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PHYSICAL AND TECHNICAL ENERGY PROBLEM

NANOTECHNOLOGIES IN LATVIA: COMMERCIALISATION ASPECT

I. Geipele[1], T. Staube[1], G. Ciemleja[1], J.Ekmanis[2], N. Zeltins[2]

[1]Institute of Civil Engineering and Real Estate Economics,
Riga Technical University,
6-210 Kalnciema Str., LV-1048, Riga, LATVIA
Email: Ineta.Geipele@rtu.lv

[2]Institute of Physical Energetics,
21 Aizkraukles Str., LV-1006, Riga, LATVIA

The authors consider the possibilities to apply the nanotechnology products of manufacturing industries in Latvia for further commercialisation. The purpose of the research is to find out the preliminary criteria for the system of engineering economic indicators for multifunctional nanocoating technologies. The article provides new findings and calculations for the local nanotechnology market research characterising the development of nanotechnology industry. The authors outline a scope of issues as to low activities rankings in Latvia on application of locally produced nanotechnologies towards efficiency of the resource use for nanocoating technologies. For the first time in Latvia, the authors make the case study research and summarise the latest performance indicators of the Latvian companies operating in the nanotechnology industry.

Keywords: *nanotechnology, application, commercialisation, innovation, research and development, science-based companies.*

1. INTRODUCTION

In the foregoing analytical forecasts the current years were estimated as the mass-market stage of the global nanotechnology development [1], but locally this might differ. In a previous research [2] the authors estimated nanoscience in Latvia as being at the early stage of development. Nanostructured materials are among the hottest and fastest growing areas in today's materials science field, along with the related field of solid state physics. Such materials and the related technologies have opened up new possibilities for future applications in a number of areas, including aerospace, automotive, x-ray technology, batteries, sensors, colour imaging, printing, computer chips, medical implants, pharmacy, and cosmetics. The ability to change properties on the atomic level promises a revolution in many realms of science and technology [3].

The **subject of the current research** is commercialisation of the research and development, and the **research object** is development of high-technology (hereafter HT), medium-high-technology (hereafter MHT), and medium-low technology (hereafter MLT) manufacturing industries in Latvia. The choice of the research object was defined by scientific interest in the analysis of local innovations in the multifunctional nanocoating technologies. The **purpose of the research** is to find out the preliminary criteria for the system of engineering economic indicators for the mentioned technologies. At the phase of the nanotechnology commercialisation the analysis should be done that would embrace the issues of competitiveness of the multifunctional nanotechnology and of the efficiency of resource use for nanocoating technologies. Therefore, the main tasks for the current research are to determine the economic indicators to be used for nanotechnology commercialisation and the relevant financial analytical data.

The article is structured into five parts the main of which entirely provide the commercialisation aspects of the targeted industry business: the analytical section (Ch. 2) is a summary from the focus research on application areas of the products from nanotechnology industries in Latvia and the problematics issued by other scientists concerning the R&D in nanotechnology business; Ch. 3 provides analytical data concerning evaluation of commercialisation dynamics and business focus of the development of high-tech products and knowledge-intensive services within the Baltic States; and Ch. 4 considers the research results on the economic benefits of the Latvian companies' activities.

2. TARGETED USE OF NANOTECHNOLOGY: CASE OF LATVIA

2.1. Application of the Latvian nanotechnology

Debates on reinforcing the European industrial policy and its contribution to the growth and economic recovery were held in 2012 at the level of the EU Council. In the debates, the key enabling technologies (hereafter KETs) were considered which are of particular importance for the innovativeness and competitiveness of industry, including nanotechnology and advanced materials [4].

In each of the current and emerging technology areas there are particular development lines of special importance for raising the nanosystems' engineering technology base. For assessment of manufacturing processes and their products, the favourable criteria and metrics include: the diversity of product materials and their properties; the extent of atomic precision, especially on exposed surfaces; the extent of controllable atomic precision structural complexity; the compatibility with aqueous processing; the range of tolerance for thermal and chemical conditions; and functional metrics for specific engineering roles [5].

Narrowing the multifunctional nanocoating technologies' development to the aircraft and spacecraft segment in HT, motor vehicles' manufacturing in MHT, and manufacturing metallic and non-metallic mineral products in MLT, the Latvian researchers are working on the composite coatings in order to improve the durability and the heat-resistance quality of the vehicle components for aircrafts by using ion-plasma deposition of multi-component coatings at the business enterprises [6] or academic institutions [7-9].

