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Daniil Frolov, Anatoly Yakovlev
Volgograd State University, Russian Federation

THREATS AND RISKS OF NANOINDUSTRY DEVELOPMENT

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Abstract: The paper deals with the negative aspects of nanotechnology development on the global and national scales. Possible economic, environmental and social risks and latent threats to the formation of nanoindustry and nanoproducts consumption are discussed. The conclusion about the need of intensive studies of this complex problem and development of regulatory mechanisms, legal frameworks and institutions of nanotechnology progress monitoring is made.

Introduction

Mankind has entered the XXI century with the prefix "nano". The nanotechnology revolution is unfolding before our eyes – the process of deep – qualitative changes in the evolution of the global economic system ongoing since the end of the XX century is associated with the creation and refinement of methods and tools for the production of nanometric (with the parameters from 1 to 100 nm) materials and products which are characterized by dramatically improved physicochemical and consumer properties. In the future, a radical change in the composition and structure of the commodity world comes[1].

[1] V.: *Societal Implications of Nanoscience and Nanotechnology*, NSET Workshop Report / Ed. by M.C. Roco, W.S. Bainbridge; National Science Foundation. Arlington, Virginia, 2001; *Nanotechnology: societal implications II. Individual Perspectives*, M.C. Roco, W.S. Bainbridge (eds.), Springer, 2007; *Nanotechnology & Society: Current and Emerging Ethical Issues*, F. Allhoff, P. Lin (eds.), Springer, 2009.

Nanotechnology "boom" coincided with the global economic crisis gradually entering the recession phase. Economists are naturally turning to rethinking the way for Russia's development in the context of a modernization paradigm. The formation of competitive nanotechnology is considered to be one of the key areas of strategic reorientation of the global economy (Inshakov, Fesyun 2009; Inshakov, Yakovlev 2010; Frolov 2010).

The article purpose is a multidimensional analysis of new calls and changes, hidden threats, risks and contradictions associated with the formation of nanotechnology in Russia and abroad.

Nano-optimists and nano-pessimists

The rapid development of nanotechnology, nanomaterials and products with nanocomponents is a new stage of the human society's progress. Nanotechnology can be a basis for the formation of a new technologic and, more widely, socio –economic structure on a global scale. However, being in the process of change it is almost impossible to make a realistic picture of the future prospects and possible consequences of this system process. There is good reason that a clear and fairly rigid division of experts in the nanofield into two "camps" – optimists and pessimists – is observed.

Nano-optimists put forward high expectations for the future nanoindustry. Thus, according to Lux Research, as soon as in 2014 the volume of the global market nanotransformed products will reach $2.6 trillion, and it will make 15% of gross world product. This conclusion follows from the analysis of the market potential of nanooptimized components and products in various spheres of their application (electronics, optics, medicine, ecology, energy, etc.). In this case, nanoproducts markets are among the most rapidly developing. Let's say, the expected average annual growth of nanosector semiconductor market (against the background of its dynamics slowing down and general volume reduction) is more than 40% for the period up to 2015.

In their turn, nano –pessimists focus public attention on potential dangers and risks of nanotech production and nanoproducts usage. In the first place they speak about possible biological and environmental risks of nanoobjects. The imperfection of the nanorisks assessment and minimization technology is exacerbated by the fact that the combined capacity of the poison test centers in Europe and the USA is not enough to study in detail dozens of thousands of new emerging materials and substances. In particular, the biological mechanisms of nanostructures toxic effect are studied very poorly. Insufficient attention is given to the problem of nanoparticles bioaccumulation and their transfer along food chains. It is known that particles with a size of less than 100 nm are much more toxic than relatively large particles of identical chemical composition. But despite

this, the issues of nanoproducts degradation (including fullerenes and nanotubes) and their acquisition of toxic properties are poorly investigated. Many researchers and experts believe nanotechnology to be one of the major global threats of modernity. It is inadmissible to develop at great cost what is not well understood and hardly controllable, namely, nanotechnology (Rees 2003).

