LATVIAN JOURNAL OF PHYSICS AND TECHNICAL SCIENCES
2016, N 5

DOI: 10.1515/lpts-2016-0034

*PHYSICAL AND TECHNICAL ENERGY PROBLEMS*

# THE DEVELOPMENT OF NANOTECHNOLOGIES AND ADVANCED MATERIALS INDUSTRY IN SCIENCE AND ENTREPRENEURSHIP: SOCIOECONOMIC AND TECHNICAL INDICATORS. A CASE STUDY OF LATVIA (PART TWO)

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Part two of the in-depth scientific study clarifies the significant social and technical indicators of the development of nano-field at the macro, micro, and meso development levels of the economic environment in Latvia in the framework of the given theme. The analytical assessment of numerical change in socioeconomic and technical factors clearly demonstrates the interaction of nano-field with the development of science and manufacture, as found out in the study. The identified indicators are proposed to use for research, comparison and implementation in any other country of the world.

***Keywords:*** *advanced materials, development of science, economic environment level, engineering economic indicator system, nanotechnologies, research.*

## 1. INTRODUCTION

The development of nano-field mainly depends on the interaction between science and entrepreneurship, where the country's socioeconomic as well as legal and political situation is particularly important. Technology and innovation development in Latvia points to the formation of scientific and business potential. According to the results of the current scientific research, the analysed development process is determined by a variety of indicators.

To reach the aim of the study the current part of work has the following tasks: (1) to make comparison of the socioeconomic and technical indicators found with that of other countries if applicable; (2) to generate the data according to the levels of the economic environment; (3) to provide remarkable recommendations for the responsible parties.

## 2. ASSESSMENT OF THE SOCIAL AND TECHNICAL INDICATORS

### *Social Indicators*

Although a significant impact on the development of nano-field is exerted by economic indicators, social data play no less important role. Quality of life is the well-being index of particular members of society, which includes the life satisfaction level in the family and society as well as material support. Thus, the material well-being of population is closely related to the economic development of a particular country. Therefore, at the macro or global level in the social indicator group the authors put forward life satisfaction, subjective well-being, median equivalised disposable income, GINI coefficient, human development index, and GNP per capita.

Life satisfaction as a component of subjective well-being indicator results from the survey of population, who had to answer the question "All things considered, how satisfied are you with your life as a whole these days?" on a 10-point scale from 1 "dissatisfied" to 10 "satisfied" and based on the data of Real and Dobewall's (2011) study, in the early 1990s after Latvia regained its independence the indicator was around 5.8 [23], while experiencing significant fluctuations in the twenty-year period in 2015 the mean estimated result of this indicator remained approximately at the same level – about 6.0 [24]. According to the analysis performed for the period of 1998–2014, in Latvia the life satisfaction index is 5.52 compared with Estonia that has reached a higher level or 6.16 and Lithuania – 5.84. The index in Latvia is similar to that in Egypt – 5.52, India – 5.51 and Belarus – 5.53. However, according to the 2014 research data by the Organisation for Economic Co-operation and Development (OECD), which was not yet joined by Latvia and Lithuania, Estonian inhabitants measured life satisfaction at a 5.6 grade. "That is one of the lowest scores in the OECD, where average life satisfaction is 6.6". Greece, Hungary, Portugal and Turkey have also less than average life satisfaction grade [25].

Lonska (2013), studying the Latvian subjective well-being indicators, found out that in the period of 2000–2010 compared to the Baltic neighbours, Latvia took the lowest position together with Lithuania. This means that the average happiness level of Latvian population is assessed by 5.3 points ("0" – the lowest score, "10" – the highest score), the average happiness level of Lithuanian population is 5.5 points, but Estonian people value their happiness with 6.0 points out of 10 possible [26], [24]. Taking into account the previously analysed economic indicators and the subsequent analysis, the authors will also prove the hypothesis of the study performed by Lonska (2013) that states that subjective well-being of Latvian population depends not only on the volume of GDP per capita, but also on factors such as unemployment rate and income inequality [26], which in the authors' present study will substantiate Latvia's low position in the subjective well-being index.

