentiation of lineages innovation (differention by the nature of innovation) such incremental vs. radical innovation or high-cost vs. low-cost innovation. The author points out that the determinants for each of the presented types of innovations are different.

Another problem is being caused by the lack of a standard definition of technological innovation (Garcia and Calantone, 2002). The different definitions and interpretations of technological innovation have led to variations in the identified determinants. The problem is the definition of themselves and the determinants of innovation. This refers to the two main types of determinants of innovation. Found that the components of the innovation of the first type, the measurement of which can produce using actual quantitative indicators is easily transportable Souitaris (2003). They fit together in various studios and measurement of the types of parameters is uncomplicated. For example, a standardized measurement of the value of companies through a quantitative indicator of existing staff in the company (Kimberly & Evanisko, 1981) can be attributed to that of the first type. By the second type is the data that is built on the perceptions and attitudes of the respondents. According to Souitaris (2003) and it is possible to carry such data such as perceptions of the intensity of competition or attitudes towards risk-taking, as well as general and usually subjective concepts (like centralisation of power or complexity of knowledge). Although the data of the second type refers to the so -called soft variables type of their importance in determining the innovation capacity is not less important than the first type, the so-called hard variables. By the way, Souitaris (2003) also notes that the data of the second type - soft variables, often there is no unified definition. In this case, the definition is often subjective and depends 's perceptions. This author also notes that the differences in the dimensions of technological innovation arises from the fact that the studies carried out between: a) different types of companies active in various sectors of economic activity, and b) the different stages of the innovation process, and c) in regions that produce empirical research.

Despite the above mentioned uncertainties in the measurements of innovation is still possible to identify the trend towards the use of certain conventional key variables with which it is possible to carry out the measurement of indicators on companies' ability to innovate.

According to Dodgson, et al. (2008) and Smith (2005) basic indicators when measuring innovation are R&D statistics, patent data, innovation surveys, and product announcements.

Tidd (2001) draws attention to the fact that other attributes are frequently measured also, such as research funding budgets, number of researchers, number of significant inventions, number of new products, amount of published research, etc. Nelson and Winter (1982) point such factors as increased productivity and growth or lower costs. Andrew et. al (2007) provide a range of common measures related to technological innovation. These include inputs such as financial resources and people; processes such as resource efficiency, actual versus planned time to market, and milestone compliance; and output measures such as number of new products and services launched, market share growth, new product success rates, number of patents filed, and publications written.

In the Carayannis, et al. (2003) publication is presented a rather wide scope of variables that are aimed to measure the innovation. Apart from identification of the variables, the publications also suggest the typology and classification of these variables.

According to Smith (2005), there are three other important classes of indicators: 1) techno metric indicators, which explore the technical performance characteristics of products 2) synthetic indicators developed for scoreboard purposes mainly by consultants 3) databases on specific topics developed as research tools by individuals or groups.

Table 1 presents the variables that measure the degree of company's innovativeness.

Table 1. The variables that measure the degree of company's innovativeness

Source	Variables	
Oslo manual, 1997	R&D, Performance, new and improved products and processes	
Souitaris, 2003	Number of incrementally innovative products introduced in the past 3 years; Number of radically innovative products introduced in the past 3 years; Number of innovative manufacturing processes introduced in the past 3 years; Percentage of current sales due to incrementally innovative products introduced in the past 3 years; Percentage of current sales due to radically innovative products introduced in the past 3 years; Expenditure for innovation in the past 3 years over current sales. Number of patents acquired in the past 3 years.	
E. G. Carayannis, et al. 2003	Hard measurables	Patents, R&D Budget, New Products, R&D Staff, Publications, R&D, Incentives, New Features, Inventions, New Markets, Product Extensions, Conferences, CRADAs, Partnerships
	Soft measurables	Productivity, Growth, Lower Costs, Flexibility, Supply/Demand, Firm Size, Market Influence, User Benefits, ,Lower Prices, Social Enablers, Time Savers
Dodgson, et al., 2008	R&D statistics, patent data, innovation surveys, product announcements	

Source: by author, based on sources indicated in table.

As some authors of empirical researches often underestimate the complexity of innovation, it is reasonable to reconsider measuring innovation determinants only upon a certain variable.

The author of this study consider that possibility to materialize technological innovation is the company performance level leading to technological innovations and influenced by many interlinked internal and external variables forming company innovation ecosystem, which requires effective management. This fact forces cast the only definitive indicator of measurement. Instead, use of several indicators together, has filed a full measure of the ability of companies to be innovative. This assumption coincides with the assumption Souitaris (2003) on the feasibility of the use of certain portfolio of indicators to identify the general ability of companies to be innovative.

Taking into account the specifics of innovations in bioethanol industry, would be logical to take into consideration the variables that are typical for this industry and that indicate the opportunity to create innovations in comparison to other companies of the same industry. Further in the text there are given and explained the dependent and independent variables that are presented in this study.

Dependent variables

There are number of reasons why the bioethanol industry cannot be evaluated by commonly accepted variables, which were mentioned above. For example, many authors suggest to measure company innovativeness by the output of products for a certain period of time. However, in bioethanol industry, like in many other large-scale industries, competition mainly occurs on the scale of economy as a whole and is based on cost leadership strategy. The novelty in this industry is improving or creating a new process, that allows to reduce expenditure of operating costs or improve the quality of the collateral, or in some cases, by-products. That is why, it is more reasonable in bioethanol industry to measure the technological processes developed leading to the technological innovation.

Nevertheless, the speed of implementation of those technological processes is still a question. Bioethanol production process involves many interrelated technological processes. Trying to improve the process in the event of failure must stop the entire plant indefinitely. According to this, development and testing of new processes take a long time, because there have been cases where this turns company in a bankruptcy. Therefore, evaluating the number of the patents implemented in a certain period, would be a doubtful approach.

The authors of the research as the most reasonable, consider the approach for technological innovativeness measurement in bioethanol industry, where the number of the patents (variable is coded as *Patent* in results) would be measured regardless of the fact whether the patent is actively implemented already or not, the knowledge acquired during the period of invention phase can be efficiently applied in practice on later stage of technology development. At the same time the number of patents that belong to Y02E50/00 class - Technologies for the production of fuel of non-fossil origin (coded as *Patent_c*), according to Cooperative Patent Classification, as well as the patents that have direct relation to the bioethanol industry (coded as *Patent_b*) will be measured.

