MEASURING THE FUNCTIONALITY OF NATIONAL INNOVATION SYSTEM

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Abstract

<u>Purpose</u> Aim of this research is, firstly – to define and analyze the most important processes that need to take place in the innovation system to lead successfully to innovation. Secondly – to create a framework for analysis of functionality of national innovation system (NIS), for detecting system failures that an innovation policy should approach to foster innovative entrepreneurship.

<u>Methodology</u> The research is organized in three sections. Introduction has explained the background and necessity of this research. The three sections include description of the development of NIS approach, description of functions and methods of analysis of NIS and description of proposed framework of analysis. The last section contains main conclusions.

Proposed framework of analysis of NIS is based on the analysis of literature carried out by author of this research. It is tested on the analysis of Latvia's innovation system and includes interviews with experts of NIS and survey of innovative companies.

<u>Findings</u> Developed framework includes combined use of functions approach and system failures approach. It focuses on the most important processes that need to take place in innovation system to lead successfully to innovation, to capabilities of actors to fulfill these functions and to interaction between them.

<u>Originality</u> There is a lack of academic research in the field of scientific and innovative activities that analysis causality and interaction between knowledge creation and commercialization and focus on the whole innovation process in the Latvia's NIS.

Proposed scheme of analysis may be used by scholars as well as policy makers to measure the functionality of the NIS, to investigate the mismatch between policies and problems, identify policy gaps and devise better policies addressing failures in their NIS with the aim to foster innovative entrepreneurship.

Category of paper: research paper.
Key words: national innovation system, innovation, functions, systemic problems.

1. INTRODUCTION

Innovation as a topic is old as humankind itself but scholarly attention to it is of much more recent origin – starting from 1960s. From 1960s to early 1990s scholarly publications on innovation were few and their major focus was on innovation at the level of the company and /or industry. In the late 1980s and early 1990s arrived a new branch of scholarly work that was more focused on policy and had a stronger emphasis on the interdependencies between the actors, organizations and institutions that influence the innovation. This new branch of the literature emerged under the brand name "national innovation systems" (NIS) and was mainly developed by three scholars: Christopher Freeman, Bengt-Ake Lundvall and Richard Nelson. (Fagerberg and Sapprasert, 2011)

Although NIS approach has gained wide attention from various researchers and policy analysts no single definition of NIS has been yet adopted not speaking about common classification of functions or instruments of analysis. Recent surveys of the literature have acknowledged the lack of comparability between these studies as well as conceptual heterogeneity in the innovation system approach that has led to the critique of the innovation systems approach. Therefore there is need for practically useful analytical framework that allows assessing the performance of the system as well as identification of the factors influencing performance (Bergek et al, 2008).

2. WHAT IS A NATIONAL INNOVATION SYSTEM?
2.1. DEVELOPMENT OF THE NIS *APPROACH*

Freeman (1987) was the first person who used the term "national innovation system" (Suriyani, 2012; Edquist and Holmen, 2008; Archibugi and Michie, 1997; Lundvall, 2007). In early 1990s,

two important books on NIS were published, edited by Lundvall (1992) and Nelson (1993). Also Porter (Porter, 1990) in his work on the national competitive advantage indirectly uses the concept of innovation system emphasizing the feedback mechanisms between local suppliers and users as a factor that creates national competitive advantage. Thereupon NIS spread rapidly and became widely used in the academic circles as well as in policy context of national governments and international organisations. (Fagerberg and Sapprasert, 2011; Niosi, 2008)

Although no single definition has yet imposed itself and despite some differences between the definitions, there is a semantic core that appears in most of the definitions used (Niosi, 2002).

Freeman defined an innovation system as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987).

For *Lundvall*, an innovation system is "the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge... and are either located within or rooted inside the borders of a nation state" (Lundvall, 1992).

Nelson and Rosenberg considered an innovation system "a set of institutions whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg, 1993 in OECD, 1997).

Meanwhile, for *Metcalfe* an innovation system is "that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies" (Metcalfe, 1995 in OECD, 1997).

Basic characteristics of NIS are the institutional set-up related to innovation and the underlying production system (Edquist, 1997 in Niosi 2002).

National innovation system like any other system consists of objects and their inter-relationships which are focused on the achievement of a common goal. It is composed of organizations, institutions and relations between them. Organizations are deliberately set up formal structures with an explicit objective. In the scientific literature organizations are referred to as players, actors or agents. As important organizations of the innovation system companies, universities, venture capital organizations and government departments could be mentioned. Institutions are common habits, routines, established practices, rules or a set of rules governing the relations and interactions between individuals, groups and organizations. (Edquist, 2005).

