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OPPORTUNITIES FOR SUSTAINABLE DEVELOPMENT AND CHALLENGES IN NANOTECH INDUSTRY IN LATVIA

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Abstract. In the coming decade, implementation of smart specialisation strategy concept will be topical for all EU member states given a special focus made on the areas of technology and innovation. Members of academic community conduct research in these areas to identify the challenges and offer optimal solutions to the complicated problems. It is of particular importance for the countries with a relatively modest capacity for innovation. Some of the aims of the Latvian smart specialisation strategy are to establish a platform for cooperation between research community and the private sector and to develop nanostructured materials industry. The paper analyses research results in the field of nanotechnology in Latvia using the data on the publications and projects, as well as publication citation indices. Publicly available information on performance results of the selected enterprises in the field of nanotechnology is analysed and benchmarked using public data on performance indicators of the manufacturing industry with regard to technological intensity.

Keywords: sustainable development, smart specialisation, SME, nanotechnology

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1. Introduction

The concept of smart specialisation strategy emerged in 1995 considering the economic gap between Europe and the USA based on productivity problem evaluation and sector analysis (van Ark et al. 2008, Foray et al. 2012; Shatrevich, Strautmane 2015; Tvaronavičienė 2014; Rezk et al. 2015; Travkina, Tvaronavičienė 2015). At present, analysis of the factors influencing smart specialisation concept and the issues of practical implementation of theoretical findings in the EU member states are widely discussed by the academic community (Foray et al. 2011, Foray et al. 2012, Sandu 2012, McCann, Ortega-Argilés 2015; Branten, Purju 2015; Lace et al. 2015; Tvaronavičienė et al. 2015a; 2015b). The Strategy for Smart Specialisation is one of the most important regional development and innovation promotion areas within Europe 2020 strategy. The need to carry out economic transformations is conditioned by regional development processes and the aim to support high-productivity industries. Therefore, planning innovations to receive financing from the EU Structural Funds at the national level each member state determines priority sectors with the established competitive advantage. It means that the selected prioritates are connected with the existing economic structure of the state, and the necessity to recognise and open new opportunities to implement real structural changes to increase general welfare level becomes topical.

It is maintained (Dougherty 1998) that the nature of innovation process and related concepts can be difficult to fully account for, as innovation comprises all social activities ranging from education, research, intellectual property protection, manufacturing process management, market research and product sales. This process overlaps with all other activities related to business environment improvement and establishment of the structures supporting innovation. Baier et al. (2013) point out that the EU smart specialisation concept has two dimensions, namely, a policy or governance dimension and economic or market dimension.

Innovation potential of an enterprise of any size, of small enterprises in particular, is determined by the ability to integrate knowledge into business, literally, to commercialise it. Ortega-Argilés (2012) stresses that small and medium-sized enterprises (SME) play a special role in the implementation of smart specialisation strategies (3S) in the EU regions, and this role should be recognised. The aim of regional development is specialisation based on core research areas and technologies of a concrete region, and according to Foray et al. (2011), this process involves different economic entities – enterprises, research institutions, and higher education institutions (HEI). Ortega-Argilés (2012) points out that the development should not be limited to one specific industry, it is important to promote cross-sectorial cooperation, niche development and internationalisation (Izsak et al. 2013).

In the present paper, the authors consider the market dimension related to manufacturing of innovative multifunctional materials using nanotechnology in SME segment in Latvia. The authors review literature on the role of small enterprises in the development of nanotechnology and provide insights into the development of the priority field of materials science in Latvia in the recent years and business unit performance. Research methodology includes four stages: 1) summary and analysis of research results in the field of nanoparticles in Latvia; 2) selection, processing and analysis of statistical data on the manufacturing industry with regard to technological intensity; 3) selection of enterprises involved in nanostructured material manufacturing; 4) retrieval, processing and analysis of performance indicators of the selected enterprises for 2013 and 2014 based on Lursoft database data.

2. Development of the research field in Latvia

In 2004, the European Commission approved the report on nanosciences and nanotechnology and adopted an Action Plan for Europe 2005 – 2009, as a considerable amount of research was devoted to nanotechnology applications in various research fields (Kaufmane et al. 2007). In 2006, nine priority research areas were defined in Latvia covering the fields in which basic and applied research projects of the Latvian Council of Science were implemented. Targeted state research programmes were launched in the respective fields as a public contract for research activities to promote the development of these areas and facilitate applied research. The National Development Plan of Latvia for 2014-2020 determines medium-term development areas; it also defines concrete target values for performance indicators – to increase the percentage of innovative enterprises until 15% from the total number of enterprises and raise innovative product sales until 25% from the total turnover by 2020. To reach this aim it is planned to establish a platform to promote cooperation between research community and the private sector and to develop nanostructured materials industry; the EU financial instruments, state budget and private funding will be used as the primary sources of finance.