An important role is also played by the median equivalised disposable income indicator, which characterises the poverty/wealth level of society and reflects the available income trends. It is used to analyse savings conditions and purchasing power for a particular year in absolute terms and to compare the dynamics in the period for cumulative changes in real and nominal values, by population structure and income levels, as well as to determine the relative median income ratio [27]. According to Eurostat data for the period of 2008–2012, the negative cumulative change in median equivalised disposable income was experienced by Greece and Iceland, i.e., more than 34 % and 23 % fall, respectively. Latvia was the third country in the EU by negative changes of this indicator in the reporting period, i.e., around 20 % below zero, which was followed by Croatia -16.2 %, Spain and Ireland around -5 %. In Hungary, these changes were much smaller -8 %; in Lithuania and Cyprus they were the same, i.e., -12 %. The highest positive changes of the indicator were recorded in Norway, Slovakia, Switzerland, Sweden and Poland [27].

Taking into account the Latvian negative result of median equivalised disposable income index, Gini coefficient that characterises income inequality perfectly matches the analysis above. According to Eurostat data, Latvia (35.5) together with Bulgaria (35.4) shared the 1st and 2nd place in terms of the polarisation degree of the EU society – they had the highest Gini coefficient in 2014 [28]. This means that the disposable income of Latvian prosperous households is growing more and more rapidly than that of other countries, thus demonstrating the high degree of polarisation of society.

Human development index refers to human development achievement in three dimensions – a long and healthy life, knowledge and a decent standard of living. In 2013, this index was 0.81 in Latvia and it was ranked 48th out of 187 countries of the world; similar results were demonstrated by Cuba, Kuwait, Croatia and Argentina [29]. The authors consider that for Latvia this figure is quite satisfactory and appropriate, as in Latvia it is possible to adopt healthy lifestyle, studying at educational institutions is available at reasonable prices and public life standards are not yet at risk.

On a global scale, well-being of Latvian population may also be determined by GNP per capita as GNP covers income belonging to residents of a particular state, including income from economic activities performed by particular country's citizens abroad. Performing the analysis, the authors have found out that the World Bank has attributed Latvia to the high-income non-OECD group of countries, which means that Latvia is ranked among the high-income countries. The World Bank data show that in 2013 the Latvian GNP per capita accounted for 15,280 US dollars; by this indicator Latvia took the 47th position out of 176 countries of the world. A little bit better situation was characteristic of countries such as Estonia, Slovakia, Oman, Uruguay, but quite similar results with Latvia were demonstrated by Chile and Lithuania in 2013 [30]. However, the authors conclude that, despite the World Bank's high rating, both economic and social indicators analysed above indicate a not-so-good situation in terms of social welfare, which shows that in Latvia in the area of income inequality and administration there are still a lot of challenges ahead.

At the meso or national level, in accordance with Fig. 2 presented in Part 1 of the scientific research [31], the authors have included the employment and unemployment rate in the country, reflecting the country's economic activity dynamics.

According to Eurostat data for the period of 2014, in Latvia 884.6 thsd people were employed, taking into account the resident population concept and age group from 15 to 64 years [32], of which 318.7 thsd employees or 36 % of the total number of employees had higher education (the specialisation sector is not indicated) in the 4th quarter of 2014 [33]. In South Korea, one of the leading countries in the nano-field, in 2013 the number of researchers per million people was 6,457, in Latvia – 1,802, very close to the number of researchers in Poland (1,851), Bulgaria (1,693) and Italy (1974). By comparison, in Lithuania this figure is about 2,900, in Estonia – 3,340 [34]. The given number of researchers in Latvia is related to low growth of R&D, which is analysed in the economic indicator group, and to inadequate salary level of researchers in Latvia. However, according to Eurostat data, in 2014 Latvia among all EU member states had a high unemployment rate of 10.8 % [35] and, in accordance with the database of the Central Statistical Bureau of Latvia, the total number of unemployed in Latvia accounted for 99.6 thsd people [36], which was a relatively high indicator, because the total population of Latvia was 1,990,351 in 2014 [37]. It is also worth mentioning that in Europe the unemployment rate of more than 10 % is characteristic of the following countries: Lithuania, Bulgaria, Ireland, France, Slovakia, Portugal, Italy, Croatia, Cyprus, Spain and Greece. The mentioned problems in Europe can be explained by political and economic factors, such as the Greek crisis, aggravate relations with Russia and alarming extent of the refugee influx in Europe. With regard to the employment and unemployment rate in the nano-field, the authors explain that unfortunately in Latvian statistics there is not freely available information, and the information available at databases is quite general – compiled by age group, education and ethnicity.

