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Nanotechnology development and regulatory framework: The case of Russia ☆

Nanotechnology is a rapidly evolving area of knowledge related to the development of the methods of study and control of the matter at the molecular level to produce materials, devices, and systems with new technical, functional, and consumer properties that were impossible to achieve previously. The many existing nanotechnology definitions all highlight three fundamental characteristics of nanotechnology: "Firstly, … the scale of measurement at which research and engineering moves into the nanotechnology domain… a threshold of 100 nm is most-often suggested. Secondly, nanotechnology is the purposeful "control", "manipulation" or "handling" of matter at a very small scale. Third, … development and engineering at the nanoscale should also enable "novel" or "new" industrial applications or "technological innovations" based on characteristics arising from size-dependent phenomena" (Le Strange, 2011). Along with Information and communications technology (ICT) and biotechnology, nanotechnology gives a promise of an increasing contribution of S&T and innovation to economic growth due to both already available and emerging multi-purpose applications in industry and households.

The rapid expansion of nanotechnology Research and Development (R&D) carries not only promised benefits (Hullman, 2006), but also potential economic, social, environmental, legal, and ethical risks (Turk et al., 2008). All these factors require the participation of national governments in regulating the creation, transfer, and application of nanotechnology (Palmberg, 2008). In many countries, such practices are implemented through the launch of national initiatives (by 2008, more than 60 countries announced the launch of large-scale public support programs for nanotechnology (Wang and Shapira, 2011, p. 571)), defining framework conditions for nanotechnology development.

However, despite high expectations supported by profound policies and substantial public investment (see, for example, Roco, 2007) the evidence of real economic effects from nanotechnology is yet incomplete. Multiple information sources do not solve a problem of obtaining reliable and internationally-comparable data on the economic scale. Today the value of nanotechnology is being derived from scientific publications and patenting (OECD, 2011) in the absence of a harmonized framework for statistical data collection (Gokhberg and Pastor, 2010; Gokhberg et al., 2011). The latter is required as a background for designing evidence-based policies to ensure identification of the boundaries of this technology area and its structure, and measurement of allied costs, outcomes, and socioeconomic impacts.

In Russia, the *Strategy for Nanotechnology Development* was adopted in 2007. Its initial goal was to direct financial and organizational resources at interdisciplinary research in nanotechnology-related areas and to create a competitive domestic market of nanotechnology-enabled products. A year earlier, in 2006, nanotechnology was included to the national list of S&T priorities, and since then has enjoyed direct financial support from the federal budget. The *Program of Nanotechnology Development in the Russian Federation until 2015* (*Program-2015*), which started in 2008. Russia has envisaged certain policy actions aimed at promoting; allied R&D, infrastructures, manufacturing, and investment in the implementation of innovative projects. The program provides overall funding at about RUR 100 bln (nearly PPP USD 5.5 bln). Another RUR 300 bln (PPP USD 16.4 bln) have been channeled to the Russian Corporation of Nanotechnologies (RUSNANO) to foster development of nanotech products and their market penetration. These decisions have stipulated ongoing expert discussions on whether public investment in financing nanotechnology at such a scale has been rational vis-à-vis the national R&D expenditure total equal to PPP USD 26.6 bln.

During the first two years of the *Program-2015* implementation, the *National Nanotechnology Network (RUSNANONET)* was established. It is comprised of research organizations, universities, and businesses, as well as individuals engaged in nanotechnology S&T and auxiliary activities (over 740 members at the end of 2011). Its primary goal is building a platform for professional communications and cooperation. Another important action was undertaken by the *Federal Service on Customers' Rights Protection and Human Well-being Surveillance (Rospotrebnadzor)* which approved health and safety regulations for the identification and control of nanomaterials in living organisms, chemicals, water supply, and food products.

Valuable insights into nanotechnology-related trends are provided by already well-established domestic statistics linked to the OECD-compatible annual R&D, innovation, and structural business surveys (Gokhberg et al., 2011). There were 480 organizations engaged in nanotechnology R&D in Russia by 2010. Most of them were concentrated in the government (37.1%) and higher education (34.8%) sectors followed by the business enterprise sector (27.9%), whereas the share of private non-profit organizations in this field was negligible. This picture has remained almost completely intact compared to the findings of earlier studies (for details and figures, see here and further (HSE, 2010, 2011)). Nanotechnology R&D expenditure in 2010 barely exceeded 3.1% of gross domestic R&D expenditure in Russia. Annual growth in this amount by one-third was registered for 2008–2010, which is a significant increase against the background of general economic recession during that period. The number of researchers employed in nanotechnology R&D accounted for 17.9 thousand (3.9% of the total researchers' population in Russia) in 2010, which is 20% greater than that in both 2008 and 2009.