One of the nanotechnology-related development areas in Latvia is closely connected with materials science – design and synthesis of functional nanomaterials and a new generation of composite materials. According to the definition adopted by the European Commission on 18 October 2011, nanomaterial is «a *natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm»*. Nanosized particles have different physical properties than bulk materials, and that is the reason why nanotechnology is a promising area with a huge development potential, which may be hard to predict. As in case of any other technology, the development of nanostructures and nanosystems is described as a sequence of generations. Inventions in this area led to the discovery of passive nanostructures around 2001, which are seen as the first generation (nanostructured metals, polymers and ceramics). First-generation passive nanostructure materials can perform one particular task. The second generation – active nanostructures – appeared around 2005, in combination with other microscopic systems they are capable to react to external environment. Fields of application include transistors, reinforcing agents, and adaptive structures. Starting with 2010 it is possible to talk about the third generation of nanostructures – three-dimensional nanosystems with heterogeneous nanocomponents and various assembling techniques. It is envisaged that the fourth generation will emerge around 2020. It will be molecular nanosystems with heterogeneous molecules based on biomimetic processes and new design (Roco 2005). Currently in Latvia the application of the first two generations of nanomaterials is highly topical, including the use of nanocoatings, nanoparticles and nanostructured materials in mechanical engineering, electronics, medicine, cosmetics, textiles, chemical and coating industries.

It is possible to trace the level of academic development of a concrete technology using both publications in ISI databases and patent application dynamics. It is recognised that the work of an enterprise aiming at long-term development is based on available resources, investments and technologies (Hart, Milstein 2003). There are studies attesting that: 1) intellectual property is an essential factor in nanotechnology commercialisation; 2) enterprises working in the field of nanotechnology are characterised by multistage (differentiated) financing; 3) enterprises should participate in partnerships, cooperate and consolidate, and unite into clusters (Miller et al. 2004).

In order to implement the changes in the context of smart specialisation strategies, it is necessary to establish groups of active participants capable of initiating change (Gianelle, Kleibrink 2015). One possible solution is creation of clusters, which are formed for a specific purpose and serve as a basis for smart technology implementation. Industry clusters stand to denote a close linkage of existing products within a value chain in a definite industry and its presence in the economy, as well as the link between the products and the existing labour skills and research capacity of a particular country. Systemic relations between enterprises are realised as outsourcing implying the use of technology, adding products to the range, and usage of specific skills (accounting, marketing). Clusters, similar to products and enterprises, develop in cycles going through several consecutive stages: 1) embryonic stage (specific research expertise, incoming investment, innovative discoveries, geographically clustered groups with specific needs); 2) growth stage (product development, vigorous entrepreneurial activity); 3) maturity (characterised by lowering costs which become a competitive advantage, products are imitated at a larger scale); 4) decay (the products become fully replaceable by lower cost substitutes) (Rosenfeld 2002).

In Latvia information on numerous clusters is publicly available. Each cluster has different aims and unites different partners:

1) The aim of the Industrial Energy Efficiency Cluster Latvia (21 partner) is to raise export capacity of the Latvian manufacturing enterprises and providers of energy efficiency services to ensure that Latvian manufacturers in the long term reduce total energy costs, which undermine product competitiveness in the foreign markets (Latvian Environmental Investment Fund 2015);
2) The main task of the Space Technology Cluster (44 partners) is to promote cooperation among space and high-tech industry enterprises, research institutes, universities and non-governmental organisations to increase their competitiveness and export performance (Ventspils High Technology Park 2015);
3) The aim of the Green Energy and Environmental Technology Cluster (about 100 partners) is to create new business opportunities, competitive advantages and added value for the participating enterprises in cooperation with municipalities, research, educational, business support and other intstitutions (Kurzeme Business Incubator 2015);
4) CleanTech Latvia (31 partner) is a non-profit organisation established to promote development and recognisability of the Latvian clean technology enterprises, organisations, research and/or educational institutions (CleanTech Latvia 2015);
5) The aim of the Latvian Electronics and Electrical Engineering Industry Cluster (38 partners) is to facilitate cooperation between companies in electronics and electrical engineering industry and research and educational institutions, to raise competitiveness of businesses and the industry as a whole, to increase exports, to promote innovation and new product development in the industry (Latvian Electronics and Electrical engineering cluster 2015);

