# Structural changes in national innovation system: longitudinal study of innovation modes in the Russian industry

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*(Presented at EMAEE 2015. Please reference the updated version of the paper: [http://link.springer.com/article/10.1007/s10644-015-9164-8](http://link.springer.com/article/10.1007/s10644-015-9164-8))*

**Introduction**

The 'national systems of innovation' framework is often considered as one of the most promising approaches to the analysis of the actors and their interactions in the field of science, technology and innovation. It generally reflects the contemporary perception of the innovation-related processes as the result of co-development of the institutions, industries and sectors, policies and infrastructures. These processes are known for their complex dynamic behavior that can be exhibited as path-dependent and highly inertial with regard to intentional regulatory efforts, but vulnerable to the specific types of exogenous and endogenous shocks.

By now the dynamics of innovation system genesis is discussed from different perspectives, including general evolutionary approaches, institutional economics and micro-level research of the innovation behavior logics and trends. At the same time, still most of these perspectives face difficulties at accounting for structural changes (especially for the case of gradual evolution and development as opposed to major shocks and shifts). Conventional tools include descriptive analysis of the institutional configuration as well as exploitation of the general macro-level indicators that typically fail to consider the heterogeneity of innovation actors, as well as the skewedness of the distributions of their characteristics.

This study focuses on revealing and testing the potential of the firm-level taxonomies as a tool for accounting for the evolution of innovation systems. Using the case of the Russian Federation, different approaches to constructing innovation behavior types are tested. The analysis of the conventional indicators of the innovation activity within the Russian industry sector is expanded using the derived meso-level trends that characterize the dynamic allocation of specific types of companies within the system.

The paper is structured as follows. Section 2 discusses the traditions of research of the dynamic change of the national innovation systems and the potential of using innovation taxonomies for understanding the path dependence phenomenon. Section 3 introduces the case of the Russian Federation by presenting an overview of recent tendencies within the national innovation system as well as the key political initiatives in the field of science, technology and innovation (STI). In section 4 several types of firm-level innovation taxonomies are constructed and exploited for deriving the meso-level trends of innovation behavior in the Russian industry sector. Section 5 summarizes and draws conclusions.

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## 2. Background: accounting for the path dependence

In the contemporary studies of science, technology and innovation (STI) path dependence is widely accepted as one of the key framing determinants of the economic development and technological change (Arthur, 1994) and recognized as the central feature of innovation systems evolution processes (Dosi et al., 1994). Pragmatic discussions on the effectiveness of policies in this field also emphasize inertial resistance to the intentional systemic redesign and deferred character of the outcomes and responds to regulation (as expressed e.g. in the OECD Innovation Strategy manifesto, 2010).

The topic of path dependence in innovation studies descends from two major domains of research. One of them concerns complexity of institutions and institutional change. Douglass North's (1990) perception of institutions as a structure of explicit rules and implicit incentives that determine the behavior of actors within the economy strongly corresponds to the development of the 'national innovation systems' (NIS) approach (Dosi, 1997; Edquist and Lundvall, 1993; Freeman, 1987; Nelson, 1993). Hart (2009) points out that in line with the literature on institutional development (see Streeck and Thelen, 2005 for an overview), NIS researchers explore two major, in some sense 'extreme' cases of system dynamics. The first one implies stability and continuity of institutional arrangements commonly observed within the STI complexes for longer timespans (Carlsson, 2006; Freeman, 1995). With this regard, institutional discourse introduces strongly related concepts of lock-in effects (North, 1994) at national and even regional levels (e.g. 'place dependence' discussed by Martin and Sunley (2006)). The second case, a traditional subject for ex-post analysis, concerns revolutionary change caused by major socio-economic (or political) shocks. Resulting fundamental shifts of actors' routine activities and networking move the systems towards newly settled trajectories (Freeman and Louçã, 2001) which again appear to be inertial and stable.

Second research domain that provides stylized facts for explaining the inertial behavior of STI systems covers the studies of persistence of innovation at the firm level. Betina Peters (2009) emphasizes two contrasting sources of persistence: state determinism (true causality between innovation over time, expressed in the hypotheses of 'sunk costs' or 'success brings success') and the unobserved heterogeneity (stability of unspecified factors or characteristics that determine propensity to innovation). A number of powerful theoretical frameworks has been developed (e.g. 'adsorptive capacity' by Cohen et al. (1989)) accompanied by the growing body of empirical evidence derived from patent statistics (e.g. Malerba and Orsenigo, 1999) and innovation surveys (e.g. Duguet and Monjon, 2004). Recent findings indicate the strong intertemporal causality between the engagements in innovation activities (as the propensity to maintain established routines) but limited persistence of innovation success (Peters, 2009; Raymond et al., 2010).

Abovementioned lines of literature frame top-down and bottom-up pathways for understanding the dynamics of innovation systems. In the absence of revolutionary changes, institutional stability and the consequent consistency of incentives meets inheritance of innovation-related capabilities at the firm level thus resulting in the observed persistence of innovation behavior of individual actors. Propensity of actors to maintain their routine behavior appears to be resistant to a wide range of shocks.