Currently, the foreign scientists are working on similar problems: to increase the stiffness, improve the failure modes and the corrosion resistance by using nanomaterials for implementation of aircraft landing gears and other components in order to find the optimal weight/stiffness combinations for the space-based structural and support applications [10,11] as well as to develop thermal barrier coatings for specific purposes among smart (e.g. self-healing), super-hard and multifunctional (e.g. in electronics) coatings in order to make light-metal alloy materials for fuel-efficient vehicles that would be resistant to chemical, physical and other type of damages [12].

Also, other miscellaneous spheres exist where nanocoatings are applied by the Latvian scientists – construction, sea and auto transport, glass industry, etc. [13-15].

According to the survey made within the NordicBaltSat project – the first common initiative of the Baltic countries in space sector [16] – the dominant part of the Latvian scientific organisations or 33% of the hit rate responses deal with material processes and manufacturing of advanced materials. A large number of the local institutions present themselves as having the capabilities of potential suppliers to the space segment (see e.g. report on the strategy of the Latvian space technology cluster [17]).

However, according to the EU Commission's definition, KETs are associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employees. The EU countries have well-defined ratios; therefore, the question of what number of announced inventions can indeed become commercialised products desirable for the society is still open [18].

2.2. Fundamentals of nanotechnology commercialisation

Technology commercialisation involves the movement of scientific and technological insights into products and services. It is the process by which the knowledge created owing to investments in R&D is translated into economic benefits, e.g., strengthening the existing firms and establishing new ones, creating jobs, producing new products, reducing the cost of existing products and improving their performance, ensuring returns to investors; and societal benefits, e.g., offering new and improved sources of renewable energy, reducing pollution and remediating environmental damage, improving human heath, etc. [19].

Commercialisation (as related to nanotechnologies) is defined as measures taken by the producer of nanotechnology-based products to generate profits from them. Commercialisation ensures that the nanotechnology meets not only the performance and reliability requirements but also the economic ones. In the light of this reasoning, one might assume that consumer acceptance has the effect of success in commercialisation processes. There are a number of researches carried on commercialisation of the nanotechnology market based on the core competence theory [20]. As related to a firm, the core competence is often applied to identify the crucial capabilities toward emerging technological development [21]. Coleman (2002) was concerned with modelling commercialisation of nanotechnology [1], and argued that all of the existing forecasting models' structure is complex. The process of the nanotechnologies' development is not linear; based on the Deloitte&Touché model it was calculated that the stage of rapid advancement will have reached the mass market by approx. 2015 [1].

Nanotechnology is emerging from recent scientific advances to which marketers and investors attribute enormous commercial potential [22]. Therefore, being determined as the fourth industrial revolution [1, 20], currently the nanotechnology is considered as "general purpose technology" [23] or a technology of multipurpose use in the economics and miscellaneous business activities, covering almost all segments of manufacturing. Obviously, the solutions of nanotechnology commercialisation have already been provided to different economy sectors for more than 30 years. Now it is possible to study the scientific development of a certain technology from the publications in the Web of Science database or from the patenting dynamics. However, it is rather hard to find publicly available reliable data about the economic results (income, market share, net turnover) on a certain nanotechnology [23]. The limited accountability of statistics is connected with the existing limitations in classification of nanoindustry production, methodological issues, and clear criteria of its categorisation. Recently, the major criterion that is commonly accepted to identify a manufacturing company as pertaining to the nanoindustry business has been determined as the share of annual sales: nanoproducts must take at least 10% of the total company's quantity traded, or nanotechnology activity must get the same rate of market share [23, 24].

Electronics entered the nanoindustry earlier and more intensely than materials or biology segments (which became "nano-concerned" later on and possibly, to a lesser extent [25]). However, the development of nanomaterials was already forecasted in 2002, and this area appeared to provide the largest opportunities: this segment also holds the greatest number of potentially disruptive applications owing to novel nanomaterial properties [1]. As a rule, the arrival of a radically new technology gene-rates new firms – either in existing industries or in entirely new ones [22]. Avenel *et al.* (2007) found that firms' nano-knowledge bases were quite diversified, regardless of their size. It also turned out that firms were following quite different trajectories in the development of their nano-knowledge bases. Small firms, at least some of them, were achieving very significant levels of diversity through intense hybridisation. Big firms, with a few exceptions, also have developed diversified nano-knowledge bases, but their use of hybridisation is much more limited [26].