Distinguishing the patents is an important aspect, as the total number of patents shows all the ongoing activities of the company, but the patents chosen according to the classification mentioned above will directly reflect the R&D activities in a particularly chosen industry's sector.

The suggested factors that are aimed to estimate what percentage of the company's turnover is invested into R&D, does not seem to be applicable: a) Data is confidential; b) R&D, often, is a rather general field where, among those related to bioethanol, are researched very diverse technologies.

This study also includes such term as company's performance expressed in production capacity (Coded as *Volume*). This figure is the expression of an almost linear dependence of the companies' turnover and thus this variable distinctly reflects company's innovation capabilities.

Next variable is – degree of innovations complexity (coded as *Techn*), which is expressed in three degrees: standard, improved or second generation. In this time period can be distinguished three main directions of technology. Standard technology means conventional bio-ethanol production technology. Improved technology allows to obtain by-products are different from the standard ones. The second generation means companies that produce ethanol from non-traditional raw materials, other variables were eliminated as not appropriate for this study and not available because of data confidentiality or evaluated as not significant. As noted by Iarossi (2006) questions on taxes, profits, and names of suppliers or clients could be the subject of distorted answers or out- right refusal.

Independent variables

The independent variables in this research are the organisational critical factors having a positive impact on the R&D and provide a positive result of the structural department. Identified with references and descriptions in the chapter "Identification of organisational CSF of R&D" CSF, number 45 composes a factor.

With the purpose of susceptibility because of a large number of identified variables, the organisational factors were grouped according to their belonging to her particular activity or having the characteristics of common features, the features of the object (see Annex I).

The study covers all the bioethanol industry in Europe. The list of the companies and the data were gathered from the database of an organization ePure (ePure, 2012). The publication of the list of participants on which the study was based is dated January 2012. ePURE represents and supports companies that produce renewable ethanol in the EU for all end-uses, i.e. fuel, potable and industrial uses. ePURE also represents companies that have an interest in ethanol production. Currently, ePURE's membership accounts for 80% of the installed renewable ethanol production capacity in Europe. This information implies that the data presented in the databases of ePure is a reliable source.

Methods

The data was collected by means of the survey. The survey was delivered by *E-mail URL embedded* – a respondent was invited by e-mail to the survey site, and the e-mail contains a URL address on which respondents click (Bradley, 1999). Respondents were redirected to the webpage *formscentral,* where was placed a questionnaire. This form of questionnaire was chosen because Web-based questionnaires have the same strength as paper self-completion questionnaires in that, in theory at least, respondents can complete the questionnaire in their own time, going away from it if they are interrupted, and returning to it later. The major disadvantage is not having an interviewer on hand to clarify questions or to repair misunderstandings. Therefore were the open-ended questions were included in the end of the paragraphs. These questions were aimed to reveal personal thoughts of respondents.

Generally, the questions were closed (or multiple choices), because using this format the respondents are restricted to a set of responses. Beside that, respondents permit the inclusion of more variables in a research study because the format enables the respondent to answer more questions in the same time required to answer fewer open- ended questions (Siniscalco & Auriat, 2005).

Identification of the variables, which have direct influence success of R&D, was up to respondents (see Annex I). After pointing out the variables that, in their view, had a positive influence on R&D the respondents had to identify the importance of each particular variable in every subgroup. The weight of every subgroup was measured according to Likert scale, results ranging from the unimportant to the very important (five number scale). Measured CSF of R&D are presented in table and can be found in Annex II.

Since the questions concern selection of the personnel responsible for R&D and innovation strategy, the target respondents were those who actually are responsible for R&D and innovation strategy. However, in practice identification of such individuals was highly complicated by companies' confidentiality policy. The number of companies producing bioethanol in Europe is relatively small and all the technology that can possibly serve as a competitive advantage for a company is thoroughly safeguarded. Moreover, some of the companies belong to multinational corporations (e.g Cargil, where the number of employees exceeds 150 000) and have a strict internal policy and strict regulations on security and communication at all levels. These policies along with no willingness of the companies to cooperate in the research process have created additional constrains and delayed completion of the research for more than a year. Reaching out for respondents was also complicated by organizational structures of bioethanol producing companies. R&D strategy is primarily the prerogative of the top managers. This has confirmed several times in the author's research. Persons responsible for R&D strategy occupying positions such as directors, plant managers, R&D director, Director engineering, managing director, Chairman of the board, Science Innovation and administration manager and etc.

The survey was conducted in 39 companies producing bioethanol in Europe in 2012. The questionnaire was completed by 14 respondents, which accounted for 36% the total number of bioethanol producers. From the capacity point of view, it represented 32% of the bioethanol industry in Europe, at the moment of survey, with a total revenue around 1,7 billion €/year, only from product sales related to bioethanol.

To establish the relationship between the individual force variables and test the statistical significance of linkages in this paper used the methods of econometric modelling.

One of the goals of the thesis is the prediction of the facts (innovativeness of companies can) on the basis of known variables (critical factors). In this case correlation does not work, as the correlation coefficient is symmetric in the sense that Cor (Y,X) is the same as Cor (X,Y).

Regression analysis differs in an important way from correlation analysis. In regression analysis the response variable Y is of primary importance. The importance of the predictor X lies on its ability to account for the variability of the response variable Y and not in itself per se. Hence Y is of primary importance (Chatterjee & Hadi, 2006).

Regression analysis allows us to predict (forecast) one variable on the basis of other / them with a straight line, which characterizes the relationship between two or more variables. In this case, on the basis of the investigated factors predicted variables will be pointing to the innovativeness of companies. In order to establish the influence of each factor on a particular variable which predicts the innovation capacity of companies a linear regression model was utilized, which in the form of a standard deviation looks like follows:

$$Y_i = \alpha + \beta X_{i} + \varepsilon \qquad (1)$$

where, as in the simple linear regression model, Y_i is an observed value of the dependent variable, a is the population intercept, b is the regression slope parameter for predictor X_i and e is the error associated with predictions of Y (Denis, 2011).