This logics, however, is somewhat limited at analyzing intermediate cases of gradual development and co-evolution of the components of the system (referred as 'bounded change' by Thelen (2004)). Recent literature recognizes this constrain and elaborates it in a number of ways.

The reference direction (as stated e.g. by Hart (2009)) is further development of the NIS discourse in order to advance from the 'approach' and a convenient set of concepts towards the 'theory' and a more systemic modelling that would make possible to perceive broader range of dynamic behavior regimes. This line of study has been stockpiled research on the identification and diagnostics of innovation systems functional layers and linkages between the actors (Edquist and Hommen, 1999; Geels, 2004a; Geels and Schot, 2007; Smits and Kuhlmann, 2004). The 'Triple Helix' approach (Etzkowitz and Leydesdorff, 2000) presents a more conceptual 'modelling' example of this strand of research. Both of the mentioned have to face the challenge of balancing between systemic complexity and measurability of the dimensions.

The complimentary perspective for analyzing the processes of change is the research on the diversity of innovation behavior. Early works on explaining sectoral variety of innovation strategies and performance (Dosi, 1982; Pavitt, 1984) initialized the tradition of taxonomy-driven approaches to accounting for the heterogeneity of innovation. The availability of novel data sources facilitated the shift from industry-level taxonomies (Peneder, 2003) towards firm-level classifications (Arvanitis and Hollenstein, 2001; Castellacci, 2008; Hollenstein, 2003; Peneder, 2010 to name a few). These studies contribute to the understanding of the complex composition of actors within the single innovation system at the given moment, which differ in terms of their performance, sophistication of strategies, general perception of the (competitive) environment, and thus potential reaction on the incentives (including the ones designed through innovation policy measures). Important advances in this area concern using international datasets (mostly based on the innovation survey data). Arundel and Hollanders (2008) emphasized the potential of the analysis of composition of the actor types (or 'innovation modes') for understanding the performance of national innovation systems.

Recent OECD efforts focused on the identification of specific modes of innovation behavior in the cross-country context (Frenz and Lambert, 2009; Lambert and Frenz, 2012; OECD, 2009). Key findings indicate (i) high variation of the distributions of these types within different national environments; (ii) observed persistence of this compositions within the specific environment (at least in the short term, i.e. 2009-2012). These characteristics of innovation modes comprise an important background for further elaborating the dynamic dimension of innovation heterogeneity, specifically exploring the meso-level trends that reflect intertemporal allocation of actor types. Accounting for the allocation of innovation modes is important not only from the perspective on the cross-environmental specificities of innovation, but also is considered as an important supply of evidence for actor-driven and diagnosis-based approaches to policy-making (Borrás and Edquist, 2013; Edquist, 2011).

Balance between the types of actor's behavior within the innovation system can be considered in the context of intersection of two abovementioned pathways of research: the institutional framework and the firm-level persistence studies. Popularity (in the statistical sense) of the particular types of behavior not only reflects the reactive perception of the NIS performance, but also determines the space of possible future trajectories (Geels and Kemp, 2007).

The use of innovation indicators for this purpose is not a coincidence. In its present state, innovation surveys represent a case of one of the most advanced internationally harmonized data sources on the broad range of strategic activities of the enterprises (see discussions in (Gault, 2013)). The Oslo Manual-inspired framework presents not only the keynote indicators of innovation, but also provides very specific information on the market priorities and networking patterns. With regard to this the dynamic accounting for innovation modes can be thought of as an empirical attempt of operationalization of the 'varieties of capitalism' discourse (Hall and Thelen, 2008) in the spirit of nonstationary measurement of the combination of business model success factors.

Next sections of this paper explore the potential of the described instruments by constructing longitudinal meso-level trends for several types of innovation modes. We use the Russian Federation as the reference case. Central research focuses include:

(1) degree of stability of meso-level trends based on the innovation modes;

(2) potential of the constructed trends for explaining the evolution of innovation system.

**3. The case of Russia: an overview of the innovation system performance**

Recent studies (Gokhberg and Kuznetsova, 2011; Gokhberg and Roud, 2012; OECD, 2014, 2011) emphasize the Russian case as an example of the inconsistency between the accumulated innovation potential (along most of the conventionally recognized components of the 'dynamic capabilities' (Teece, 2007)) and the resulting poor efficiency over broad range innovation output indicators.

At the background of relatively stable economic growth of the last decade, the STI complex demonstrated stagnant or even decreasing performance, in fact, reflecting the gradual loose of competitive positions among other developed and rapidly developing countries. This holds true for the most of the conventional measures of STI performance, such as Russia's participation in the international markets of technologies, high-technology exports, publication of scientific articles and international patenting (Gokhberg and Roud, 2012; Kotsemir, 2012).