Although industries and applications are (or will be) influenced by nanotechnology, Bhat (2005) argues that the mentioned multidisciplinary nature of nanotechnology makes it very difficult to pin down and predict the future impact in any specific sector appropriately. The authors of [27] assume that the concept of formation and development of nanoindustry or scientific & technological developments having commercial potential must be worked out by the public administration. Otherwise (e.g. in Latvia) the economic activities' results of the represented business entities prove low efficiency of the commercialisation process. Another example of weak or partial administrative concept is participation of Latvia (publically announced but not accepted by the government) in European Space Agency, which might cost the national economy over 4.2 million Euros by 2016. According to official information, the purpose of such participation is the opportunities potentially provided for national business entities to enter the ESA projects on the space research, development of technologies and "know-hows" [28].

The features that characterise the company's activities relating to commercialisation in nanoindustry are:

1) intellectual property;

2) multiple stages of financing;

3) partnerships, cooperation, and consolidation [29].

In the "Spectrum of nanotechnology commercialisation activity" developed by Tsuzuki (2013), in all marked stages (basic research, applied research, product and production development, intellectual property, sales and marketing) the following blocks of activities are involved: a) public engagement, b) government initiative, regulation and standardisation, c) health and safety, and d) life cycle assessment [30].

However, there also distinct differences in commercialisation marked by the size of a company. Small firms are in a better position than big firms to exploit the opportunities created by the emergence of nanotechnologies [26]. The small companies are considered as having more ability to take advantages and redefine markets, whereas large enterprises meet threats from the targeted market's severe competition and low organisational activity as a result of bureaucratic procedures and short-term focused incentives [31, 32]. In fact, technical entrepreneurs are not always focused on the growth or profit maximization but rather on independence [33]. Therefore, a diversified management team with a balance of technological (management) expertise and business (management) skills are more desirable synergy for successful commercialisation process [33, 34].

2.3. Problem of nanotechnology commercialisation in scientific literature

Insufficient "innovation ecosystem" in Latvia. Muiznieks and Putans proved in 2011 [35] that development process of the local R&D has certain weaknesses due to several reasons: low funding into commercialisation of knowledge and technology transfer opportunities and into business environment development; problems with high-quality secondary education system, availability of highly qualified workforce, infrastructure and financial resources, effectively functioning institutional and legal provisions as the main components of the public and private sectors' institutional network (i.e. "innovation ecosystem" [35]). These researchers pointed to the lack of young scientists and infrastructure at the pan-European scale, and extremely low private sector investments in R&D in comparison with the rest EU. Staube *et al*. [6] found out that despite the business investments in R&D the GDP increased twice in Latvia from 0.08% to 0.16% in 2001-2012, and even reached to the Government and Higher Education sector's investment level of 0.17%. Last year (2013) the Latvian rate of these investments was the lowest within the Baltic Sea Region (after Belarus) [6].

Diffusion of nanotechnology and risks. Following Coleman (2002), already in the early 21st century diffusion was marked as a process or an event of the technology integration into several industrial or business segments. Moreover, the leverage of the nanotechnology products and processes was named blurring of lines between nanotechnology and material sciences, manufacturing and mechanical systems [1]. This is an issue now recognised by the authors at processing the statistical and financial data.

The Dutch representatives at the EU Council (2011) argued that the current legislation is not geared to evaluating the specific hazards related to nanoengineered particles [36]. They called upon the Commission to propose that the EU policy ensures a coherent legal framework on the risk assessment and management of nanomaterials.

Zeltins *et al.* (2011) [37] considered the risk management methods in the international organisations dealing with innovations. The scientists concluded that the use of innovations implies dynamic and sometimes chaotic behaviour of systems under the conditions of non-knowledge and involvement of the notions borrowed from other spheres.