The hypothesis of research claims that between organisational CSF of R&D activities and determinants of technological innovations in bioethanol industry the relationships are identifiable with a particular strength of impact and these relationships are not accidental.

This is possible when $\beta \neq 0$ (Siegel, 2000), ie, in the linear model for the determinants of innovation component is saved, depending on the R&D CSF. Mathematical expression of this hypothesis has the following equation:

$$H1: \beta \neq 0 \qquad (2)$$

The sample size of thesis is small and consists of 14 respondents. Because the standard error depends on sample's size (Cohen, Cohen, West, & Aiken, 2003), a small sample size oblige to set the reduced level of significance (Sachs, 1984). Correspondingly in selecting meaningful critical factors, the significance level in this thesis was set to the level of $p < 0.1$.

Criterion according to which companies should determine the belonging to the existing population should be based on the size of companies. According to the authors, this criteria is the most fairly represented value, indicating the companies belonging to a particular group. This grouping has the advantage over other possible identifiers because it predicts and determines the largest number of known factors interrelated with the size of companies. Such as: company size determines the technology of production (second generation bioethanol production is not yet possible at high capacity), the estimated size of funding R&D (large companies has the ability to allocate more funds for research), location (large companies producing bioethanol are mainly concentrated in the more economically developed countries), etc. To establish belonging of the sample to the population the sample means of production capacity are compared (see Table 2).

Table 2. Sample and population production capacity comparison

Variable	N	Min	Max	Mean	Std. Deviation
Population	39	5.4	1265.0	**186.2**	266.38
Sample	14	5.4	850.0	**168.6**	221.54

Source: by authors, based on ePure (2012)

Descriptive statistics show a rather close nature of both variables. Putting forward the null hypothesis, which states that the difference between mean values, between population and sample is not present, we obtain the following mathematical expression of this hypothesis:

$$H0: \mu\text{-}186.24=0 \quad (3)$$

Here μ is mean of the population.

The carried analysis using one sample t-test shows that the difference between the average values of both variables is only 17.64 mln. Litres /Ann (< 10% from population).

Table 3. One sample t test

Variable	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Sample	-.298	13	.770	-17.64	-145.55	110.27

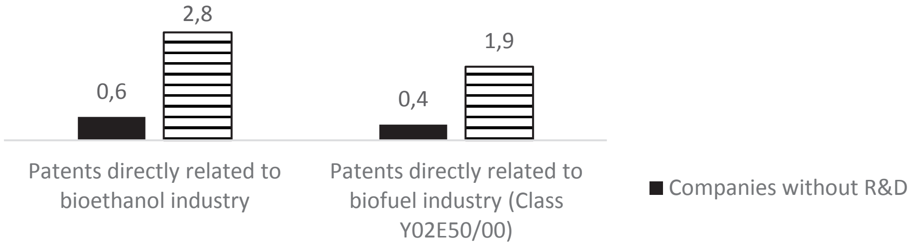
Source: by author. Test value186.24. Std error mean 59.21.

The results are listed in Table 3 indicate that the value hypothesized fall in the confidence intervals indicating a fail to reject the null hypothesis. Therefore, we can assume that the enquiry respondents will reflect the entire population of bioethanol producers in the EU.

Statistical evaluation of the data in this thesis was performed using IBM SPSS Statistics 21, graphs performed with MS Excel.

Analysis of the results produced by the survey as part of this thesis confirmed that the presence of R&D in the bioethanol industry is a predictor of technological innovation. Based on the assumption that patents are one of the main indicators for measuring the technological innovativeness of companies (Dodgson, et al., 2008), the average numbers of patents owned by companies reflect the company ability to generate innovative knowledge, which is a major predictor of the development or improvement of new products/processes.

Fig. 1 Average number of patents belonging to bioethanol producers depending on the presence of R&D and the class of patents, 2012



Source: by author, based on EPO (2012).

In the figure 1 the average number of patents (EPO, 2012) owned by bioethanol companies is shown, it is split into two groups - with and without their own R&D. Analysis was made on the data provided by the companies who participated in the survey as a part of this thesis *(n = 14; Y/N - 9/5).*

Evaluating the obtained results from companies that have their own R&D centres and companies that don't have it was found that the ratio between the arithmetic mean values was more than 4.5 times. This result is similar in both cases - both in relation to patents belonging to bioethanol industry and patents related to the whole biofuel system. These results indicate that despite the focus on a particular industry, in this case bio-ethanol industry, in any case R&D increases technological innovativeness of companies. In some cases, existing patents in companies that do not have their own R&D centre shows that the alleged ability to generate their own knowledge without R&D centres in the bioethanol industries is less effective compared to those organizations that have R&D.

Given the versatility of companies the difference between the number of patents for companies that have their own R&D centres and companies that don't becomes even more expressed in favour of companies that do have their own R&D centres (see Fig. 2). The difference between the arithmetic mean reaches up to 7 times. Despite the fact that even the largest producers of bioethanol in some cases don't have an R&D, the fact that R&D is an obvious influential predictor for production of patents should be accepted, and is the reason what causes an increase in technological innovation capacity of the bioethanol companies.

Fig. 2. Average number of all patents owned by bioethanol producers depending on the presence of R&D, 2012

Source: by author, based on EPO (2012).

Further the text of the research presents an analysis of the results of quantitative studies of individual components, critical R&D factors, that have a direct impact on previously established in the thesis determinants of innovation in the bioethanol industries.

Population intercept α in this research will not be discussed, because in the considered set of data there are no such determinants of innovation. That is why permanent member α, should be considered just as a secondary value, needed for optimal prognosis, but it should not be interpreted literally. In that case in presented tables which are showing coefficients of simple linear regression, this value is not displayed.

It should be noted, that the analysis and interpretation of the data because of the high number of variables is not fully set forth herein. The paper presents the main and only interpreted having the highest value ratios. The models which are not statistically significant in this study are excluded and in the data collection are not given.

Effect of Organisational CSF of R&D on determinants of technological innovation

The results of descriptive statistic of this block starts with the group of factors related to the organizational structure*. Horizontal management* structure R&D was relatively highly correlated with patents in the bioethanol industries and CPC classifications. These relationships are highly significant ($p < 0.05$). Even higher correlation coefficient in this group stand out the relationship between the *flexible structure* and the dependent variables denoting the patents in the bioethanol industries and CPC classifications. Despite the very high significance, the number of respondents linked to this factor was insignificant, therefore should not rely on the data link.