Nanoindustry commercialization: opportunism and information asymmetry

Strong polarization of opinions is typical for the origination and rapid growth phase of any structure generating technology. Along with its mass dissemination and routinization against the background of growing new industry macrogenerations, an average social position is being formed, taking into account both the advantages and disadvantages of progressive types and modes of production. So far, the "scales" in the nanotechnology debate are clearly inclining in favor of lobbyists and their followers. Of course, this effect can be explained on the basis of joie de vivre socio –psychological concept (Akerlof, Shiller 2009), but a methodological institutional approach is more realistic as it can break the illusion of social neutrality of scientific research and technologic development (Frolov 2008).

The institutional determinism of scientific and technologic progress is associated with the leading role of various "related groups" influence lobbying their public and private status interests in this process. Any breakthrough technology is potentially connected with the accumulation and expanded reproduction of big capital. Therefore, purely scientific research problems are acquiring secondary character, and the problems of marketing and lobbying are brought to the forefront.

Mass replication of demonstration strategies connected with the imitation of belonging to advanced technologies is taking place in the scientific community. Thus, in recent years in Russia, a rapid torrent of projects and papers which titles are intentionally added by the "significant" prefix "nano" with a view of updating them to gain grants and investments is growing. The similar situation is observed in the developed countries (Berube 2006). Consolidation of a national strategic priority status of nanotechnology means corresponding changes of grant donors' politics which is rationally used by researchers through marketing mimicry; they update titles, but not the content of their papers. This "psevdonanoindustrialization" is of specific danger due to the underdevelopment of expert community in the nanotechnology area.

The leading research centers, in their turn, boost researches trying to justify received financial "injections". An example is the Large Hadron Collider as no confirmed scientific results in the course of its work have been achieved yet. But

the news that "scientists faced an unexpected effect" or "discovered a fundamentally new phenomenon" appears on a regular basis. Investors "customize" researchers, and researchers mystify investors with imaginary results. If for "pure" science the negative final result is a result too, the modern high-tech and capital - consuming science has no right to error: it is not given by investors and grantors.

Confidence in the bright future of nanotechnology is primarily based on foresights and forecasts of the market, which is impressive range of variation (table 1).

Table 1. Projected field of the nanoproducts world market ($ billion)

The developer and the year of the forecast	2010	2011	2012	2013	2014	2015	2020
LuxResearch (2006, 2008)	–	–	–	–	2600	3100	–
BCC (2008)	–	27	–	–	–	–	–
Cientifica (2008)	–	–	263	–	–	1500	–
RNCOS (2006)	1000	–	–	–	–	–	–
Wintergreen (2004)	–	–	–	–	–	750	–
MRI (2002)	148	–	–	–	–	–	–
Evolution Capital (2001)	700	–	–	–	–	–	–
NSF (1999, 2001, 2010)	–	–	–	–	–	1000	3000

Source: compiled by the authors on: C. Palmberg, H. Dernis, C. Miguet, *Nanotechnology: an Overview Based on Indicators and Statistics*, STI Working Paper 2009/7, p. 22; M. C. Roco, C. A. Mirkin, R. C. Hersam, *Nanotechnology Research Directions for Societal Needs in 2020: Retrospective and Outlook*, Springer, 2010; OECD, *Science, Technology and Industry Outlook 2010*, URL: http://dx.doi.org/10.1787/sti_outlook-2010-en.

While the global economic crisis adjusted all forecasts, it is important not so much accuracy as the order of evaluation. Note that all forecasting organizations use different definitions of nanotechnology and nanoproducts, as well as weakly comparable calculation techniques. In this sense, the comparison of different forecasts can not be, that researchers often ignore.

When science becomes an object of big business interests scientists inevitably transform into engaged persons. Such institutional jointing occurs in most sheres of modern big business, for example, pharmaceutical industry. Following their status interests, analytical and marketing companies serve economic interests of big capital in nanotechnology, in fact making its agents, but ignoring their direct function – to provide objective assessment of market trends. For example, the analysts of the Lux Research Agency predict that the nanotechnology products market by 2015 will have exceeded $2.5 trillion.