Low efficiency of resource use. Determination of cash flows at valuing a nanotech company is problematic due to high growth rates, a high degree of innovations and the early stage of maturity of nanotech companies. Some companies are mature but have at the same time small nanotech ventures or arms that are still in a growth phase of the business cycle. Therefore, using the annual growth rate to identify future cash flows is reasonable, as its growth process will probably not be completed during the investment period [38]. It should be pointed out that during the early stages of a new industry, start-ups face great uncertainty as to the efficiency of their ill-defined routines and products and about how these will fit the environment within which they are embedded [22].

3. EVALUATION OF COMMERCIALISATION FOR THE HIGH-TECH PRODUCTS

Foreword to the practical evaluation of nanotechnology commercialisation

Initially, to become recognised in the market and protect the intellectual property rights, the patent is required. The information gathered in the statistical offices from the patenting office databases is used for identification of the country's ranking [6]. In the global market there were certain indices used for financial transactions. In the previous decade, C60 Market Monitor ratio covered R&D funding and venture investing information. Lately, the following commercial indices were used: Merrill Lynch Nanotech Index, Credit Suisse Global Nanotechnology Index, and Lux Nanotech Index. However, these are considered limited as to evaluation of the nanoindustry commercialisation of certain companies. The generic approach and high level of economic, financial, operational and other risks are compared with other existing financial instruments (NASDAQ index and others) [39]. Therefore, the authors conducted further research and made comparisons using the official statistical databases: EUROSTAT – to provide analytical conclusions at the global scale; and LURSOFT – related to practical findings and calculations on economic benefits of the local business.

Analytical findings on commercialisation of the high-technology industries in the Baltic States

Financial statistics on the business enterprise R&D activities in high-technology sectors is limited. Unavailable data in EUROSTAT database for Estonia, Latvia and Lithuania have confidentiality restrictions. However, provided narratives of the categories show approximate figures (at least before 2012) that help estimate the average range of industry's capacities. It is suggested that the annual amount of expenditure on R&D of the business enterprises in HT and MHT industries is approximately 5-8 million Euros, and even lower level of expenditure with downswing dynamics is registered for the MLT industries.

Analytic statistics – i.e. the percentage ranking of the high-technology industries in producing new and improved products from total turnover of the small- and medium-size companies – is available only for 2000 (Table 1).

Table 1

Analysis of turnover by SMEs (10-249 employed persons) and high-technology industries in 2000, in percent (the authors' calculation from EUROSTAT data)

Country	*Technology groups*	*Share of total turnover, %*	
		new products to the market	*not new products to the market*
Estonia	HT	19.19	20.1
	MHT	13.47	16.2
	MLT	2.47	6.43
Latvia	HT	7.65	5.62
	MHT	13.31	13.9
	MLT	2.84	6.51
Lithuania	HT	12.72	10.8
	MHT	13.99	3.91
	MLT	11.91	9.03

The economic calculations showed that 20% from total turnover of the small- and medium-size companies working in high-technology industries in Estonia was gained from producing the HT products in 2000. This brought Estonia to the top position among the Baltic States. Comparing the regional results by separate groups of technology, Latvia did not achieve high rates in any of them. However, at the national scale Latvia gained a large share from the MHT industry of the targeted high-technology market. Working on the improvement of high-tech items, the MHT and MLT industries of Latvia achieved better capacities than in launching new products; as concerns Latvian HT industry, a higher share (7.65%) was fixed for launching new products.

According to EUROSTAT database [40], in the years from 2004 to 2010 a general share of the companies working in the mentioned industries has fluctuated around 17% ratio from the total number of enterprises, with a fixed decrease by three percent points from 2008. The highest national average share among the Baltic States in all core NACE activities related to innovation as a percentage of the total number of enterprises from 2004 to 2010 is that of Estonia – 48%. Statistical data on the number of enterprises by the high-technology industrial sectors of Latvia are available only from 2008, and only the MLT industries' ratio of the product and/or process, regardless of organisational or marketing innovations, as percent of the total number of enterprises has gone up since that period considerably – from 51% to 60%, i.e. five percent points higher than in Lithuania and ten percent points lower than in Estonia. Lithuania kept the leading position in the balance of total trade of the high-technology industries among the Baltic States (see Fig.1). In 2012 the trading surplus reached 88 million Euros.