Given the geographic distribution of R&D center, respondents in most cases recognized, that the positive results of R&D center, this center should be oriented *In house*. Unfortunately the results do not allow to accept the decision as directly related to the determinants of innovation in the bioethanol industries. The only factor having the highest value was expressed negative correlation between the presence of R&D center and the geographic distribution centers.

The results in the described statistics in terms of the relationship between the orientations of the organizational structure of the R&D and the dependent variables were not significant in this study. It can only be the result of an arithmetic average stress having the highest value. This factor determines the orientation of the R&D structure for the project.

In the control group of factors describing the R&D, the respondents, as the success factors of the presented method of indicating their preference for *Dual hierarchy*, where both professional and managers levels are incorporated. This choice proved to be the change and has weak relationship with the variables indicating the determinants of innovation . Significant in relation to innovation variables were two relationships - between the factor that indicates *poor control* within the R&D, and patents in the bioethanol industries and CPC classification. These coefficients are significant at $p < 0.01$.

Factors of R&D related to organizational culture show that some of these factors have a relatively high negative relationship with dependent variables, such as the relationship between *Innovative organizational culture* and the presence of R&D center. According to the survey, this factor is important for many respondents, as determined by the success of R&D. Although this relationship can't be considered significant at the standard of significance, but the high average value is impossible not to pay attention to this factor.

In the group of factor which determine the strategy, several positive and thus significant correlation coefficients are present. All the most important relationship in this group apply only to patents in the bioethanol industries and CPC classification. These factors are - *Adapting elements of strategy*, *Information gathering, Portfolio diversity.* Besides a very high correlation coefficient of 0.944 in relation to patents *Adapting elements of strategy* correlation is significant at $p <0.01$.

The last group of factors Human resource management in the unit which addresses the organizational factors have a strong correlation coefficient describing the relationship between technology and *Researchers to spend a small portion of their time of development of their own ideas*. Obviously it can be concluded that the free time allowed for the study encourages the development of new technologies.

Table 4. Regression estimate of R&D organisational CSF effects on technological innovation determinant – "Technology Degree" in EU bioethanol industry

Variables	Unstandardized Coefficients		Std. Coef.	90.0% Confidence Interval for B	
	B	Std. Error	Beta	L. Bound	Up. Bound
Researchers to spend (a small portion of their) time of development of their own ideas	0.260	0.071	0.729	0.134	0.386

Source: by author. p<0.05;

Researchers to spend (a small portion of their) time of development of their own ideas was the only regressor having a significant impact on the level of technology in the group belonging to the organizational factors (see Table 4).

Table 5. Regression estimate of R&D organisational CSF effects on technological innovation determinant – "Volume" in EU bioethanol industry

Variables	Unstandardized Coefficients		Std. Coef.	90.0% Confidence Interval for B	
	B	Std. Error	Beta	L. Bound	Up. Bound
R&D strategy is an integral part of overall company mission	41.268	21.581	0.483	2.805	79.732

Source: by author. p<0.1;

Dependence variable under the codename *Volume*, determines the size of companies and therefore the availability of resources for R&D, it was possible to establish a significant influence only in one independent variable *R&D strategy is an integral part of overall company mission* (see Table 5) Allocated variable has a relatively low importance in the presented model.

Table 6. Regression estimate of R&D organisational CSF effects on technological innovation determinant – "Patent_b" in EU bioethanol industry

Variables	Unstandardized Coefficients		Std. Coef.	90.0% Confidence Interval for B	
	B	Std. Error	Beta	L. Bound	Up. Bound
Horizontal structure	1.363	0.573	0.566	0.342	2.384
Flexible structure	3.231	0.524	0.872	2.297	4.164
Not too tightly controlled	1.916	0.468	0.763	1.081	2.751
Adapting elements of strategy	2.272	0.229	0.944	1.863	2.681
Information gathering	1.053	0.443	0.566	0.264	1.843
Portfolio diversity	1.477	0.549	0.614	0.499	2.455
Other R&D strategy	2.585	0.419	0.872	1.838	3.332
*Other organisational variables	0.993	0.519	0.483	0.067	1.918

Source: by author. p<0.05; p<0.1*

In the table 6 significant coefficients are given by a simple linear regressions indicating the influence of critical factors belonging to the organizational group for a set of determinants of technological innovation - patents belonging to the bioethanol industry. *Flexible structure* has the highest coefficient of regression in the group describing the organizational structure of R&D. In the group describing the relationship between factors of R&D strategies and patents in bioethanol industry established significant regression coefficient of factor *Adapting elements of strategy*. Regression coefficients of the critical factors *Other R&D* strategy and *Other organisational variables* affecting established determinants are associated with patents in bioethanol industries and have high coefficients of regression, but in this case, the factors are variables identified in different ways depending on the respondent. Using the regression coefficients of variables *Other R&D strategy* and *Other organisational variables* in order to determine the influence of individual factors on critical determinants of innovation is impractical.

Table 7. Regression estimate of R&D organisational CSF effects on technological innovation determinant – "Patent_c" in EU bioethanol industry

Variables	Unstandardized Coefficients		Std. Coef.	90.0% Confidence Interval for B	
	B	Std. Error	Beta	L. Bound	Up. Bound
Horizontal structure	0.846	0.383	0.537	0.163	1.529
Flexible structure	1.788	0.472	0.738	0.948	2.629
* In-house (centralized one R&D lab)	0.801	0.414	0.488	0.064	1.539
Research oriented R&D structure	1.269	0.301	0.773	0.734	1.805
Adapting elements of strategy	1.471	0.162	0.934	1.182	1.759
Information gathering	0.672	0.293	0.552	0.150	1.194
* Portfolio diversity	0.789	0.393	0.501	0.088	1.490
Other R&D strategy	1.431	0.377	0.738	0.758	2.104
* Recruitment policy	0.630	0.298	0.521	0.098	1.162
*Other organisational variables	0.640	0.341	0.476	0.032	1.247

Source: by author. $p<0.05$; $p<0.1$*

Coefficients of the regression analysis describing the effects of organizational factors on the predicted critical innovation determinant Patent_c are listed in the table 7. From the organizational structures - *Flexible structure* turned out to be the strongest predictor variable. Explanatory variable *Horizontal structure*, belonging to the group of variables in the organizational structure, also has a significant impact on predicted variable Patent_c. Predictor *In-house* that determines location of R&D centre has had a significant effect on the production of certain patents for Y02E50/00 classifications. With the group that determines the orientation of the project variable *Research oriented R&D structure* proved to be a significant predictor. It should be emphasized that the predictor *Adapting elements of strategy* that has a strong influence on the response variable. *Other strategy* should be excluded from the list of predictors of technological innovation because of the changeable variable form.