Despite worries about the consequences of the rise of unemployment rate, by continuing development of innovative technologies [38], it is known that in the nano-field there is demand for highly qualified specialists. Consequently, in terms of unemployment by educational attainment, in Latvia the average number of unemployed with higher education was 16.5 % of the total number of unemployed in 2014 [39], according to the State Employment Agency data at the beginning of 2015 almost 15 % of unemployed were specialists with higher education [40].

To be able to precisely determine the development of nano-field in science in Latvia, the authors put forward the following parameter at the meso level: number of specialists trained at vocational education institutions in the field of nanotechnology. According to the data by the Ministry of Education and Science of Latvia, from 2000 to 2011 approximately 58 % of secondary school graduates continued studies at universities and colleges. Industry representatives expressed a demand for specialists in engineering (23 % of respondents) and manufacturing technologies (15 % of respondents), while in 2011, 21 % of students majored in engineering and natural sciences. The largest number or more than 50 % of students studied at programmes related to social sciences, business and law in 2011 that demonstrated potential obstacles to non-compliance of labour demand and supply. The greatest human resource provision in engineering and technological sciences belongs to materials sciences – 25 % and to biotechnology – 2 %. According to the number of doctoral theses defended in Latvia, the number of specialists in engineering accounts for about 13 % of the total number of young scientists in the period of 2000–2013 [41].

As a last social indicator at the meso level, the authors have chosen the public and private social spending share of GDP, which is an important indicator of social protection and security in any country's economy. According to Eurostat data for 2012, the expenditure on social protection in Latvia was the lowest among the EU member states, and it accounted for only 14.0 % of GDP [42]. Compared with Latvia, the average EU expenditure on social protection is 29.1 % of GDP, which demonstrates that in Latvia social protection and security are not developed.

At the micro or business level, in the social indicator group it is worth noting the experts' average monthly salary level in the nano-field according to qualification. With regard to this indicator, the aggregated statistical information in Latvia was not available to the authors, but during the survey carried out by the authors it was found out that also in Latvia specialists working in the nano-field comprised highly qualified professionals who depending on their company's remuneration policy were appropriately motivated. However, in order to clarify the data from the official sources of information available, it is worth mentioning that as of December 2014 professional, scientific and technical services staff received the average monthly salary of 963 EUR gross, scientific research staff – 1,301 EUR gross and personnel working in the education system – 675 EUR gross [43].

By comparison, in Germany an average monthly salary is 2,290 EUR in teaching/education, while in science and technical services – 3,686 EUR. In Lithuania, in the teaching/education category an average monthly salary is 756 EUR, while in Poland – 747 EUR [44], which demonstrates that in the Latvian education system employees receive a relatively low salary in the EU. In turn, "U.S. salaries for nanotechnology engineering technicians range from $ 30,000 to $ 94,000" per year or according to other sources, the average annual salary is $ 79,000 [45].

The authors have also found out that one of the reasons that hinders the development of research in Latvia is human resources problem: a too small number of people employed in science and the lack of renewal potential. There is a lack of motivation and the ability to attract young professionals to scientific and academic activities. A serious cause for the lack of interest in research is compared to other EU countries: low salary levels and limited career opportunities at research institutions [46]. The problem of the average monthly remuneration in Latvia also complements the situation of the large number of unemployed with higher education. At present, there are situations when people tend to retrain, take positions in other sectors or at all go abroad just because of a poor salary level in Latvia, thus demonstrating the importance of this social indicator, i.e., it is crucial to make residents in their own country feel valued and safe.

*Technical Indicators*

At the macro or global level, in technical indicator group there are the following innovation development indicators: number of patents in the nano-field per year: nanotechnology patents in EPO, USPTO, German Patent Office (DPMA); nanotechnology patent applications published in EPO, USPTO, German Patent Office (DPMA). At the website of nanoscience statistics, in the section of nanotechnology patents in EPO Latvia is ranked 62nd out of 67 countries, presenting one patent per year from 2010 to 2014, except for 2012 when no patent was granted [47]. By comparison, in Ukraine in 2012 and 2013 one patent was granted every year, in 2014 – none; in Estonia and Cyprus in 2014 – one patent, but as of June 2015 – 2 patents; in Croatia and Romania in 2014 and June 2015 – 1 patent every year; in Egypt and Algeria in 2014 – one patent to each country. With regard to nanotechnology patents in the USPTO, Latvia was ranked 57th out of 67 countries, although in the period from 2010 to June 2015 Latvia did not have any patent registered in the USPTO [48]. In the specified time period, no patent was presented by Serbia, Algeria, and Uzbekistan. By comparison, Latvia's neighbour Estonia was ranked 54th in this report, presenting 5 patents in 2013, 6 patents in 2014 and 1 patent as of June 2015, while the other neighbour Lithuania was ranked 46th – with 2 patents in 2013, 4 patents in 2014 and 1 patent as of June 2015. The same situation for Latvia can be observed in the section of nanotechnology patents in the German Patent Office (DPMA) – no patent in the period from 2010 to 2015. Here it should be noted that many countries (67 countries) do not have a patent in this report. The best indicators in this report are demonstrated by Germany, the USA and Japan [49].