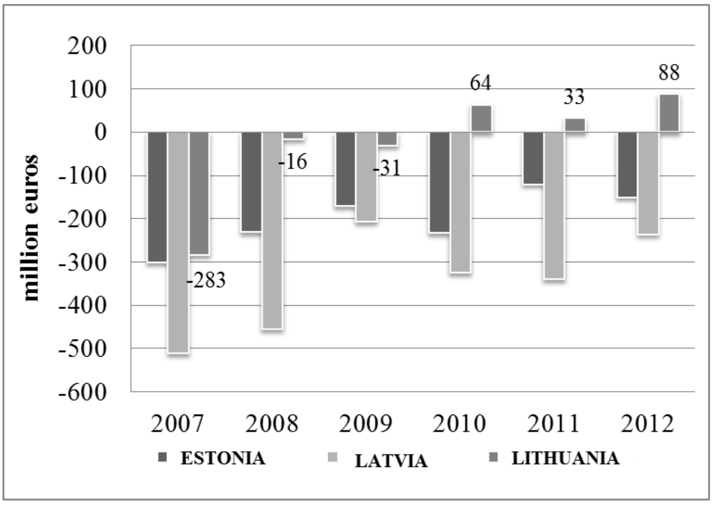

Fig. 1. Total high-technology industry trade balance in the Baltic States, in million Euros, from 2007 to 2012 (the authors' calculation from EUROSTAT data).

In comparison with neighbour economies, Latvia has no significant specialisation in high-tech manufacturing industry. Despite the observed tendency for dependence on the imports, general upswing dynamics in the Latvian high-technology sectors' balance trade was fixed for the aerospace, armament and a positive surplus in electrical machinery. The calculations made by the authors for the selected categories are illustrated in Fig.2.

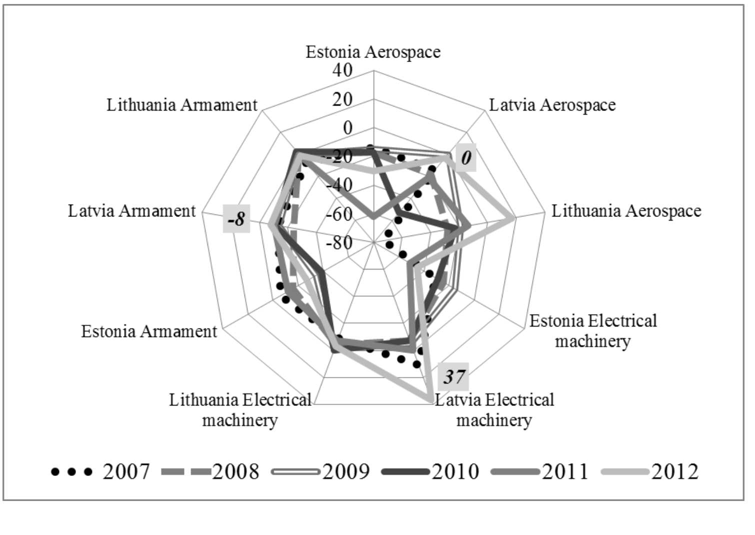

Fig.2. High-technology trade balance in the Baltic States with top three high-tech products of Latvia in million Euros (2007- 2012). The authors' calculation from the EUROSTAT data.

Having summed up the results, the authors conclude that Latvia might be considered as a leader in exporting the electrical machinery items in the MHT manufacturing industry; however, only last year Latvia reached here a reasonable increase. Lithuania has occupied a clearly leading position of very ambitious five years' growth, changing from the pure importer to an exporter and getting the international interest in the local aerospace sector productions in the HT manufacturing industry. In 2012, Latvia returned to the second rating of that industrial segment to the rate of 2009. In recent years, all Baltic States have had almost equal balance of trade results in the weapons and ammunition (armament) or MHT industry with a negative share or import dominance.

4. ECONOMIC BENEFITS OF THE LATVIAN COMPANIES

Before presenting the results, the authors would like to mention the facts from the survey made in Latvia within a span of 2010 -2012 among the business entities with R&D background: 1) only 38% of all companies made investments in R&D; 2) only 20% from the surveyed firms developed new products, services and/or technologies; 3) 31% of the respondents are planning to make investments in R&D in the nearest three years; 4) 40% of the Latvian companies (most of them continually) faced the problem of limited financing when this was highly needed for raising the R&D intensity [41].