2.2. FUNCTIONS WITHIN A NATIONAL INNOVATION SYSTEM

A fundamental problem confronting analysts of national innovation systems is the danger of expanding the concept to the point where it includes virtually all aspects of a country's social, economic, political, and cultural activities (Feinson, 2003). One way to avoid this risk is to identify functional boundaries of NIS.

Work of several authors (Liu and White, 2001; Johnson and Jacobsson, 2000; Rickne, 2000; Edquist, 2005; Galli and Teubal, 1997; Hekkert et al, 2007) shows that there is still no agreement regarding which functions or activities should be included in the innovation system.

Liu and White (2001) state that a system-level analysis should begin with an understanding of how fundamental activities of the innovation process are organized distributed and coordinated. They identify five fundamental activities:
 1. research (basic, developmental, engineering);
 2. implementation (manufacturing);
 3. end use (customers of the product or process outputs);
 4. linkage (bringing together complementary knowledge;
 5. education.

Johnson and Jacobson (2000) suggest that performance of an innovation system can be evaluated by assessing how well its functions are served. They present a list of five functions, which are to:

1. create new knowledge;
2. guide the direction of the search process;
3. supply resources, i.e. capital, competence and other resources;
4. facilitate the creation of positive external economies (in the form of an exchange of information, knowledge and vision);
5. facilitate the formation of markets.

Rickne's (2000) functions are to (in Suriyani et al, 2012; in Feinson, 2003):

1. create human capital;
2. create and diffuse technological opportunities;
3. create and diffuse products;
4. incubate in order to provide facilities, equipment and administrative support;
5. facilitate regulation for technologies, materials and products that may enlarge the market and enhance;
6. market access;
7. legitimize technology and firms;
8. create markets and diffuse market knowledge;
9. enhance networking;
10. direct technology, market and partner research;
11. facilitate financing;
12. create a labour market that the new technology-based firms can utilize.

Edquist (2005) presents a provisional list of activities that can be expected to be important in most NIS:

1. provision of R&D, creating new knowledge, primarily in engineering, medicine and the natural sciences;
2. competence building (provision of education and training, creation of human capital, production and reproduction of skills, individual learning) in the labour force to be used in innovation and R&D activities;
3. formation of new product markets;
4. articulation of quality requirements emanating from the demand side with regard to new products;
5. creating and changing organizations needed for the development of new fields of innovation, e.g. enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms, creating new research organizations, policy agencies, etc.;
6. networking through markets and other mechanisms, including interactive learning between different organizations (potentially) involved in the innovation processes. This implies integrating new knowledge elements developed in different spheres of the SI and coming from outside with elements already available in the innovating firms;
7. creating and changing institutions, e.g. IPR laws, tax laws, environment and safety regulations, R&D investment routines, etc., that influence innovating organizations by providing incentives or obstacles to innovation;
8. incubating activities, e.g. providing access to facilities, administrative support, etc. for new innovative efforts;
9. financing innovations processes and other activities that can facilitate commercialization of knowledge and its adoption;
10. provision of consultancy services of relevance to innovation processes, e.g. technology transfer, commercial information and legal advice.

Galli and Teubal (1997) distinguish hard functions requiring hard organizations (i.e., equipped with laboratories and performing research and development), and soft functions, which may be operated within soft organizations. Hard functions include:

1. research and development, involving universities and public (governmental, local, mixed) and non-profit organizations;
2. supply of scientific and technical services to third parties (business sector and public administration) by industrial firms, technological centres, technical service companies, universities, governmental laboratories, and ad hoc organizations.

Soft functions include:

1. diffusion of information, knowledge, and technology towards economic and public operators acting at the interface between knowledge suppliers and users; such bridging organizations include various forms of innovation centres and liaison units universities and public labs, etc.;
2. policy-making by government offices, technology assessment offices, academies, universities, ad hoc fora, national committees and councils, etc.;
3. design and implementation of institutions concerning patents, laws, standards, certifications, regulations, etc.; these functions are usually performed by public or intermediate organizations;
4. diffusion/divulgation of scientific culture through science museums, science centres, etc.;
5. professional coordination through academies, professional associations, etc.