In the first group of technical indicators, a better situation is experienced by Latvia in terms of nanotechnology patent applications published in EPO, which means that the nanotechnology patent applications were published (but not yet granted) in EPO. According to this report, as of June 2015 Latvia was ranked 16th out of 67 countries, presenting 17 patents, which meant a very significant increase because in 2014 there was only one patent and in 2013 – 3 patents [50]. However, it is too early to speak about the positive development of nanoscience, since in other nanoscience statistical sections Latvia does not demonstrate such high rates, and a level of public funding for research and innovation is still low in Latvia. This is demonstrated by the next analysis on nanotechnology patent applications published in USPTO, where Latvia took the last position out of 67 countries [51]. By contrast, the analysis of data on nanotechnology patent applications published in the German Patent Office (DPMA) indicates that the patenting activity is very low in the German region, as well as in Iran, Bulgaria, Lithuania and many other countries; and Latvia also did not have patent applications in this section during the period from 2010 to 2015 [52].

As a last indicator of the technical indicator group at a global level, there is the ratio of nanotechnology patents to nano-articles, where Latvia took the last position out of 67 countries [53]. The above-mentioned analysis of patent types confirms that, unfortunately, at present in Latvia research, technological development and, in particular, innovation infrastructure are underdeveloped, as well as commercialisation activities are weak compared with mean indicators of other countries, but a report on nanotechnology patent applications published in EPO points to a positive "take-off", which suggests that Latvia has potential in this area.

At the meso or national level, in the technical indicator group the authors have included indicators such as production volume, structure and dynamics, as well as science-based product sales volumes. It is worth noting that in 2012 Ltd. GroGlass was attributed to a large and medium-sized commercial group in Latvia. The high-tech factory GroGlass is one of five companies in the world that is able to produce glass with anti-reflective nano-coating. Being the youngest – established in the 21st century, GroGlass is the only one manufacturer that can cover technologically glass from both sides simultaneously. The glassed artwork in the Louvre and National Gallery of London – Bang&Olufsen TV displays – these are just a few examples of diverse opportunities and outstanding quality of non-reflective glass manufactured in Latvia [54].

As a last indicator at the meso level, it is worth mentioning the nanotechnology transfer infrastructure efficiency (incubators, parks, prototyping laboratories, pilot plants, technological development and competence centres, clusters), which is an important technology transfer and innovation infrastructure development indicator and points to the development of necessary environment for new technology development and research result commercialisation. Taking into account the fact that the Latvian nanotechnologies, intelligent materials industry and science have historically evolved quite significantly and in a timely manner, for example, "by establishment of the vacuum metallization design bureau and later production of vacuum coating systems" in the early 1960s, and in the early 1990s working on the "concept of the development of the technology centres" [55], or development of nuclear physics starting from the 1950s [56], there are separate scientific developments and areas that still continue developing or have already been sold and then patented in other countries, or the infrastructure is relatively outdated and operates with low capacities and requires new investment. Therefore, the authors conclude that in terms of nanotechnology transfer infrastructure Latvia just undergoes the stage of development, as demonstrated by NanoTechEnergy cluster [57], Space Technology cluster activities [58] and metalworking cluster development [59]. Latvian entrepreneurs, especially small and medium-sized enterprises, and scientists cannot implement the technology transfer stage that is important for innovation process before the product is ready for production, because there is no technology transfer infrastructure and there is a lack of instruments to attract researchers to manufacturing enterprises [46]. According to the informative report by the Ministry of Education and Science of Latvia, in 2011 a number of "separate clusters were established, for example, in such fields as electronics, chemistry, pharmaceutics, space technology and logistics; however, their added value was unclear. Latvia has undertaken the first modernisation attempts by establishing nine research centres of national importance, but it seems that they are disproportionately much more focused on academic science" [41].