Table 8. Regression estimate of R&D organisational CSF effects on technological innovation determinant – “Patents” in EU bioethanol industry

Variables	Unstandardized Coefficients		Std. Coef.	90.0% Confidence Interval for B	
	B	Std. Error	Beta	Lower Bound	Upper Bound
*Researchers to spend (a small portion of their) time of development of their own ideas	15.104	7.511	0.502	1.718	28.490

*Source: by author. * p<0.1*

According to regression analysis an independent *variable Researchers to spend (a small portion of their) time of development of their own ideas* is identified, it has a positive impact on predicted variable which describes production of patents that have been produced throughout the multidisciplinary activities of the companies including bioethanol industry (see table 8).

The results of the authors’ study allow us to affirm the existence of different types of relationships between critical factors of R&D center and innovation, or rather the various determinants of innovation. Based on the primary hypothesis put forward by the author asserts that the relationship between these variables is the rule rather than an accident, the results of the analysis using linear regression indicates that in most cases the regression coefficient is significant.

Naturally, these facts allow us to say that a hypothesis put forward by author (see Eqn. 6) is confirmed.

Accordingly, following the construction of regression model of technological innovation in the bioethanol industries reveals the dependence of the change in the form of innovative determinative from the critical factors of the R&D and regression coefficients.

$$Y \approx f\,(CSF_{org}, \beta) \qquad (4)$$

where CSF_{Org} organisational critical factor of R&D (see tables 4-8)

Consequently, the results of the regression analysis indicate the degree of influence of each of the presented and subjected to factor analysis to identify determinants of technological innovation. Since each of the organisational CSF manifested R&D as a predictor of technological innovation it must be assumed that the sum of the designation of these variables will denote the overall effect on specific determinants. Accordingly, it can be argued that the innovative abilities, from here and it becomes possible to produce innovation is higher in the objects of study in which quantitative indicators at the time of their definition has the highest value. Considering conducted modelling technological innovation capacity of the companies in bioethanol industry is expressed by a model having the following mathematical equation:

$$Y = \sum_{j}^{5} \frac{\Sigma_{i}^{n_j} \beta CSForg_{ij}}{\overline{X}_j} \qquad (5)$$

In other words conducted research and created model (eqn. 5) gave companies an opportunity to identify organisational critical factors, following which they can more successfully perform technological innovation, i.e. change the company in a technical aspect, so that these changes would allow producing a new product or a process allowing the company to beat the competition.

The author suggest, the insertion of standardized coefficients in to the developed model should be avoided, as dependent variables have different scale of measurement. Standardized coefficients should be considered as a specific indicator having some power to influence with calculated significance on single, specific dependent variable, provided that we are going to compare a single dependent variable.

Summary

This research contributes to the literature dedicated to R&D organizational factors in bioethanol industry of European Union in order to find out the CSF influencing technological innovativeness capacity. Scientific literature, which studies R&D, mainly focuses on one or several factors separately, having an impact on certain conditions, in particular on productivity or a degree of innovativeness of companies expressed by certain specific determinant. Therefore, connections and their power/degree of influence are found only in some cases. These relationships in the scientific literature are isolated, not represented in the complex relations and it is not possible to determine the influence of each of them, thereby eliminating the possibility of modelling in a particular environment.

Development of technological innovation processes, for a new generation of bioethanol production as well as for conventional, is a knowledge-intensive process, which requires the possession of special knowledge and training - accumulates in the R&D function. Identify critical factors R&D having direct links with the determinants of innovation, defining a coherent innovation of companies is becoming a necessity conducive to sustainable competitiveness.

Systematic overview of factors contacting with R&D, therefore creates uncertainty direct effect on the R&D, showed that facts published in the scientific literature have a vast population. Nevertheless, such a large variation of factors involved in all areas of the R&D require some organizing, allowing to further their processing system.

Derived determinants of innovation in the bioethanol industries - the capacity of companies, since R&D center, the level of technological innovation, the number of patents and their relationship to critical factors allow the use of econometric methods study to identify the coefficients indicate the action force established relationships, the total value of which determines the technological innovation capacity of companies in general bioethanol industries.

The empirical study of this thesis, has discovered and presented existing connections between innovation determinants and critical factors of R&D, with defined values which indicate virtue of certain groups and R&D critical factors on a certain innovation determinant in bio-ethanol industry, it allows to use established relationships in various types of models describing the dependence of the innovativeness of companies from critical factors R&D.

The developed model allows to identify CSF given the specificity of the R&D industries would allow companies to identify and strengthen its innovative capabilities. Since ethanol is a product that has a standardized quality parameter, the cost of the final product is a key parameter used in nodule struggle.

As the large scale chemical production is very much similar in its specifics to bioethanol industry, would be fairly to state that this research is equally important for these industries.

References

Allen, T. J., 1977. *Managing the Flow of Technology: Technology Transfer and the Disseminationof Technological Information within the Research and Development Organization.* Cambridge: MIT Press.

Andrew, J. P., Sirkin, H. L., Haanaes, K. & C, M. D., 2007. *Innovation 2007: A BCG Senior Management Survey,* Boston: Boston Consulting Group..

Arnold, E. & Thuriaux, B., 2001. *Innovation and enterprise creation: statistics and indicators. Proceedings of the conference held at Sophia Antipolis, 23 and 24 November 2000.* Luxembourg, European Communities.