6) Nanostructured materials and high-energy radiation cluster NanoTechEnergy (6 partners) consolidates and updates the existing infrastructure of research institutions to develop a platform for modern material technology development, materials research and education in the Baltic Region to design innovative multifunctional materials that will be used in competitive research-intensive products. Multifunctional materials are envisaged for radiation energy conservation, data recording, storage, transfer and transformation, as well as their efficient application in high-tech devices (NanoTechEnergy 2015).

Partners of NanoTechEnergy cluster work in many areas: 1) research on thin-film and coating technologies and their applications; 2) research on thin film boundaries; 3) research on plasma synthesis of nanoparticles and their applications; 4) nanowire production and research; 5) nanocomposite material production and research; 6) research into applications of hybrid materials and systems; 7) synthesis and research of photonic materials; 8) theoretical modelling of multifunctional materials; 9) theoretical and applied magnetohydrodynamics; 10) geomatic measurements; 11) radiochemistry and research into materials used in thermonuclear reactions (NanoTechEnergy 2015). It should be noted though that all cluster participants are research institutions and real enterprises operating in the market are mentioned as stakeholders rather than participants. Moreover, research centre of state significance LATNANO-C dealing with nanostructured and multifunctional materials, constructions and technologies is only at the initial stage of its development. There is an opinion (Motoyama et al. 2011) that the development of nanotechnology is not possible without state support, at the expense of private business only, as research results reach the market after some 10-20 years, but entrepreneurs make investments if returns are expected in 3-5years at the latest. It means that the main aim of cluster activities is to reconcile the interests of the state, research and business communities.

The web page CORDIS (European Commission Community Research and Development Information Service) provides an opportunity to select projects connected to nanoscience, where Latvia is represented as a participant (in the period from 2002 to 2013). In total € 3.5 billion were allocated to the field of nanomaterials and nanotechnologies within the *European Union's Research* and *Innovation* funding programme FP7. Information summarised in Table 1 demonstrates that the largest fraction of project funding came from the EU Structural Funds and the parties involved in the implementation of the projects or project participants from Latvia were mainly universities and associated research centres. Nanomaterials and nanotechnologies are a new field for Latvia, and this is attested by the number of projects implemented in the last ten years. There is a clear indication that there are problems related to the funding allocated to date, as the existing structure is not viable in the long-term perspective (TECHNOPOLIS Group 2013).

Table 1. Investment summary on the Latvian scientist participation in the projects in nanotechnology, YY 2002-2013

(*Source*: retrieved by authors from http://cordis.europa.eu/fp7/)

Institution	Number of projects	Total cost, EUR	EU contribution	
			EUR	%
University of Latvia	9	17,699,509	13,089,207	74
Riga Technical University	4	8,340,086	5,815,428	70
Latvian Academy of Sciences	1	1,529,032	1,332,494	87
Commercial companies	2	2,308,819	1,439,576	62
Other (public organisation)	2	765,913	718,413	94

Despite the fact that Latvia is in the group of so-called «modest innovators» and R&D intensity index (GERD to GDP, %) in 2012 was 0.66 (EUROPE 2020), it has been recognised that the country has a good specialisation level in materials both in terms of research and technology (except nanotechnology) (*European Commission* 2014). Small number of R&D employees in the private sector is a sign of insufficient knowledge absorption capacity of the industry, which in its turn does not facilitate cooperation between science and industry. Insufficient number of employed in science, research, technology advancement and innovation and low staff renewal rate in these areas are the main drawbacks of Latvia's innovation system, as a result Latvia is ranked second-to-last among the EU member states in the field of innovation, leaving behind only Bulgaria (European Union Research and Innovation 2014).

The majority of indicators describing research capacity of a country in a particular field is based on the number of internationally recognised publications and granted patents. If publications appear as a result of cooperation between business and research community, they have a much higher impact, but in Latvia cooperation of this kind is still relatively rare. If support instruments are in place, it is possible to facilitate joint action at the international level and to promote collaboration between researchers and entrepreneurs. There is ample evidence that smart strategy activities prove to be successful, the development of regional smart specialisation network, which is realised as collaboration in new patent applications and joint publications, can be mentioned as an example (David et al. 2009).