At the micro or business level, the technical indicator group includes three subgroups: the number and capacity of qualitative laboratories, capacity and power of technology and equipment, sufficiency of resources; qualitative indicators of existing product development and processing: the effect from improvement, nanomaterial characteristics; number of patent applications published in the nano-field, number of patents sold in the nano-field.

According to the report of the Ministry of Education and Science of Latvia, "the knowledge base is fragmented and degraded, including research, technological development and, in particular, innovation infrastructure is underdeveloped. As a consequence, there are an extremely low number of spinoffs, as well as start-ups based on the developments made in the public research sector" [41]. Some manufacturing companies in the nano-field consider that they have "strong internal capacities such as more experience in the use of the high technologies, higher ability to increase the capacities of production and level of the salaries" [31]. However, the above-mentioned set of indicators (the number and capacity of qualitative laboratories, capacity and power of technology and equipment, sufficiency of resources) is very important, as it provides information on the provision of infrastructure of local market manufacturers. These data should be clarified for separately organised targeted study, as each sub-sector of nano-field could have its own requirements. Thus, in the survey conducted by the authors it has been found out that 75 % of the Latvian innovative multifunctional material manufacturers have their own laboratories, 14 % use outsourcing services, and the same number of responses has been received by companies who do not use laboratories at all.

Qualitative indicators of existing product development and processing – the effect from improvement, nanomaterial characteristics – are essential indicators that indicate to what extent the goal set by technology use or innovative material development has been achieved, for example, ratios of different types of efficiency measured by: degradation [60], encapsulation [61], thickness of the coating and dependence on external actions [62], use of resources [63], [64], time [65], [66], and other efficiency measures depending on the type of the nanotechnology or nanomaterial and goal of research.

With regard to the number of patent applications published in the nano-field, which has already been analysed at the macro level, the authors consider that this indicator is also important at the micro level, as well as the number of patents sold in the nano-field or copyright transfer should be clarified by organising the targeted study, for example, by a direct survey method. This would provide valuable facts about the country of origin of the invention, which is not reflected at the official databases at least in relation to Latvia.

## 3. FURTHER RESEARCH

The authors will continue to collect and aggregate data from primary and secondary sources and improve the developed engineering economic indicator system in terms of other indicator groups: scientific, legal, political, ecological, health and safety, information and communication, and management implementation levels and indicators.

## 4. CONCLUSION

1. Analysis of the types of patents confirms that Latvia is ranked among the less active countries in terms of commercialisation of inventions and, unfortunately, at present in Latvia research, technology development as well as innovation infrastructure, in particular, are underdeveloped and weak in comparison with mean indicators of other countries. It is possible to quite distinctly observe the target markets of Latvian manufacturers in the nano-field: primarily – the EU and for individual companies – the United States.
2. Publicly available information on the development of nano-field in Latvia, the most influencing socioeconomic and technical indicators in the Latvian specific macroeconomic context allow concluding that the nanotechnology and advanced materials industry are still developing slowly in Latvia and for its proper iden-

tification separate target studies should be organised in order to obtain missing analytical information.

3. In Latvia, at the national level it is necessary to make conceptual solutions in order to promote cooperation among science, research and business, as well as the parties' own activity and interest in mutual cooperation and support are of importance.

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## NANOTEHNOLOĢIJU UN VIEDO MATERIĀLU INDUSTRIJAS ATTĪSTĪBA ZINĀTNES UN UZŅĒMĒJDARBĪBAS JOMĀS: SOCIĀLEKONOMISKIE UN TEHNISKIE RĀDĪTĀJI. LATVIJAS PIEREDZE (OTRĀ DAĻA)

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### Kopsavilkums

Padziļinātā zinātniskā pētījuma otrajā daļā publikācijas tēmas ietvaros tiek noskaidroti Latvijā nozīmīgākie nano jomas attīstību raksturojošie sociālie un tehniskie indikatori makro, mikro un vidējā ekonomiskās vides attīstības līmeņos. Sociālekonomisko un tehnisko rādītāju skaitlisko izmaiņu analītiskais vērtējums skaidri pierāda nano jomas mijiedarbību ar zinātnes un ražošanas attīstību, kā tas konstatēts pētījumā. Identificētie indikatori tiek piedāvāti pētījumiem, salīdzināšanai un izpildei jebkurā citā pasaules valstī.

24.08.2016.