However, one should take into account the peculiarities of calculation methods, because all products containing even small nanotechnology components (na-

nointermediates) are considered to be nanotransformed. The primary task of the study was not to assess the nanoproducts market, but to justify the nanotechnology stock index – The Lux Nanotech Index. We can also recollect a "dotcom bubble" created by the "pumping" advertising of stock shares of Internet companies by numerous experts heralding the "new economy" outbreak. The collapse of the NASDAQ high-tech companies' index in March 2000 put an end to the illusions having adjusted the parameters of the artificially "overheated" market. Is this nanoindustry's fate? According to the conservative forecast of the Scientifica research company, the nano market will have reached "only" $1.5 trillion by 2015. The script of Global Industry Analysts is even more pessimistic: according to it, the global nanomaterials market have reached the amount of $10 billion by 2012 The difference with the Lux Research data is more than impressive, even from the perspective of abrupt intensity growth of the sixth unfolding Tec structure.

Even estimates of the nanoproducts world market current state are varied in absurdly broad range – from the modest $12 billion to a whopping $224 billion (*The Big Downturn …* 2010). This is not surprising. In the absence of clear rules for the registration and labeling nobody really knows the actual number of products containing nanoparticles and manufactured using nanotechnology. However, estimates of Lux Research, appealing to the maximum values of the scale were the most quoted. This proves the primacy of nanotechnology "boom" institutional factors, enhances the effect of sociopsychological mechanisms.

The lobbyists and promoters of nanotechnology are governments, regional and city administrations, large corporations, research institutions and foundations, expert communities. Nanotechnology is actively promoted and advertised in the U.S., EU and many countries around the world through technology integrated marketing. But this PR – campaign and advertising tricks inevitably give rise to information asymmetry, retouching and hiding any potential negative effects and risks of nanotechnology.

Nanotechnology risks and threats

According to the experts of the UN World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), the following specific properties of nanotechnology are of greatest concern (*Nanotechnology and Ethics*... 2008, p. 5):

- Invisible character: invisibility of nanotechnology usage hampers monitoring of its effects (as with nuclear technology);
- Rapid development: rapid development of nanotechnology makes it difficult to forecast, especially in a long term perspective, its potential consequences and appropriate measures;
- Use for military purposes and for security purposes: the use of nanotechnology for these purposes may violate human rights;

- Global impact: its potential impact even in those countries and societies that are not involved in nanotechnology development;
- Danger of «nanogap»: possibility of increasing inequalities between developed and developing countries.

In addition, in the medium term perspective, the usage of nanochemical and nanobiological weapons by criminal organizations including terrorists can be a real problem. In principle, it becomes possible to imagine a nanorobot with a size of the smallest insect (about 200 microns) capable of finding vulnerable people and inject poisons. The lethal dose of botulism toxin is about 100 ng, so 50 billion units of such a weapon can be stored in one suitcase, enough to wipe out all the Earth's population. The Nanotechnology White Paper (2007) made by the Science Policy Council of the US Environmental Protection Agency, is an impressive list of potential risks of nanotechnology and nanomaterials (Nanotechnology White Paper 2007, p. 29–62) which according to the authors, will grow with the increase of created nano –objects complexity.

Some scientists say that nanotechnology is of global danger. For example, at the end of the last century, E. Deksler, the US Foresight Nanotech Institute, suggested a theory according to which the planet surface and all the life on it will turn into a single layer of sticky dust or mucus. In his opinion, it will happen if self –copying nanorobots capable of taking substances from the environment get out of human control. This theory is called the grey goo problem. Another group of scholars has a more plausible hypothesis – the green goo problem which is based on the existence of the danger of creating destructive viruses and bacteria capable of rapid multiplying and destroying all the life on this planet by disintegrating protein structures into separate molecules.

The real danger may lie in the fact that we simply do not have time to timely assess and develop safety precautions. Many experts claim that the political discussion about the assessment of possible nanotechnology impacts lag about five years behind the actual technological development (Hartmann 2008, p. 140). It is necessary to remember the experience of nuclear technology development, genetic engineering development, etc., that is to take precautions and warnings about possible dangers seriously.