Hekkert et al (2007) define functions as processes that are highly important for well performing innovation systems. They outline seven primary functions:

1. entrepreneurial activities;
2. knowledge development;
3. knowledge diffusion through networks;
4. guidance of the search;
5. market formation;
6. resource mobilization;
7. creation of legitimacy/counteract resistance to change.

In this research as main or direct functions of NIS implemented by primary actors are *proposed*:

1. development of new knowledge;
2. knowledge use (commercialization),

and as support or indirect functions:

3. influence on the direction of search;
4. supply of resources;
5. creation and change of the „rules of the game”;
6. formation of markets;
7. facilitation of information and knowledge exchange.

Development of new knowledge is implemented through combination of new and existing knowledge in an innovative way. As sources of new knowledge research and development, research and experimentation, learning in connection to everyday activities – learning-by-doing, learning-by-using and imitation can be mentioned (Johnson, 2008). This function also includes development of ideas, research studies, and creation of prototypes.

Knowledge use (commercialization) relates to the production of products or development of services.

Influence on the direction of search meaning influence the direction in which actors of NIS employ their resources. This function can be served by the knowledge creators – companies, universities or government, for example, in form of standards and regulations.

Supply of resources. The most mentioned resources are finances and human capital or competence. Resources are necessary as a basic input to all activities within the innovation system. The allocation of sufficient resources is necessary to make knowledge production possible. (Hekkert et al, 2007)

Creation and change of the „rules of the game” (that is – institutions). The creation, abolition and change of institutions are crucial to maintain the dynamism of the innovation system. Institutions can either facilitate or hinder the interaction between actors of an innovation system. For example, governments may support collaborative programs, remove barriers to cooperation and

facilitate the mobility of skilled personnel between different kinds of organizations. Institutions created by public agencies are often formal (codified) ones. Those formal institutions are policy instruments. Others (informal ones) develop spontaneously over history without public involvement. (Chaminade and Edquist, 2005)

Formations of markets since markets do not develop spontaneously. New technology often has difficulty to compete with previously existing techniques. Therefore it is important to create protected space for new technologies either by formation of temporary niche markets for specific application of technology or creating a (temporary) competitive advantage by favourable tax regimes. (Hekkert et al, 2007)

Facilitation of information and knowledge exchange. This function is important for providing feedback between system performance and goals and for diffusion of technology and products on the market. This function is related to promotion of cooperation between actors and to division of labour between them when the cooperation is established, and also to coordination of information and knowledge exchange within companies (Johnson, 2008).

3. OVERVIEW OF METHODS OF ANALYSIS OF THE INNOVATION SYSTEMS

There are three the most problematic methodological issues which arise in the application of innovation system approach. The first is the level of analysis to which a system approach is applied. A second is how the boundaries of the innovation system are defined, i.e. how to delineate the system and identify the actors. A third is how to measure the performance of the system. (Carlsson et al, 2002)

Similarly as there exist different definitions of NIS, there have been proposed also different approaches to evaluate performance of the innovation system (Woolthuis et al, 2005; Hekkert et al, 2007; Bergek et al, 2008; Guan and Chen, 2012; Chaminade et al, 2012). The short overview of these methods is provided further in the text.

Woolthuis et al (2005) after reframing the system failure framework by distinguishing between actors (players) and rules (institutions) design an innovation system framework that enables policy makers to analyse and address systemic failures in their innovation systems (whether they are national, regional or e.g. a cluster). The functioning of the framework is illustrated on the basis of two cluster initiatives in the Netherlands.

Hekkert et al (2007) suggest to connect events in the innovation system with its functions and to show the development of each of the function over time in the picture. A non-linear model is proposed with multiple interactions between seven functions, which will either positively or negatively affect the overall performance of the system. This mapping gives a quick and strong visible presentation of which functions perform well and which do not. For the example biomass digestion in Netherlands is used.

Bergek et al (2008) provide a six step scheme to analysing innovation systems, describing and assessing performance and identifying key policy issues. This framework not only captures the structural characteristics and dynamics of an innovation system, but also the dynamics of a number of key processes (functions), that directly influence the development, diffusion and use of new technology and, thus, the performance of the innovation system. As an illustrative case "IT in home care" is used.

Guan and Chen (2012) propose a relational network data envelopment analysis model for measuring the innovation efficiency of the NIS by decomposing the knowledge innovation process into a network with a two-stage innovation production framework – a knowledge production process and a knowledge commercialization process. The hybrid two-step analytical procedure is used to consider 22 OECD (Organisation for Economic Co-operation and Development) countries.