Cooperation can be interregional, and it is possible that joint projects with, for example, Lithuanian or Estonian academia can promote development of a definite sector in Latvia. The Baltic Region is not just an ideal concept; it is the region with common territory and common business culture.

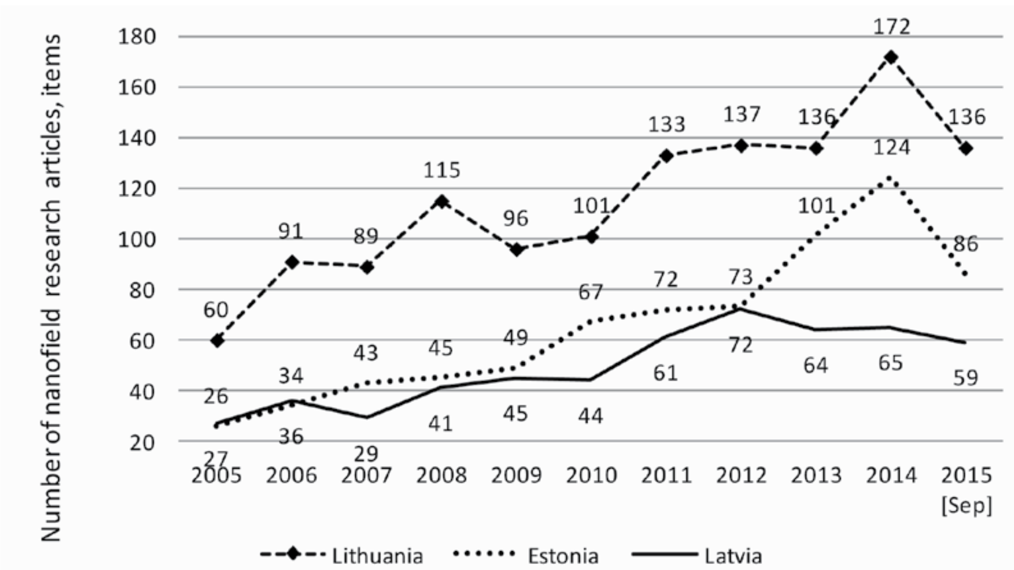

Fig.1. Nanofield research articles, the Baltic Region

(*Source:*compiled by authors using http://statnano.com/)

Summarising information about publications in nanotechnology in three Baltic States from 2005 until 2015 it can be seen that Lithuanian researchers published more articles in the field than researchers from the other Baltic States. As of 1 September 2015 Latvia was ranked 64th in the world with 59 publications. According to EPO (European Patent Office) data, as of 1 June 2015 Latvia was in the 62nd place with 0 granted patents and its h-index showed tendency to decrease – in 2010 it was 12, but in 2014 – just 3.

Nanotechnology research indicators are summarised in Table 2.

Table 2. Nano-related research indicators in Latvia

(*Source:* compiled by authors using http://statnano.com/)

Indicator	2010	2011	2012	2013	2014
Average citation per nano-related article	8.32	5.56	3.6	2.33	0.7
H-index of nano-related articles	12	11	8	6	3
Nano-related articles	44	61	72	64	65
Local share in nanoscience generation (Percent)	11	10.63	12.77	10.27	10.06
Nano-related articles per million people	19.65	29.64	35.55	31.79	32.16
Published patent applications in nanofield (EPO)	**1**	**1**	**0**	**1**	**1**

In Latvia, public and private research cooperation is very weak, and that leads to reduction of outward foreign investment channelled to support research-intensive and innovation-based industry specialisation. Fig. 2 shows the total number of publications in Latvia and the number of articles in nanotechnology included in the ISI databases in the last 10 years.