The negative properties of nanoparticles comprising the main component in all nanomaterials are a continuation of their positive characteristics and qualities. Measures are needed to examine possible threats and their prevention. Today, the US and other countries are trying to estimate the risk of nanotechnology development and usage. However, in the US the analysis of potential threats of nanomaterials is still very little funded. According to the estimates of the Project on Emerging Nanotechnologies experts, it is only a total of $39 million, that is only 4% of all allocations for nanotechnology coming from the Federal Treasury. The number of funded projects is also quite modest – just around 160.

The European countries take the issue of safety in the field of nanotechnology more seriously. The safety of nanotechnology was given a separate place in the second Implementation report 2007–2009 of the European Commission. In particular it states that all nanotechnology products shall meet a high level of environmental protection and public health protection, which is characteristic of the European legislation. The same report argued that nanotech products will be accepted by the society only after their producers demonstrate their security, as well as their consumers consider them safe.

The key problems of nanotechnology effective institutional regulation include:

- wide range, variety and growing number of nanomaterials and products made by their use;
- uncertainty associated with the lack of nano consumer goods mass production;
- lack of standardized definitions of nanotechnology and nanoproducts as agreed at the international level;
- limited knowledge about the toxic, allergenic, mutagenic, carcinogenic, teratogenic and other adverse effects of nanomaterials;
- deficit of common databases on nanomaterials safety and risks, the overcoming of which is constrained by intellectual property rights;
- asymmetry of information in the nanotechnology field among science, industrial businesses, regulators and the public;
- continuing backlog of technology nanomaterials standardization, metrology and certification, which negotiation can take 5–10 years against the background of the nanotechnology intensive development;
- potential inability of national governments to react to the development of nanotechnology through the issuance of comprehensive legislation in this area of regulation.

Unfortunately, Russia can not boast of a good legislative framework in the field of nanotechnology and nanomaterials. Its current legislation is intended, primarily, to finance the development of innovative high technologies, including nanotechnology. The problems of production safety of nanomaterials are not regulated by law which, on the one hand, allows for common legal standards for safe working operations, compliance with occupational safety regulations, and protection of patients, and, on the other hand, the specificity of nanotechnology is such that the existing legislative restrictions do not always make it possible to provide adequate security (table 2).

Certainly, there is a need to overcome the mistification of nanotechnology and its accompanying social phobia. They can be compared with the fear of artificial intelligence and pervasive invisible control that accompany the rise of the fifth information and technological structure. We should recognize the possibility of mass unemployment resulting from nanorobots' replacing people on the

labor market to be illusive like an imaginary threat of "Neo –Luddism". On the contrary, nanotechnology progress will lead to the need for universal higher education and dramatic development of competencies in population.

Table 2. The nanotechnology SWOT – analysis

Strengths (S)	**Weaknesses (W)**
– unique physical and chemical properties of nanomaterials – fast transformation of fundamental scientific research results in practically significant results; – powerful state support and propagation of nanoindustrialization; – superintensive rates of growth of nanoproducts markets; – cascades of innovative industrial and consumer goods with qualitatively new properties; – sharp gain of new knowledge and increase of an average level of people's competence.	– nanochanges cover technologies in a greater degree than the market; – prognosis distortions in the estimation of growth rates and volumes of the nanoproducts market; – insufficient level of scrutiny of biological and ecological danger of nano –objects; – deficiency of capacities of toxicological test centers concerning new nanomaterials and substances; – complexity of the control over nanotechnology usage in connection with their invisibility; – formal use of the prefix «nano» in marketing purposes.
Opportunities (O)	**Treats (T)**
– overcoming the global economic crisis consequences on the basis of nanoindustrial development in the leading countries and diffusion of positive growth effects; – solving some global problems of mankind (treatment of fatal illnesses, sharp reduction in price and mass distribution of information technology, etc.); – new impulse for the development of small and average innovative business, and the high capital intensity of research and development in nanotechnology sphere will not create significant obstacles; – rapid progress in natural and social studies in connection with studying nanolevels of their subject domains, creation of the bases for productive interdisciplinary synthesis on a global scale.	– use of nanotechnology in military purposes, as well as by power departments and special services; – application of nanochemical and nanobiological weapons by international terrorists; – formation of a deep «nanogap» between the leading and developing countries; – aggravation of the waste recycling problem of nanoproduction in connection with export to the third world countries; – failures on nanoproduction and huge damages to the environment; – transformation of the labour market, mass unemployment and rise of « Neo –Luddism »; – inflating a new « soap bubble» in the world share market and creation of the basis for a new global crisis; – defamation of the nanotechnology idea as a result of cognitive dissonance

Source: own compilation.