Baker, B., Murphy, D. & Fisher, D., 1988. Factors Affecting Project Success. In: D. I. Cleland & W. King, eds. *Project Management Handbook.* s.l.:John Wiley & Sons, Inc, pp. 902-919.

Baumgartel, H., 1957. Leadership style as a variable in research administration. *Administrative Science Quarterly,* 2(3), pp. 344-360.

Bradley, N., 1999. Sampling for Internet surveys: an examination of respondent selection for Internet research. *Journal of the Market Research Society,* 41(4), pp. 387-395.

Brown, K., Schmied, H. & Tarondeau, J. C., 2002. Success factors in R&D: A meta-anlysis of the empirical literature and derived implications for design management. *Design Management Journal,* 2(1), pp. 72-87.

Carayannis, E. G., Gonzalez, E. & Wetter, J., 2003. The Nature and Dynamics of Discontinuous and Disruptive Innovations from a Learning and Knowledge Management Perspective. In: L. R. Shavinina, ed. *The International Handbook on Innovation.* s.l.:Elsevier Science Ltd., pp. 115-138.

Chatterjee, C. & Hadi, A. S., 2006. *Regression analysis by example.* 4 ed. New Jersey: John Wiley & Sons, Inc..

Chiesa, V., 2001. *R&D strategy and organisation. Managing Technical Change in Dynamic Contexts.* London: Imperial college press.

Cohen, J., Cohen, P., West, S. & Aiken, L., 2003. *Applied Multiple Regression/Correlation Analysis for Behavioral Sciences.* 3 ed. London: Lawrence Erlbaum Associates.

De Meyer, A., 1992. Management on international R&D operations. In: O. Granstrand, L. Hakanson & S. Sjölander, eds. *Technology management and international business: internationalization of R&D and technology.* Chichester: John Wiley and Sons, pp. 163-178.

De Meyer, A., 1993. Management of an International Network of Industrial R&D Laboratories. *R&D Management,* 23(2), pp. 109-120.

Denis, D. J., 2011. *Multiple Linear Regression Using SPSS Part II.* [Online] Available at: http://psychweb.psy.umt.edu/denis/datadecision/front/stat_II_2011/psyx_521_multiple_regression_part_II.pdf
[Accessed 12 04 2013].

Dodgson, M., Gann, D. & Salter, A., 2008. *The Management of Technological Innovation: Strategy and Practice.* New York: Oxford University Press Inc..

Downs, G. W. & Mohr, L. B. J., 1976. Conceptual issues in the study of innovation.. *Administrative Science Quarterly,* Volume 21, pp. 700-714.

Drucker, P. F., 2002. The Discipline of Innovation. *Harvard Business Review,* Issue August, p. 95–103.

EPO, 2012. *European Patent Office.* [Online] Available at: http://www.epo.org/.[Accessed 2012].

ePure, 2012. [Online] Available at: http://epure.org/statistics/info/Productioncapacityinstalled1.[Accessed 23 01 2012].

European Commission, 2006. *Ricardis: Reporting Intellectual Capital to Augment Research, Development and Innovation in SMEs,* Brussels: European Commission.

Galbraith, 1952. *American Capitalism: The Concept of Countervailing Power.* NY: Houghton Mifflin.

Garcia, R. & Calantone, R., 2002. A critical look at technological innovation typology and innovativeness terminology: a literature review. *The Journal of Product Innovation Management,* Volume 19, pp. 110-132.

Granstrand, O., Hakanson, A. & Sjolander, S., 1992. *Technology Management and International Business - Internationalization of R&D and Technology.* Chichester: John Wiley & Sons.

Hakanson, L., 1992. Locational Determinants of Foreign R&D in Swedish Multinationals. In: O. Granstrand, A. Hakanson & S. Sjolander, eds. *Technology Management and International Business - Internationalization of R&D and Technology.* Chichester: John Wiley & Sons, pp. 97-115.

Hamel, G. & Prahalad, C. K., 1993. Strategy as stretch and leverage. *Harvard Business Review,* 71(2), pp. 75-84.

Hax, A. C. & Maljuf, N. S., 1996. *The Strategy Concept and Process: A Pragmatic Approach.* 2 ed. Englewood Cliffs: Prentice Hall.

Henderson, R., 1994. The Evolution of Integrative Capability: Innovation in Cardiovascular Drug Discovery. *Industrial and Corporate Change,* 3(3), p. 607–630.

Hirschey, R. & Caves, R., 1981. Research and Transfer of Technology by Multinational Enterprises. *Oxford Bulletin of Economics and Statistics,* 43(2), pp. 115-130.

Howells, J., 1990. The Location and Organisation of Research and Development: New Horizons. *Research Policy,* 19(2), pp.