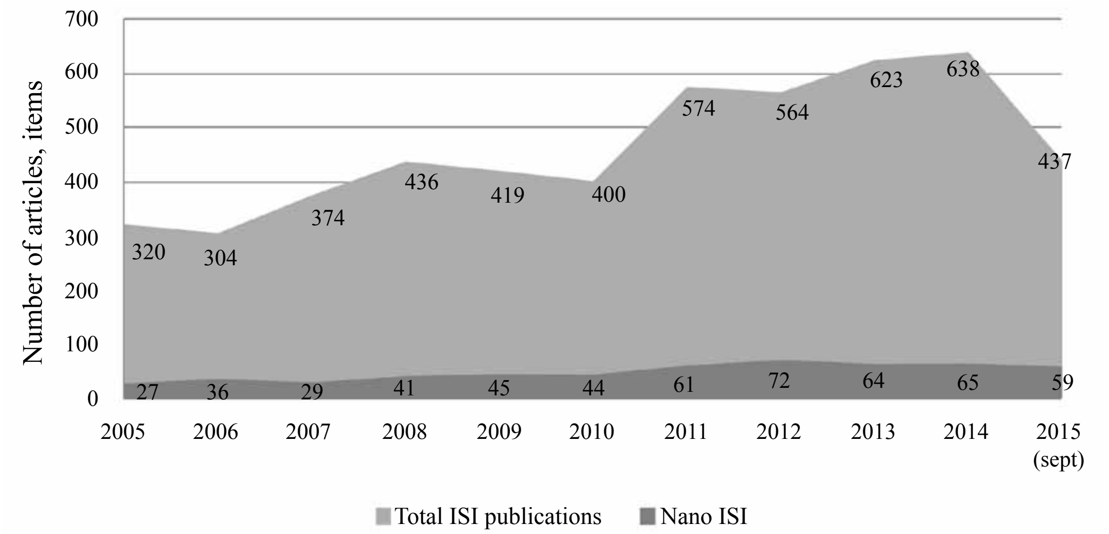

Fig.2. Publications in ISI databases in 2005 – 2015

(*Source:*compiled by authors using http://statnano.com/)

The number of publications in the established databases is an important quantitative and qualitative indicator used in the Latvian science. At present, a new university financing model «Money Follows Quality» has gained prominence, and the issue of long-term development opportunities of the field in question has become topical. Publications and conference materials on physics and astronomy published in 2014 have been recognised as having fundamental significance on the world scale, however, publications in the nanofields have low citation index (Latvian Council of Science 2015).

3. Aspects of commercialisation

The structure of the Latvian business is mainly formed by micro, small and medium-sized enterprises (in 2015 they constituted 98.9%). SMEs are traditionally seen as the backbone of economy, however, SME capacity to make investments in research and new product development is relatively low. SME activities in a definite field are influenced by objective factors: small market share and informal organisational structure (Bolton 1971). Although SMEs can react flexibly at external impacts, the size of their market is small, specialisation with regard to factors of production is limited and qualification of workforce is not always sufficient (McAdam, Keogh 2004). The issue of intellectual investment absorption capacity also remains topical, because to ensure the private sector is able to use research innovations, it is necessary to establish the culture for innovation, as according to Morone and Testa (2005) the attitude of an enterprise to innovation determines its competitiveness in 61.7 % cases. Innovation behaviour is an important aspect determining competitiveness of a business; it provides the basis that allows the enterprise to work in the global markets, develop niche specialisation, and participate in a knowledge network (cluster) (Morone,Testa 2005). These related processes depend on the availability and quality of human resources. Izsak et al. (2013) mention the problems with human capital after the crisis of 2008, as many talented people left Latvia seeking better-paid jobs and career opportunities abroad. Freel (2000) concludes that creative innovation potential and opportunities to introduce innovations in SMEs are limited, and they mainly focus on product improvement.

It is recognised that small enterprises establish important links between market and research in the field of nanotechnology. For example, Genet et al. (2012) note that patent application intensity in SMEs that work in nano-related fields is more than 50%, whereas in large enterprises it is below 10%; small enterprises perform technology-bringing role, but it may be stated that they are not always capable to transfer knowledge from state research sector to industry. Small enterprises can use breakthrough technologies more efficiently and see new market opportunities, at the same time, large enterprises can face significant challenges in the introduction of revolutionary technologies, as they may be driven by organisational inertia and short-term goals (Christensen, 2013; Kostof et al. 2004). Small commercial nanotechnology companies operate in a dynamic and volatile nanotechnology business environment. Studies attest that tech savvy entrepreneurs do not always strive for development and profit maximisation, but, for instance, for independence (Oakey 2003). Berry and Taggart (1998) and Oakey (2003) point out that a multi-skilled management team where technological excellence is supplemented with managerial skills is seen as an important factor to gain success in technology-based business. According to Maclurcan (2005) nanotechnology promotes cross-disciplinary research collaboration. Nanotechnology unites numerous research fields and technologies: information technology, biotechnology and materials technology (Invernizzi, Foladori 2005).