The nanotechnology revolution is a natural stage of global science and technology progress. The deeply differentiated system of nanorisks and their high level of objectivity reflect the enormous potential of nanotechnology. Moreover, the unique properties of nanomaterials and nanotransformed products are objectively accompanied by unique risks. But this does not mean that these risks and their associated threats should not be considered. We shall regard them in the context of nanotechnology system strengths and weaknesses, as well as provided possibilities for intensification of economic development.

Nano-industrialization and Russia

With the development of nanotechnology, the economic security problems are becoming increasingly relevant to this rapid process. They are of particular relevance for Russia which joined the competition in the global market of nanotechnology. Nanoindustrialization which began in our country is supported by the vast amounts of state funding and accompanied by an expanded reproduction of illusions which leads to underestimating the threats and risks inherent in the new technological structure.

Thus, according to the widely reprinted in the media view of MV Kovalchuk, nanotechnology development program in Russia exceeds the purposes scale of space and nuclear projects in the Soviet Union. But we shouldn't forget that the Soviet superprojects had specific goals – creation of the atomic –bomb, sending a man into space and landing on the Moon. The expected outcomes of this Program by 2015 are:

- sales volume of Russian nanotechnology products – about 900 billion rubles.;
- share of domestic products of the nanotechnology industry in the total nanotechnology industry output sold in the global high-tech market – about 3.0% (*Development Program*... 2008, pp. 5).

The established clear key indicators of program could be a key factor in its success. However, the laid amorphous terminology leave a broad prospect for manipulating the results of the Russian nanotechnology industry. The key term of the Program – "nano –products (nanotech products)" is defined as "highly competitive products (goods, works and services) produced with nanotechnology usage and having as a consequence previously unattainable technical and economic performance parameters" (ibid., pp. 44). Thus, all the four groups of the Lux Research nano classification can be referred to as nanotechnology products:

- nanomaterials – nanoscale structures in unprocessed form (nanoparticles, nanotubes, fullerenes, etc.);
- nanotools – technical equipment for nanomanufacturing, including software for molecular modeling;

– nanointermediates – nanocomponents for more complex products (coatings, fabrics, superconducting fibers, chips, contrast media, etc.);
– nano –enabled products – all products (from airplanes to plastic containers) in a given volume containing nanointermediates and characterized by improved consumer properties.

Given such a "fuzzy" definition of nanotechnology production, the estimation of its volume becomes very difficult and can be vary widely.

We should consider dangerous the illusion of the rapid and successful integration of Russia into nanotechnology "race" with the leading economic powers of the world. We should take into account the lessons in the XX century, the historical experience of unsuccessful attempts to break into socialism bypassing the stage of capitalism. The Utopian scenario of creating a "postindustrial society" in the immature industrial basis. The nanoindustrialization of the Russian economy should be seen as the key, but not the only component of its neoindustrialization strategy.

In addition, the World nanoindustrialization will inevitably affect the global division of labor manifesting itself in the consolidation of countries specialization in "high" and "low" nanotechnology. Some countries will produce "nanoconsumables", others will deliver "nanoresources etc. What role will Russia play in the emerging global system of nanoeconomics coordinates? The continuously accelerating development of nanotechnology and nanoindustry in the world can quite possibly become an ordeal for the Russian dominant rigid system of administrative –bureaucratic relations. What are the prospects for exports of the Russian nanoproducts? They are unlikely to directly depend on public funding of R & D in nanotechnology, and the growth of private –sector investment in nanotechnology remains a much more urgent task.