The authors of the present article have carried out research on the economic benefits of the Latvian science based companies using the EUROSTAT approach, which implies aggregation of the manufacturing industries according to the technological intensity and based on NACE Rev. 2 at a 3-digit level for compiling the aggregates related to high-technology (HT), medium-high-technology (MHT), and medium-low-technology (MLT).

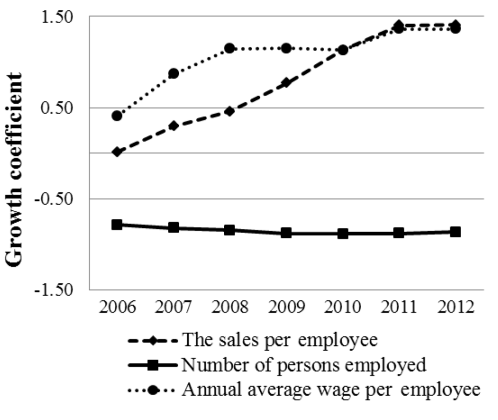

Fig. 3. Dynamic coefficients' comparison to Y2005 in hi-tech industries in Latvia (NACE Rev.2 codes C26, M72). The authors' calculation from the CSB of Latvia data.

The sales per employee ratio is an asset utilisation metric that allows analysts to understand how efficiently a company uses its staff to generate revenues [42]; therefore, Figs. 3-5 contain results on analysis of the annual employment, salary and sales dynamics made on the data from the Central Statistical Bureau (CSB) of Latvia [43]. The authors have summarised the research results on the HT industries for the following economy branches in Latvia: the manufacture of computer, electronic and optical products, and the scientific R&D or services (NACE Rev.2 codes C26 and M72, respectively). In Fig. 3 it is seen that the number of employees in these industries significantly decreases in the time span 2005-2012: 31% in C26 and 77%

in M72. The reduction in the work force in both the branches is total 2785 working places; however, consistent growth of rates in the sales volume per employee and the average annual wage since 2010 positively characterise further development of this market segment.

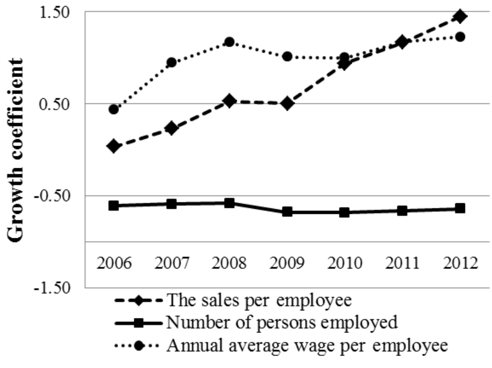

Fig. 4. Dynamic coefficients' comparison to Y2005 in medium-high-technology industries in Latvia (NACE Rev.2 codes C20, C27). The authors' calculation from the CSB of Latvia data.

Data from such MHT industries as the manufacture of chemicals and chemical products (C20) and the manufacture of electrical equipment (C27) are shown in Fig.4. It is seen there that the number of employees in C20 and C27 from 2005 to 2012 dropped by 7% and 8%, respectively, while the total reduction in the work force in both these branches was 445 working places. The authors point to the given market segment's development tendencies since 2011, when a positive trend in the growth rate of sales volume per employee is fixed outdistancing an average annual wage rate.

Figure 5 provides information on the following economy branches: the manufacture of other non-metallic mineral products (C23), and the manufacture of fabricated metal products, except machinery and equipment (C25). Comparing the statistics of 2012 with that of 2005, the number of the employed people decreased 21% in C23, and increased 8% in C25. Total, reduction in the work force in both the economy branches was 558 working places, whereas the growth rate of an average annual wage outdistances that of the sales volume per employee.

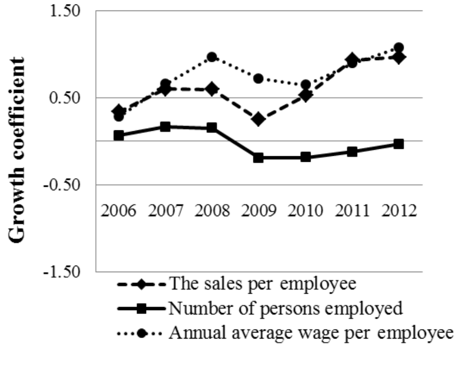

Fig. 5. Dynamic coefficients' comparison to Y2005 in the medium-low-technology industries in Latvia (NACE Rev.2 codes C23, C25). The authors' calculation from the CSB of Latvia data.