Chaminade et al (2012) provide a framework – two stage hierarchical factor analysis to identify systematic problems (institutional, science and technology (S&T) infrastructure, support services

and network) in national innovation system. The framework is tested on the evaluation of Thailand innovation system.

4. DEVELOPED FRAMEWORK FOR THE ANALYSIS OF NIS

Framework developed in this research rests on the synthesis of research of Bergek (2008), Chaminade et al (2012) and Hekkert et al (2007).

Identification and analysis of the NIS is based on the analysis of theory, strategic documents and regulations, studies, indexes and statistics, case studies, interviews with experts (actors of NIS or representatives of participants of NIS) as well as survey of innovative companies.

Proposed scheme of analysis of NIS consists of four steps (figure 1).
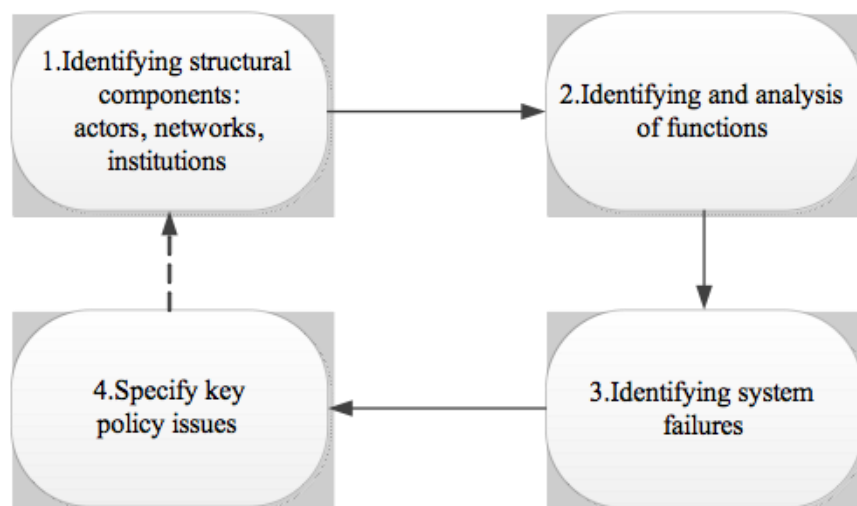
**Figure 1.** Scheme of analysis of NIS
Source: Author's illustration

The first step involves setting the starting point for the analysis, i.e. defining the national innovation system in focus and identifying structural components of NIS – actors, networks institutions. In the second step functions of NIS are analysed describing what is actually going on in the NIS in terms of the seven key processes (two main or direct functions and five support or indirect functions) and their fulfilment is assessed – how well they are implemented. In the third step mechanisms that either induce or block the NIS and system problems are identified. In the fourth step – key policy issues related to these inducement and blocking mechanisms are defined.

First step: identifying structural components: actors, networks, institutions.

After analysis of strategic documents, regulations and different researches actors of the Latvia's NIS were determined and divided into categories covering primary and secondary actors (table 1).

Second step: identifying and analysis of functions.