133-146.
Iarossi, G., 2006. *The power of survey design : a user's guide for managing surveys, interpreting results, and influencing respondents.* Washington: The International Bank for Reconstruction and Development/The World Bank.
Jabri, M. M., 1992. Job satisfaction and job performance among R&D scientists: The moderating effects of perceived appropriateness of task allocation decisions. *Australian Journal of Psychology,* 44(2), pp. 95-99.
Jain, R., Tiandis, H. C. & Weick, C. W., 2010. *Managing research, development, and innovation.* 3rd ed. New Jersey: John Wiley & Sons, Inc.
Janis, I. L., 1982. *Groupthink: Psychological Studies of Policy Decisions and Fiascoes.* 2 ed. Boston: Cengage Learning.
Katz, R. & Allen, T. J., 1985. Project performance and the locus of influence in the R&D matrix. *Academy of Management Journal,* Issue 28, pp. 67-87.
Keller, R. T., 1994. Technology-information processing fit and performance of R&D project groups: A test of contingency theory. *The Academy of Management Journal,* 37(1), pp. 167-179.
Kemp, R. G. M., Folkeringa, M., de Jong, J. P. J. & Wubben, E. F. M., 2003. *Innovation and firm performance. Research Report H200207,* Zoetermeer: SCALES.
Kimberly, J. R. & Evanisko, M. J., 1981. Organisational innovation: The influence of individual, organisational and contextual factors of hospital adoption of technological and administrative innovations. *Academy of Management Journal,* 24(4), pp. 689-713.
Larsson, A., 2004. *How can R&D strategy be shaped, integrated and monitored to support corporate strategy?.* [Online] Available at: http://epubl.ltu.se/1402-1773/2004/095/LTU-CUPP-04095-SE.pdf. [Accessed 07 12 2013].
Lawrence, P. B. & Lorsch, W. J., 1967. *Organization and Environment: managing differentiation and integration.* Boston: Division of Research, Harvard Business School .
Likert, R., 1967. *Human Organization: Its Management and Value.* New York: Mcgraw-Hill .
Mairesse, J. & Mohnen, P., 2001. *To Be or not To Be Innovative: An Exercise in Measurement.* Cambridge, MA.: NBER Working Paper 8644, December 2001, National Bureau of Economic Research.
Marquis, D. G. & Straight, D. L., 1965. *Organizational Factors in Project Performance, No 133-65,* Cambridge: Massachusetts Institute of Technology.
Mintzberg, H., 1973. *The Nature of Managerial Work.* New York: Harper & Row.
Mohnen, P. & Dagenais, M. J., 2002. Towards an Innovation Intensity Index. The Case of CIS-I in Denmark and Ireland. In: A. Kleinknecht & P. Mohnen, eds. *Innovation and Firm Performance. Econometric Explorations of Survey Data.* London: Palgrave, pp. 3-30.
Nadiri, M. & Prucha, R., 1993. *Estimation of the depreciation rate of physical and R&D capital in the US total manufacturing sector, NBER Working Paper 4591.* Cambridge: National bureau of economic research.
Nelson, R. & Winter, S. G., 1982. *An Evolutionary Theory of Economic Change.* Cambridge: The Belknap Press of Harvard University Press.
Ortega-Argiles, R., Potters, L. & Voigt, P., 2009. *R&D-intensive SMEs in Europe: What do we know about them?.* Luxembourg: IPTS Working paper on Corporate R&D and Innovation No. 15/2009, European Communities.
Pelz, D. C., 1956. Some Social Factors Related to Performance in a Research Organization. *Administrative Science Quarterly,* 1(3, Special Issue on the Administration of Research), pp. 310-325.
Pelz, D. C. & Andrews, F. M., 1966. *Scientists in Organizations: Productive Climates for Research and Development.* New York: John Wiley&Sons.
Perrino, A. & Tipping, J., 1989. Global management of technology. *Research Technology Management,* 32(3), pp. 12-19.
Peters, T. J. & Waterman, R. H., 1988. *In Search of Excellence-Lessons from America's Best Run Companies..* New York: Harper & Row.
Prahalad, C. K. & Hamel, G., 1990. The Core Competence of the Corporation. *Harvard Business Review,* 68(3), pp. 79-90.
Rheem, H., 1995. Improving productivity: The importance of R&D. *Harvard Business Review.*
Roberts, E., 1995. Benchmarking the Strategic Management of Technology--I. *Research Technology Management,* 44(January-February).
Rosenbaum, M. E. et al., 1980. Group productivity and process: Pure and mixed reward structures and task interdependence. *Journal of Personality and Social Psychology,* 39(4), p. 626–642.
Rothwell, R., 1976. *Innovation in Textile Machinery: Some Significant Factors in Success and Failure.* Bringhton, Sussex: SPRU Occasional Paper Series No2, SPRU.
Rugman, A., 1981. Research and Development by Multinational and Domestic Firms in Canada. *Canadian Public Policy,* 7(4), pp. 604-616.
Sachs, L., 1984. *Applied Statistics.* 2 ed. New York: Springer-Verlag New York Inc..
Sakakibara, K. & Westney, E., 1992. Japan's Management of Global Innovation: Technology Management Crossing Borders. In: *Technology and the Wealth of Nations.* Stanford: Stanford University Press, pp. 327-344.
Schriesheim, J., Von Glinow, M. A. & Kerr, S., 1977. Professionals in bureaucracies: A structural alternative. In: P. C. Nystrom & W. H. Starbuck, eds. *Prescriptive Models of Organizations.* New York: North-Holland, pp. 55-69.

Scott, S. G. & Bruce, R. A., 1994. Determinants of Innovative Behavior: A Path Model of Individual Innovation in the Workplace. *Academy of Management Journal,,* 37(3), pp. 580-607.
Siegel, A. F., 2000. *Practical business Statistics.* s.l.:Irwin McGraw-Hill.
Siniscalco, M. T. & Auriat, N., 2005. *Questionnaire design.* Paris: International Institute for Educational Planning/.
Smith, K., 2005. Measuring Innovation. In: J. Fagerberg, D. Mowery & R. R. Nelson, eds. *The Oxford handbook of Innovation.* New York: Oxford University Press Inc., pp. 148-177.
Souitaris, V., 2003. Determinants of Technological Innovation:Current Research Trends and Future Prospects. In: L. V. Shavinina, ed. *The International Handbook on Innovation.* s.l.:Elsevier Science Ltd., pp. 513-528.
Sundbo, J., 2005. Foreword. In: P. Trott, ed. *Innovation Management and New product development.* Harlow: Pearson Education Limited, p. 5.
Terpstra, V., 1977. International Product Policy: the Role of Foreign R&D. *Columbia Journal of World Business,* 12(4), pp. 24-32.
Tidd, J., 2001. Innovation management in context: Environment organizational and performance. *SPRU Science and Technology Policy Research,* Volume Working paper no. 55.
Trott, P., 2005. *Innovation management and new product development.* Harlow: Pearson Education Limited.
Vernon, R., 1966. International Investment and International Trade in the Product Cycle. *The Quarterly Journal of Economics,* 80(2), pp. 190-207.
Wolfe, R. A., 1994. Organisational innovation: Review, critique and suggested research directions. *Journal of Management Studies,* 31(3), p. 405–431.
Wright, P., Kroll, P. & Parnell, J., 1996. *Strategic Management Concepts and Cases.* New Jersey: Prentice Hall, Inc..
Zaltman, G., Duncan, R. & Holbek, J., 1973. *Innovations and organizations.* New York: John Wiley.

Annex I. Independent variables of Organisational CSF in R&D.