The carried out research allows the authors to make the following inference: currently, the identification of a homogeneous branch by a consistent method in order to generate a set of the statistical data for nanotechnology industries is rather complicated or even impossible, because nanotechnological solutions are identified in miscellaneous economy branches. Therefore, the fields of the companies' primary activity differ, which makes it complicated to compare the operational results from development and implementation of such solutions into practice.

For the current case study, the authors selected six Latvian companies working in the area of nanotechnology, and analysed their financial data using the unified EUROSTAT approach following aggregation of the manufacturing industries according to the technological intensity and based on NACE Rev. 2 at 3-digit level.

The return-on-assets (ROA) shown in Table 2 is one of the most important representative ratios for a company's competitiveness. For the calculation of ROA the authors used publicly available data from the annual balance sheets of the selected companies from 2007 to 2013 [44].

Table 2

Return-on-assets (ROA) ratio of the Latvian nanotechnology companies from 2007 to 2013 (in percent). The authors' calculation from the LURSOFT data

Technology groups/ NACE	*Year*						
	2007	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
HT/72	*-51.20*	*22.27*	*-64.57*	*-7.17*	*8.68*	*-5.64*	*17.63*
HT/26	*5.23*	*-11.86*	*13.11*	*0.89*	*2.95*	*1.72*	*6.04*
MHT/20	*1.75*	*7.30*	*1.14*	*0.26*	*0.45*	*0.15*	*0.04*
MHT/27	*4.69*	*1.45*	*0.60*	*0.39*	*10.75*	*-2.26*	*15.75*
MLT/23	*-3.78*	*-11.80*	*-19.06*	*-14.32*	*-11.14*	*8.97*	*1.79*
MLT/25	*not available*			*-99.0*	*-23.6*	*-20.3*	*-51.0*

Table 2 demonstrates a significant swing in the ROA dynamics among the companies and economy branches in the period from 2007 to 2013, which evidences the companies' launch into the market (some new companies providing nanotechnology products and services have recently been established in Latvia) when larger investments are required despite international financial support, which eventually leads to a low return on the total assets. The result can be seen in Table 2 from the ROA ratio of the MLT/25 company that has been working in the C25 since 2010. The operational results of the HT/72 coded company working in the M72 are typical of the Latvian market. Within a period of six years the cycling character of the financial pressure determined the given ROA ratio fluctuation. According to the company's annual statements, this might be explained by its participation in the EU projects.

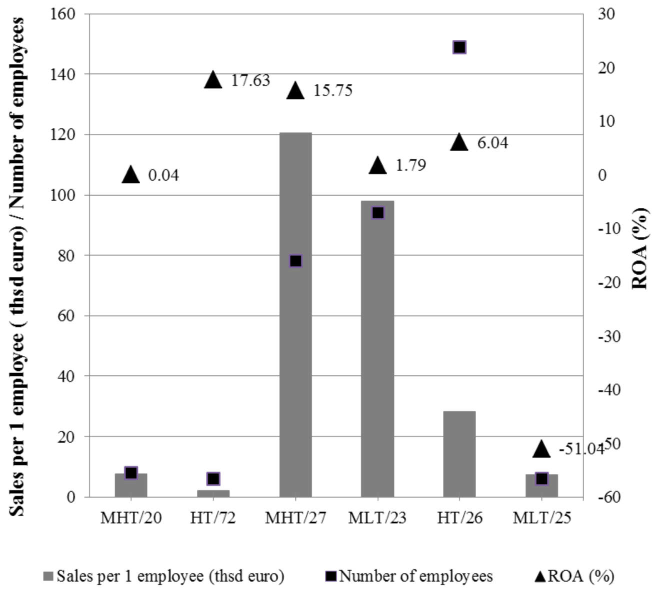

Fig.6. Performance indicators of the Latvian nanotechnology companies in 2013 (the authors' calculation from the LURSOFT data).