Based on the literature analysis author of this research has developed a model that maps the interaction of actors and proposed seven functions (figure 2). These functions have been described in the sub-chapter No.1.2. of this paper.
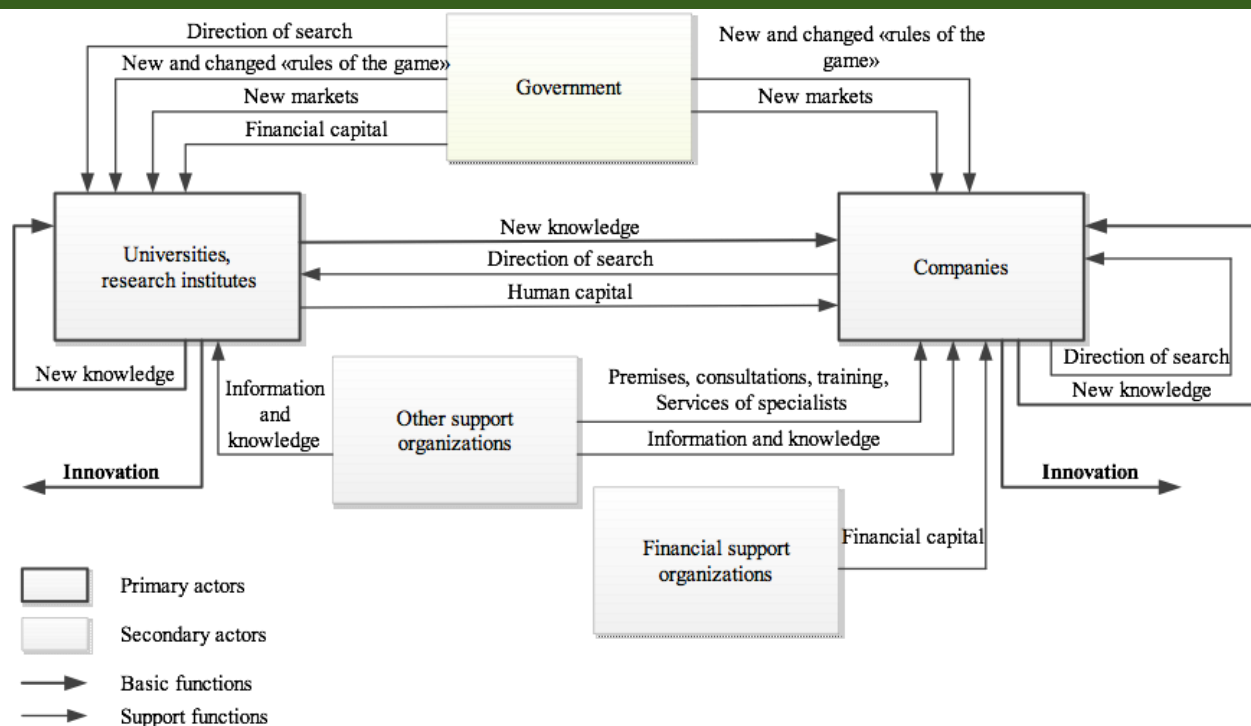
Figure 2. Model of NIS using functions approach
Source: Author's illustration

To plot a complex picture of the innovation system and innovation system problems not only viewpoint of companies but also of representatives of all actors of the NIS should be taken into account.

From 21 February 2014 to 26 March 2014 there were carried out face to face interviews with 45 experts representing all actors of the Latvia's NIS with the aim to evaluate the functionality of NIS and to identify the main obstacles to innovative entrepreneurship in Latvia (table 1).

Table 1

Structure and number of interviews of experts

Type of actor			Number of
1.Primary actors	1.1.Universities	1.1.1.State universities	3
		1.1.2.Universities	3
		1.1.3.Private universities	2
	1.2.Research institutes	1.2.1.Public research institutes	2
2.Secondary actors	2.1.Government	2.1.1.Political level	2
		2.1.2.Advisory level	5
		2.1.3.Operational level	6
	2.2.Financial support organizations	2.2.1.Credit institutions (banks)	2
		2.2.2. Seed, startup and venture capital funds	3
	2.3.Other support organizations/activities	2.3.1.Business incubators, technology	4
		2.3.2.Industry clusters	3
		2.3.3.Technology transfer contact points	4
		2.3.4.Competence centers	3
		2.3.5.Public interest research centers	2
		2.3.6.Other	1
		Total	**45**

Source: Composed by the author

Interviews were carried out following twelve pre-prepared open ended questions (there have been also different additional questions during interviews) from which one question was to evaluate the main barriers or obstacles to innovation for companies (table 2). Experts were asked to use five-point scale, 1 having no impact, 2 – small impact, 3 – average impact, 4 – significant impact, and 5 – large impact.

Interviews of experts showed that not all the experts have comprehensive knowledge about NIS and its main processes/functions. However dominant opinion was that NIS in Latvia does not work and the weakest link in the system is legislation. There exists no common innovation strategy in the country and without strategy stronger innovation system cannot be developed. Actions between all the actors are coordinated weekly and there are created no tools to facilitate cooperation between actors. It has been also marked that for a small developing country like Latvia it is important to enumerate also these innovations that are not based on the patents. According with the evaluation of the main barriers to innovation for companies experts considered internal factors slightly more important than external factors (average evaluation 3,5 for internal factors and 3,1 for external factors). Limited financial resources (average score 4,2) and costs related to the introduction of innovation (average score 3,7) were evaluated as the most impedimental factors for innovation. This corresponds with the assessment of external factors where as the main barriers to innovation a lack of qualified personnel (average score 4,0), a lack of financial support (average score 3,7) and a lack of government support (average score 3,4) were chosen.