One of the key indicators of the economic impact of nanotechnology is the sales of nanotechnology-enabled goods and services. We proposed a classification of particular product groups and criteria for their identification, based on consultations with the scientific community regarding definitions (Alfimov et al., 2010) and results of pilot statistical studies. The official

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version of the classification adopted by the Government of the Russian Federation (July 2011) contains the following four basic categories: (1) primary nanotech products (nano-objects and systems) that i.a. can be involved into manufacturing other types of products; (2) conventional products that include nano-components; (3) services rendered with the use of nanotech processes; (4) specialised equipment intended for study and control of the matter at the nanoscale level, including manufacturing of the above-mentioned types of products (these classification approaches are considered a background for developing an integrated framework for measuring emerging, enabling and general-purpose technologies at the OECD (Gokhberg and Pastor, 2010; Fursov et al., 2011)).

In 2009, total sales of nanotech products approached RUR 92.6 bln (PPP USD 5.1 bln), or 24.3% of the overall industry output. The 2010 figure demonstrates a positive trend: RUR 112.1 bln (PPP USD 6.1 bln, or 23.3%). This amount is almost completely represented by "conventional" products manufactured with the use of nano-enabled processes (92.1%) or nanomaterials (7.2%). As occurred, elementary nano-objects and nanodevices are often manufactured by R&D institutions (44% of all nanotech manufacturers) as unique prototypes or small-scale pilot series, though the share of such products is minimal (0.6%) as well as that of specialised equipment for nanotechnology (0.1%).

The output of innovative (i.e. those either newly introduced or significantly modified) products related to nanotechnology was RUR 53.4 bln (PPP USD 2.9 bln) in 2010, of which 44.6% was exports. Manufacturing of goods with the use of nano-components and nano-enabled processes is concentrated mostly in medium low-tech sectors due to high (overestimated) sales in oil and gas refining where nano-catalysts are widespread. Although the inclusion of these products into "nano" categories is debateable (Gokhberg et al., 2011), respective figures additionally contribute to positive dynamics of nanotech production. The innovation survey results suggest that innovative nano-enabled products are characteristic of such economic activities as the manufacture of food products, machinery and equipment, motor vehicles, radio, TV, and communication and medical equipment. It coincides with the results of recent Foresight exercises carried out by HSE for RUSNANO (RUSNANO (online)).

The goal of the Foresight study was to identify the most promising nanotechnology markets for the medium and long-term periods (until 2030), and provide a list of product groups with the highest innovation and market potentials. The expert panel included over 1000 domestic experts (an interdisciplinary panel and several thematic panels) plus more than 100 international experts from leading nanotechnology research centers in the US, UK, Canada, China, Germany, and other countries.

According to the Delphi survey results, the market nano-enabled products in Russia can reach RUR 3 trln (constant PPP USD 164.3 bln) by 2015 under a moderate scenario. For 2030, its growth is expected to be more than 6-fold. Provisionally, exponential growth may happen in 39 nanotechnology areas, notable for high market potential and strong Russia's competitive positions in R&D. Among them there are durable nanocoatings, heat-resistant ceramic nanomaterials, solar cells, sensors and markers for medical diagnostics, nanodiagnostics equipment, water purification and treatment systems, etc. Promising areas also include nano-enabled applications for oil and gas processing, nuclear power engineering. The demand for nano-enabled products will be generated by such large market as electronics, automobiles, road infrastructures, medical equipment, and pharmaceutical industries, construction, etc. In the long-term period, experts foresee a wider use of nanotechnologies in transport equipment (automobiles, aerospace, and vessels), food industry (new packaging materials, labeling techniques, nanomaterial-based filters and membranes, etc.), and consumer chemicals. Innovations will affect not just high-tech sectors but more traditional industries (e.g. agriculture) as well.

In addition, technology roadmaps have been drafted to design forward-looking innovation strategies for priority areas determined in the Foresight framework. These areas include sectors of economy (nuclear power generation, space, aircraft and health), specific product groups like: LEDs, carbon fibers, catalysts for oil processing, and horizontal (intersectoral) technology areas (drinking water purification, energy saving). Roadmaps point at the demand for innovative products and major related markets. They provide an assessment of technological capabilities required for manufacturing and scenarios for R&D activities, taking into account market prospects of innovative technologies and products in concordance with possible consumer strategies.

Foresight and roadmapping along with statistical frameworks can assist expert discussions and policy making on standardization and regulation of nanotechnology development in line with the emerging international conventions.

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