In Fig.6 the authors provide information on the sales volumes per employee, ROA and number of employees of the companies in 2013. Obviously, the companies that work in the high-technology industries (HT/26 and HT/72) have comparatively higher ROA ratios, and five companies that have already operated in the market more than seven years are able to generate profit.

5. CONCLUSIONS

1. For the first time in Latvia the authors have made the case study research and summarised the latest performance indicators of the Latvian companies that operate in the nanotechnology industry. The research is based on a different approach than that used by the authors previously [2, 6] using the accepted practice of analysing the commercialisation aspect of nanotechnology from the patented data, or recently failed method of global indexing for the leading companies of the market [39]. The results are worked out in the frame of the multidisciplinary scientific project supported by the European Social Fund and the National Research Programme.

2. Among the main factors that decelerate the development of nanotechnology commercialisation the following should be mentioned: insufficient "innovation ecosystem" [35]; diffusion of nanotechnology [1]; risks and low efficiency of financial resource use [22, 38].

3. Identification of a homogeneous branch by a consistent method in order to generate a set of statistical data for the nanotechnology industries is rather complicated or even currently impossible, since nanotechnological solutions are identified in miscellaneous economy branches. Therefore, the fields of the companies' primary

activities differ, which makes it difficult to compare the operational results on the development and implementation of the nanotechnological solutions.

4. Currently, Latvia keeps consistent development of the nanotechnology sector. However, separate companies show very strong capabilities (compared to the overall sectorial dynamics in EUROSTAT) and achieve high ROA ratio while only a slight increase in the turnover and number of employees.

5. As has been shown by another survey (see [41]) and proved by our scientific results, significant investments are required to launch the nanotechnologies into the market. In the majority of cases, the Latvian companies attract foreign investments and/or join the international scientific projects in the framework of financial support programs. Eventually, this leads to a low return on the total assets. Obviously, the Latvian well-established companies that work in the high-technology industries have higher ROA ratios, and the companies of more than seven years' operating experience are able to generate profit, as compared with new business.

6. As EUROSTAT data show, Latvia – as compared with Lithuania and Estonia – is not strongly specialised in high-technology manufacturing industry. General upswing dynamics in the Latvian HT sectors' balance trade was fixed for the aerospace and armament; a positive dynamics is observed in the electrical machinery.

7. Practical application of nanotechnologies produced by the Latvian scientists requires further attraction of investments and expansion of the product market boundaries to increase the demand on the local manufacturing industries.

8. Concerning the system of engineering economic indicators for multifunctional nanocoating technologies, the authors point to the importance of the following criteria and assessments: market segmentation, rivalry analysis, practical surveys, and ROA ratio analysis.

9. Further practical implementation of the current research is surveying the local companies and making supplementations and comparisons with the current results. The main issues might be the share of nanotech products in the total sales volumes and their life cycle assessment.

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ESF EIROPAS SOCIĀLAIS FONDS

EIROPAS SAVIENĪBA

IEGULDĪJUMS TAVĀ NĀKOTNĒ

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NANOTEHNOLOĢIJU PIELIETOJUMS LATVIJĀ: KOMERCIALIZĀCIJAS ASPEKTS

I. Geipele, T. Štaube, G. Ciemleja, J. Ekmanis, N. Zeltiņš

K o p s a v i l k u m s

Autori atspoguļo problēmu par nanotehnoloģiju industrijas produktu pielietojumu to turpmākajai komercilalizācijai Latvijā. Pētījuma mērķis ir noteikt pamata kritērijus inženierekonomisko rādītāju sistēmas izstrādei daudzfunkcionālo nanopārklājumu tehnoloģijām. Rakstā ir ietverti jaunie risinājumi un aprēķini vietējā nanotehnoloģiju tirgus izpētei: rādītāji, kas raksturo nanotehnoloģiju ražošanas jomas attīstību; autori norāda uz problēmām, kas ietekmē Latvijas aktivitāšu zemo novērtējumu pasaulē vietējās nanotehnoloģiju ražošanas jomā nanopārklājumu tehnoloģijas izstrādāšanas resursu izmantošanas efektivitātes novērtējuma ietvaros. Pirmo reizi Latvijā autori veic pētījumu un apkopoto rezultātus par Latvijā strādājošo uzņēmumu nanotehnoloģiju ražošanas jomā jaunākajiem ekonomiskās darbības rādītājiem.

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