Assessing the prospects of the sixth nanotechnological way of life, we should not forget the lessons of the fifth structure evolution which coincided with the "latest" Russian history. A society always learns new technologies to the extent of its needs and skills to use them. What is the potential algebra of the internal market of products for the Russian nanotechnology industry in the conditions of an unexpressed industrial policy and preservation of a "resource model" of development? Corruption is a systemic factor of distortion of nanotechnology in Russia. "Sputtering" of budgetary resources through shade channels and corrupt schemes may be justified only by the fact that some of them will "reach" the real science and will be translated into real innovations. But what will be the profitability of the huge public investments in nanoindustry?

We should not forget that small and microbusiness solving the crucial problems of producing relatively simple nanoproducts is a foundation of the national nanotechnology network. An attempt to replace the need of creating infrastructure and institutional conditions for increasing competition by creating an artificial monopoly in the field of nanotechnology is doomed to failure. Hypertrophic

government funding is not a panacea for institutional pathologies in innovation sphere.

The prospect of "labor hunger" is almost the key threat to the economic security of the emerging Russian nanoindustry. Given the stated growth rate of domestic "nano-tech" and the current pace of staff training, just over 10% of the human demand of nanoeconomics will be covered by 2015. Of course, the extrapolation of current trends is quite a simplified method of human foresight. But we can not deny the observed ignoring of the role of specialists in management and controlling of nanoproduction, nanosertification and expertise of nanoprojectos, marketing of nanotechnology and nanoprooducts, legal and accounting provision of nanoinnovatsy etc. The personnel for nanotechnology should be trained both in natural and humanitarian spheres of training (*Implementation Mechanisms*..., 2009, p. 152).

Proactive institutional policy in nanoindustrialization is required. Existing monitoring and supervision mechanisms should be adapted to the specific problems of nanotechnologies and nanomaterials application, including development of standards and regulations pertaining to cosmetics, food, health and workers nanomanufacturing security, environmental safety, medical devices and pharmaceuticals, etc. The most pressing issues in the nanotechnology institutional regulation are currently associated with the unification of nanoproducts measure units (such as production volumes), standardization and metrology, the nanomaterials and nanoproducts typology and classification, providing data on safety and informing end-users (labeling and certification, creating nanomaterials and products containing them databases). Their decision should be a priority, but the main emphasis should be transferred to the regulation of security issues.

According with the decision of the Chief State Sanitary Doctor of Russia (2007), each designed and intended for use nanomaterial should undergo a full toxicological evaluation. Prior to the establishment of specific nanomaterials risk should be considered as new products and refer to substances potentially harmful to human health. But the idea of "continuous" toxicological evaluation and classification of nanotechnology products and nanotechnology in the degree of potential risk in practice difficult to realize and has the highest potential for corruption. It's safe to assume that in Russia at the present state of laboratory and technical resources behind research and expertise in the safety assessment of nanotechnology products and nanotechnology will total.

Nanomanufacturing workers and their trade unions should be involved in the development of standards for workplace safety. Because many threats to the interaction with nanoparticles have not yet been identified, employees should be provided with the maximum possible information about nanotechnology and nanomaterials, with their contacts. Education and medical supervision should be binding components of the production processes in the field of nanotechnology.

It is equally important to provide extension of preventive measures and education programs in nanotechnology, to promote various forms of informing and educating the general public.

Conclusions

The equalization of nanoindustrializationin funding Russia and the US is a unique phenomenon in itself. But for the output growth and competitiveness increase of the domestic nanoproducts we need, above all, some systemic institutional changes. They are associated with the development of the target-oriented mechanism of government funding of long-term innovative projects, with creating a network of nanotechnology research and educational centers,and independent certification service, „cultivation" of public-private partnership venture, formation of an effective patent system and strengthening protection of intellectual property, introduction of strategic and indicative planning of research and development institutions with establishing their activities targets through rigid requirements and standards of nanomaterials safety, etc. In terms of fuzzy rules, the institutional pitfalls and high transaction costs and speeding up of governmental promotion of nanoindustry in Russia will certainly give a lot of positive effects. But weather this mass will become critical for the real modernization of the Russian economy is the question more rhetorical than open.

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