Group	Code	Independent variables
Type of organisational structure	A01	Centralized
	A02	Decentralized
	A03	Combined
	A04	Horizontal (few or no levels of intervening management between staff and managers)
	A05	Divisions (groups each organizational function into a division. Each division within a divisional structure contains all the necessary resources and functions within it)
	A06	Matrix structures (groups employees by both function and product)
	A07	Individual autonomy
	A08	Flexible
	A09	Other
Geographic location of the R&D	B01	Geographic distribution of R&D labs
	B02	In-house (centralized one R&D lab)
Orientation of the organizational structure of R&D	C01	Project-oriented structure
	C02	Input oriented structure (oriented by research discipline, technical area or activity)
	C03	R&D structure is organized by product line
	C04	Research oriented (research analyses properties, structures, and relationships with a view to formulating and testing hypotheses, theories or laws)
	C05	Development oriented (installing new processes, systems and services, or to improving substantially those already produced or installed)
Type of organisational control	D01	Dual hierarchy (both professional and managers levels are incorporated)
	D02	Triple hierarchy (managers, professionals and professionals with administrative status)
	D03	Influence of the two supervisors
	D04	Not too tightly controlled
	D05	Internal entrepreneurship teams (independent, accountable structures)
	D06	Other
Organisational culture	E01	Innovative organizational culture
	E02	Tolerance of failure
	E03	Competitiveness between employees
	E04	Groupthinking
	E05	Other
R&D strategy	F01	Long-term strategic planning
	F02	Long-term objectives
	F03	R&D strategy is an integral part of overall company mission
	F04	Adapting elements of strategy (objectives, policies, programs)
	F05	Horizontal strategy (expands business into different products, processes that are similar to current lines)
	F06	Information gathering
	F07	Technology strategy (selection, timing, acquisition mode)
	F08	Portfolio diversity
	F09	Other
Human resource management	G01	Recruitment policy
	G02	Explicit career plan
	G03	Incentives to motivate personnel
	G04	Motivation through job security
	G05	Keeping a researcher at the innovation stage (individual goes through number of stages in a given position. At first socialization stage, then innovation and stabilization stage)
	G06	Job rotation
	G07	Researchers to spend (a small portion of their) time of development of their own ideas
	G08	Other
Other	J01	Other

Annex II. Descriptive statistics and correlations of variables in analysis

Variables	Min	Max	Mean	S.D.	Techn	Volume	Patents_b	Patents_c	Patents
Techn	0.0	2.0	.4	.6	1				
Volume	5.4	850.0	168.6	221.5	.086	1			
Patents_b	0.0	14.0	2.0	4.0	-.031	-.016	1		
Patents_c	0.0	8.0	1.4	2.6	.057	-.073	.967**	1	
Patents	0.0	226.0	20.2	59.5	.310	.884**	-.086	-.088	1
A01	0.0	5.0	1.4	2.0	.351	.213	-.249	-.251	.334
A02	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
A03	0.0	5.0	2.1	2.0	-.267	-.349	.343	.385	-.278
A04	0.0	5.0	.6	1.6	.132	.008	.566*	.537*	-.083
A05	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
A06	0.0	4.0	1.0	1.7	-.355	-.069	.318	.226	-.144
A07	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
A08	0.0	4.0	.3	1.1	-.162	.080	.872**	.738**	-.030
A09	0.0	3.0	.2	.8	-.162	.301	-.073	-.151	-.093
B01	0.0	3.0	.4	.9	-.234	.231	-.146	-.217	-.092
B02	0.0	5.0	3.2	1.6	.148	-.084	.443	.488	.135
C01	0.0	5.0	3.0	2.0	.179	.209	.210	.306	.280
C02	0.0	5.0	.4	1.3	-.162	-.037	-.145	-.151	-.098
C03	0.0	3.0	.2	.8	-.162	-.050	-.145	-.151	-.020
C04	0.0	5.0	.4	1.3	.292	-.203	-.073	-.151	-.093
C05	0.0	5.0	2.1	2.3	-.038	-.112	.136	.017	-.265
D01	0.0	5.0	3.5	1.2	-.052	-.141	.100	.166	.122
D02	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
D03	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
D04	0.0	4.0	.8	1.6	-.302	-.040	.763**	.773**	-.067
D05	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
D06	0.0	4.0	.3	1.1	-.162	.301	-.073	-.151	-.093
E01	0.0	5.0	3.0	2.0	.119	.284	-.029	-.044	.157
E02	0.0	5.0	2.3	2.1	-.196	-.137	.329	.315	-.282
E03	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
E04	0.0	5.0	2.3	2.4	.080	-.448	-.113	.032	-.292
E05	0.0	3.0	.2	.8	-.162	.301	-.073	-.151	-.093
F01	0.0	5.0	1.6	2.3	.305	-.447	-.227	-.209	-.225
F02	0.0	5.0	1.6	2.2	.118	-.346	-.255	-.200	-.188
F03	0.0	5.0	2.5	2.6	.351	.483	.225	.200	.285
F04	0.0	5.0	.6	1.6	-.237	-.001	.944**	.934**	-.060
F05	0.0	5.0	.6	1.6	.132	-.076	-.094	-.040	-.077
F06	0.0	5.0	1.3	2.1	-.367	-.105	.566*	.552*	-.157
F07	0.0	5.0	1.6	2.3	.094	-.053	-.219	-.209	-.189
F08	0.0	5.0	.6	1.6	-.237	-.040	.614*	.501	-.088
F09	0.0	5.0	.4	1.3	-.162	.080	.872**	.738**	-.030
G01	0.0	5.0	1.5	2.1	.028	-.220	.427	.521	-.139
G02	0.0	4.0	.3	1.1	-.162	-.050	-.145	-.151	-.020
G03	0.0	2.0	.3	.7	-.239	-.212	-.214	-.222	-.140
G04	0.0	5.0	1.3	2.0	-.088	.348	-.353	-.367	.502
G05	0.0	4.0	.3	1.1	-.162	-.024	-.145	-.151	-.098
G06	0.0	0.0	.0	.0	.[a]	.[a]	.[a]	.[a]	.[a]
G07	0.0	4.0	1.1	1.8	.729**	-.247	.394	.396	-.144
G08	0.0	4.0	.3	1.1	-.162	-.050	-.145	-.151	-.020
J01	0.0	5.0	1.2	1.9	.121	.162	.483	.476	.286

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.