Critical lack of cooperation between entrepreneurs and representatives of science and research institutions is a different strategic trend. In the period from 2008 until 2012, RTU researchers applied for 11 patents in nano-related fields: synthesis of nanoparticles for nanocomposites, nanocoatings, solid body nano-acceleration measurement, and nanostructured materials in the micron and/or nanometre size range. Researchers study fundamental scientific problems they are interested in, whereas entrepreneurs try to produce and sell what their clients want, as special equipment at the disposal of the enterprises can be utilised only in the particular niche they operate. Research activity in the production sector is also very low; in some nanotechnology sectors it is virtually non-existent. To obtain information from the enterprises that deal with nanotechnology, researchers mainly use surveys and questionnaires, as structured publicly available statistical data is not available. Surveys have been used: 1) to acknowledge the significance of nanotechnology in the USA manufacturing industry (NSF 2005), 2) to assess health and safety practices in the nanomaterial industry (Conti et al. 2008), 3) to determine the level of commercialisation in nanotechnology (Fiedler, Welpe (2010). In order to find out which Latvian companies work in the field of nanotechnology, the enterprises were analysed considering their core activities according to NACE Rev. 2 codes and the relevant business entities were selected using the database of the Central Statistical Bureau and information available in Lursoft database, as well as company home pages. Table 3 presents summarised information on performance indicators in the manufacturing industry in Latvia with regard to technological intensity in 2013; the number of selected enterprises using nanotechnology in each technological intensity group and the industry, in which they operate, are shown opposite.

Table 3. Performance indicators in the processing industry by technological intensity, 2013 (CSB data processed by authors)

Technological intensity group	NACE Rev. 2 code	Annual sales per employee, thsd euro	Monthly labour costs per employee, euro	Number of selected enterprises in nano-related fields (NACE Rev. 2 code)
High technology (HT)	21, 26, 30.3	96.8	1,144	**3 (26)**
Medium-high technology (MHT)	20, 25.4, 27, 28, 29, 30, (except 30.1 and 30.3), 32.5	62.4	872	**2 (20); 1 (32.5)**
Medium-low technology (MLT)	18.2, 19,22, 23, 24, 25 (except 25.4), 30.1, 33	70.4	808	**1 (23); 1(25)**

Table 3 presents mean values – sales and labour costs per employee in the Latvian manufacturing companies by technological intensity in 2013. The selected 8 enterprises (highlighted in bold), which deal with multi-functional material production including materials for nanocoatings, operate within several industries in Latvia: NACE 20 Manufacture of chemicals and chemical products – medium-high technology (MHT); NACE 23 Manufacture of other non-metallic mineral products – medium-low technology (MLT); NACE 25 Manufacture of fabricated metal products, except machinery and equipment (MLT); NACE 26 Manufacture of computer, electronic and optical products – high technology (HT); NACE 32.5 Manufacture of medical and dental instruments and supplies (MHT). In Latvia, nanotechnology is used within all three technological intensity groups. It means that nanotechnology as an important form of innovation can promote establishment of new enterprises and even create completely new fields within the existing industries (Bozeman et al. 2007).

Characterising the field of nanotechnology in Latvia it should be recognised that it is heterogeneous, enterprises have narrow specialisation and work in different market niches. The number of such enterprises is relatively small considering the manufacturing industry overall. Only a small fraction of produce manufactured by these companies reaches domestic market, as their export volumes range from 75% to 100% of the total output. Export flows are managed by each enterprise individually, each of them being involved in a separate international supply chain. Table 4 provides summarised data on 7 enterprises that export their products indicating export volumes and export industries, which utilise their output. Only one company working in the field of manufacturing of medical and dental instruments and supplies (MHT/32.5) sells all its products in the domestic market.

Table 4. Latvian nanotechnology enterprise exports according to NACE Rev. 2 codes by technological intensity in 2014

Manufacturing industry according to technological intensity/NACE Rev. 2 code	Export industry	Export volume, %
HT/26A	Aviation and aerospace industry	90-100%
HT/26B	Manufacture of computer, electronic and optical products	
MHT/20A	Manufacture of chemicals and chemical products	
MHT/20B	Aviation and aerospace industry; Manufacture of fabricated metal products, except machinery and equipment; Manufacture of non-metallic mineral products; Scientific research and development	
MLT/23A	Manufacture of motor vehicles; Manufacture of medical and dental instruments and supplies; Manufacture of pharmaceutical products; Biomedicine; Biotechnology; Manufacture of computer, electronic and optical products	
HT/26C	Aviation and aerospace industry; Manufacture of motor vehicles; Manufacture of computer, electronic and optical products; Manufacture of electrical equipment	Up to 85%
MLT/25A	Manufacture of motor vehicles; Manufacture of fabricated metal products, except machinery and equipment; Scientific research and development	Up to 75%