Table 2

Main barriers to innovation for companies: factors and average evaluation from experts

No	Factor	Average evaluation
1.	INTERNAL FACTORS	3,45
1.1.	Too high risk of failure	3,42
1.2.	Too high costs related to the introduction of innovation	3,73
1.3.	Limited financial resource	4,20
1.4.	Lack of information on technology	2,88
1.5.	Lack of information on market demand	3,19
2.	EXTERNAL FACTORS	3,07
2.1.	Lack of qualified personnel	4,00
2.2.	Lack of support services	3,19
2.3.	Support services do not meet the companie's needs	3,20
2.4.	Lack of financial support	3,68
2.5.	Too expensive financial support	3,31
2.6.	Lack of government support	3,35
2.7.	Lack of customer's interest in innovative products or services	2,77
2.8.	Lack of competition in the domestic market	2,40
2.9.	Need to meet the legislative requirements of the Republic of Latvia	2,60
2.10.	Need to meet the requirements of EU and other international organizations	2,69

Source: Composed by the author

Survey of innovative companies was conducted within three months – from May 7, 2014 until 7 August. The survey was conducted via electronic mail (e-mail). 71 questionnaires were received: fifty-six from the micro and small companies, eleven from medium-sized companies and four from large companies.

Evaluating of the main barriers to innovation owners and/or managers of micro and small companies considered internal factors more important than external factors, but owners and/or managers of medium and large companies – on the contrary (table 3). For the micro and small companies the main barriers for innovation were limited financial resources, lack of financial support and lack of government support, for the medium and large companies – support services do not meet the needs of company, lack of support services and lack of qualified personnel. It means that there should be developed different kind of support instruments for micro and small companies and different ones for medium and large companies.

Table 3

Main barriers to innovation for companies: factors and average evaluation from entrepreneurs

No	Factor	Average evaluation from companies	
		micro and small	medium and large
1.	INTERNAL FACTORS	3,23	3,04
1.1.	Too high risk of failure	2,96	2,79
1.2.	Too high costs related to the introduction of innovation	3,70	3,36
1.3.	Limited financial resource	4,07	3,50
1.4.	Lack of information on technology	2,46	2,64
1.5.	Lack of information on market demand	2,93	2,93
2.	EXTERNAL FACTORS	3,15	3,06
2.1.	Lack of qualified personnel	3,32	3,64
2.2.	Lack of support services	3,23	3,64
2.3.	Support services do not meet the companie's needs	3,36	3,79
2.4.	Lack of financial support	3,79	3,50
2.5.	Too expensive financial support	3,71	2,93
2.6.	Lack of government support	3,79	3,57
2.7.	Lack of customers' interest in innovative products or services	2,66	2,93
2.8.	Lack of competition in the domestic market	2,23	2,14
2.9.	Need to meet the legislative requirements of the Republic of Latvia	2,66	2,07
2.10.	Need to meet the requirements of EU and other international organizations	2,73	2,36

Source: Composed by the author

If to compare answers of experts with the answers of companies the conclusion is that providers of support activities are rather well informed about the main problems of innovative companies that allows predicting that appropriate policy instruments will be at least developed if not implemented.

5. CONCLUSION

This paper aimed at designing a policy framework based on the innovation system approach because in accordance of opinion of author of this research there still lack a practical framework for assessment of functionality of national innovation system, identification of system failures, consequently – key policy issues, and for setting policy goals. Based on the review of the innovation system literature, a framework was designed that enables a clear cut distinction between the system functions, the different forms of system failures and the actors that should be involved to address these failures. This enables policy makers to analyse, evaluate and design innovation policy measures. The functioning of the framework was illustrated by evaluating Latvia's national innovation system.

Assessment of the NIS using this framework provides insight of the system that is relevant for policy. According with the Hekkert et al (2007) when policy initiatives aim to influence the direction of technological change, insight in the current functioning of the innovation system is the first step in determining the optimal policy strategy. The next step is to develop policy initiatives to stimulate the weak functions and remove system failures with the aim to improve functioning of the innovation system and raise the level of innovative entrepreneurship.

There is a need for more research on how to assess NIS functionality. The illustration of the framework on the basis of analysis of one NIS is not sufficient to draw conclusions on the usefulness of the framework. This needs a further study, whereas the framework could further be used as a tool to analyse system failure and design and evaluate innovation policy measures.

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