(*Source:* compiled by the authors)

All Latvian enterprises working in high-tech fields deal with manufacturing of computer, electronic and optical products, but only two of them cooperate with aviation and aerospace industry, one enterprise delivers products to foreign partners within its core industry. Enterprise HT/26C exports its products to more than one industry and that in a way attests that the products are unique and widely applicable. Two enterprises in the MHT niche manufacture chemical substances and chemical products, and one of the enterprises exports its produce to a high-tech industry.

Figures 3.1, 3.2 and 3.3 illustrate sales per employee in 2013 by technological intensity group. Although all enterprises work in nanotechnology, it can be clearly seen that they demonstrate significant differences in the annual sales per employee. Comparing the annual sales per employee by technological intensity group, three high-tech sector enterprises, namely, HT/26A, HT/26B, HT26C fall considerably behind the mean annual indicator for the group, which is 96.9 thousand EUR. In turn, from three enterprises in the MHT group only MHT/20B shows annual sales per employee amounting to 77.7 thousand EUR and that exceeds the mean indicator of the group – 62.4 thousand EUR. At the same time, enterprise MLT/23A in the MLT group managed to reach annual sales of 98 thousand EUR per employee, and that is the highest indicator among the companies in the sample. All enterprises selected can be classified as SME. It has been confirmed that differences in nanotechnology commercialisation depend on the size of the enterprise, and that small enterprises are in a better position to use the opportunities provided by nanotechnology than large ones (Avenel et al. 2007).

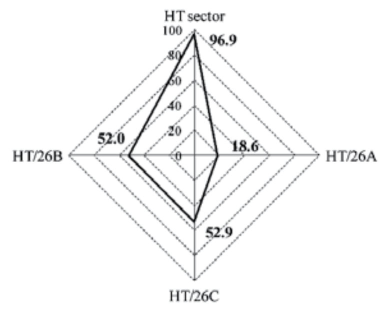

Fig.3.1. HT sector sales per employee in 2013

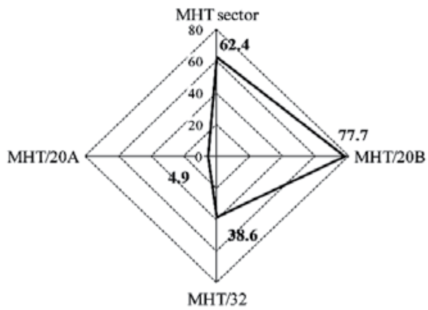

Fig.3.2. MHT sector sales per employeein 2013

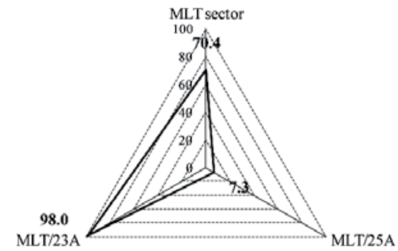

Fig.3.3. MLT sector sales per employee in 2013

The authors consider that performance results of the selected enterprises are influenced by macroeconomic and demand factors, as well as the structure of the industry. It should be noted that it is rather the field that can be discussed than the industry as a whole, because to make an informed decision on the industry, it is necessary to have structured data and summarised statistics. At present these data are not available. Therefore, market orientation of the purposefully developed field depends on the economic policy of the country and the implemented support instruments to promote enterprise and product development in the industry. In such a way both intermediate seller and end consumer market or national demand are formed. Technologically consolidating the attracted resources an enterprise develops the total of supply factors, which characterises, e.g. a definite product range and potential manufacturing capacity. That is the reason why each enterprise with its factual production volume can be considered an inherent element of the industry and it has a certain impact on its further development. The enterprise depends on the change and development of the industry and in this connection can face both stimuli and limitations in further work of the business. Commercialisation of nanotechnology is implemented by enterprises in many industries and Wiek et al. (2008) use the notion "development potential", which covers development opportunities of the research field, qualification and competences of the available workforce, patents and cooperation among management, different industries and academic institutions. Practical implementation of 3S concept is not possible without sustainable development. Sustainability is formed by the sum of partial equilibrium states of separate elements in the system. The more system elements demonstrate the features of equilibrium state, the higher sustainability of the system is Sustainable development factors of the enterprises focused on innovative technologies include: 1) income from the buyers of the produce manufactured by the enterprise; 2) financial stability and positive profitability dynamics; 3) workforce competences and skills; 4) consideration of ecological issues within the general enterprise management process; 5) positive public attitude towards enterprise activities. Analysing the situation in the USA (Sargent 2013) notes that there is a lack of available official data that can be used to identify how research and commercialisation of nanotechnology influence creation and retention of jobs. However, the authors consider that the following aspects can be used setting the boundaries of some industry and comparing the contribution of an enterprise to economy: firstly, the number of employed and its dynamics, secondly, workforce efficiency, which can be characterised by the added value, or production volume per employee, and thirdly, labour tax and contributions. That is why considering annual performance results of the selected enterprises in 2014 presented in Table 5, tax contributions made by the enterprises were also analysed – personal income tax (PIT) and *mandatory state social* insurance *contributions* (MSSIC) per employee. ROA indicator was used to compare profitability of the selected enterprises; the highest value of ROA was demonstrated by the enterprises in the HT group (19.8 and 13.5).

Table 5. Performance results of the enterprises in the field of nanotechnology in 2014 (compiled by authors using Lursoft database)

Enterprise code	Age of the enterprise, years	Number of employees	Sales per employee, thsd euro	PIT+MSSIC per employee annually, thsd euro	ROA (%)
MLT/23A	11	111	108.9	8.3	8.5
HT/26A	12	67	19.2	3.6	19.8
HT/26C	18	46	57.5	6.0	13.5
HT/26B	3	25	50.4	2.2	-3.6
MHT/20B	11	7	5.7	2.5	-3.6
MHT/32.5	18	5	48.8	2.0	6.4
MLT/25A	4	6	5.9	7.3	-63.3
MHT/20A	2	6	0.4	2.9	-22.2

In addition, Table 5 provides information on the age of the selected companies in accordance with the date of registration in the Register of Enterprises, as age is one of the parameters within business life cycle concept used to determine the stage of development of a particular company at a particular time. It can be concluded that the enterprises compete for workforce, and remuneration is one of the parameters, because the specifics of the field call for human resources with a definite level of qualification. Assessing development opportunities of the enterprises in the field of nanotechnology, it seems that companies MLT/25A and MHT/20A face considerable problems – their average annual sales per employee are in numerical terms lower than tax contributions per employee. However, it can be explained by the age of the enterprises. Three enterprises that operate for a short period of time are incurring losses, which is characteristic of the companies in the growth phase. If within this phase a business can be considered new, empirical research (Robinson, McDougall 2001) on the development of new enterprises attests that business performance results are greatly influenced by the structure of the industry and the strategy adopted by companies. It is in line with the findings on uncertainty and efficiency problems faced by enterprises in an emerging industry at the early stage of their development (Bozeman et al. 2007).

Conclusions

According to Innovation Union Scoreboard 2014, Latvia is included in the group of «modest innovators», as Latvia's achievements in the field of innovation are 50% below the average EU level. These are modest results to be used as a foundation for introduction of S3 concept and establishment of a cooperation platform between research and private sector to implement one of the aims of the National Development Plan of Latvia for 2014-2020 – to develop the field of nanostructured materials. It may be problematic to promote knowledge-based entrepreneurship and make it sufficiently attractive to all stakeholders, as each of them pursues different goals.

Very few enterprises work in the field of nanotechnology in Latvia, half of them have incurred losses in the last two years of operation, therefore the issue of sustainable development of these enterprises and the way how it can be ensured by company management remains topical. These companies deal with innovative technologies, which are included as a priority to be supported within the National Development Plan of Latvia for 2014-2020. However, the enterprises face certain difficulties in using the EU financial instruments directly and receiving state funding, as well as providing private co-financing. Even if a company works in the supported industry, it is not practical to allocate funds for development of a concrete enterprise, as the main goal is to support and develop the entire field providing that it unites research and commercialisation.

The authors consider that cluster development is an important prerequisite to strengthen weak cooperation between academic and business structures in the field of nanotechnology. It is an unresolved task, as the analysis of current activities (projects, publications, patents) shows that the academic structures dominate. Testable criteria should be included into state support instruments to measure the success of cooperation between academic institutions and businesses in the priority sector development. If concrete enterprises participate in the work of nanotechnology industry clusters, it is necessary to conduct further monitoring of their activities to be able to make conclusions whether these enterprises make progress and what problems they face.

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