The volatility of the composite country rankings (in the INSEAD/WIPO Global Innovation Index Russia's rating was 56 of 143 in 2011, 51 in 2012, 62 in 2013 and 49 in 2014) is generally produced by the business and investment climate perceptions, maintaining stability over the diagnosis of the strengths and weaknesses of the Russian NIS. High level of the human capital and the accumulated capabilities for scientific research, inherited and functional high-technology sectors set the scene for the country's excellence in the field of science, technology and innovation. The exploitation of this potential is significantly hindered due to persistent systemic failures, such as:

- Poor framework conditions (political environment and stability, regulation quality, rule of law and general quality of institutions (Polischuk, 2013), limited access to finance and investment opportunities) hamper sophistication of the business models (Yakovlev, 2014). Resulting regimes of competition are perceived as unfriendly to innovation (Kuznetsova and Roud, 2013). Enterprises are tempted to pursue types of rent different from the Shumpeterian – using various forms of vertical integration, establishing special linkages with the state authorities and finding other strategies less vulnerable to the economic and political risks (Yakovlev, 2014; Yakovlev and Zhuravskaya, 2013).
- Lack of contingency between the components of the innovation system, including sectoral and regional polarization, inefficient institutional structure of the public R&D sector, limited connections between industry and science (Zaichenko et al., 2014) reduce possible spillover effects of the policy measures, considerably decreasing the efficiency of the regulation and magnifying the costs and risks of establishing the advanced value and knowledge chains.

Retrospective analysis of the policies (Gokhberg and Roud, 2012; Simachev et al., 2014) derives that innovation has been gained central positions in the official discourse only in late 2000s (somewhat facilitated by the World economic crisis). Early post-soviet stages were associated with providing general economic stability as well as maintaining the inherited S&T capacities. That was generally implemented by gradual increase of the public R&D funding while preserving obsolete institutional structures and governance principles. Only recently the contemporary approaches to the STI policymaking has being adopted at the conceptual level and still there are large scale obstacles to the efficient implementation of the new models of govenance. The set of initiatives has been launched in 2009-2010, targeted at promoting cross-sectoral interactions and compensating risks directly associated with complex innovation strategies. Key measures concerned competitive-based support for cooperation between companies, research organizations and universities (Gokhberg and Roud, 2012, pp. 126-127), facilitation of the regional innovation clusters (Kutsenko and Meissner, 2013), development of the technology platforms (Proskuryakova et al., 2014). Major role of the state in the Russian economy inspired the special ‘innovation enforcement’ initiative that implies the mandatory elaboration and implementation of the innovation development strategies for the larger state-owned companies (Gershman, 2013) with the particular accent on the cooperation with small and medium business as well as the research institutions.

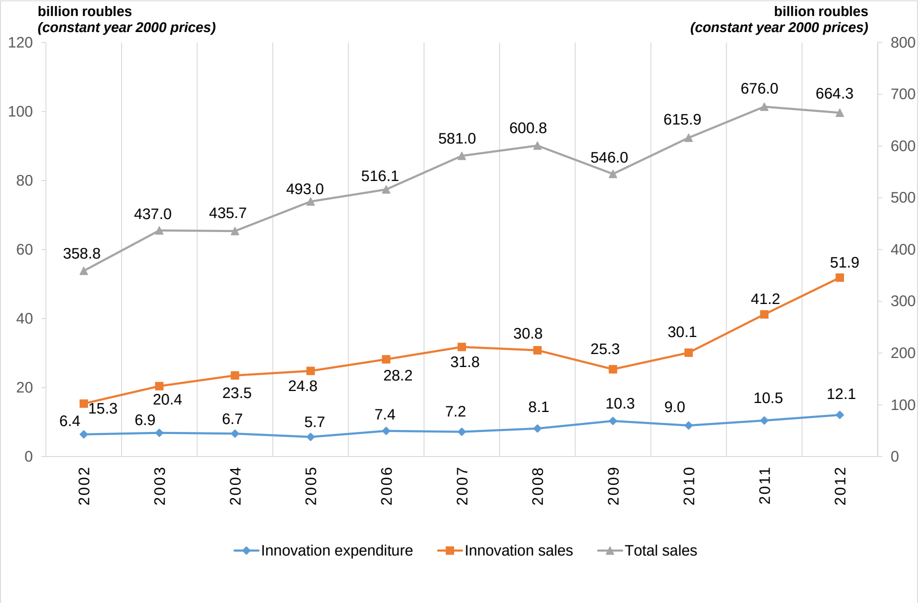
Institutional upgrade of the public R&D sector remains the central area for the reforms. In 2013, large-scale transformations in the Russian Academies of Science took place, initiating the process of total change of the system of governance, by now largerly inherited from the Soviet Union. This is accompanied with the hot debates on promoting excellence-based competitive-based funding mechanisms for the public R&D and researchers’ rewards (Gershman and Kuznetsova, 2014).

Fostering the efficiency of the regulation remains one of the fundamental challenges for the governance of STI. Major effort is concentrated along fostering the holism of the regulatory initiatives as well as synchronization of the activities between all the governmental bodies. Impact evaluation has been gaining actuality, giving a start for general reconsidering of the existing policy instruments (e.g. tax incentives for R&D and innovation activities, Gokhberg et al. (2014)) and increasing demand for all sorts of evidence for policy-making.

With this regard the special attention is traditionally driven to the observation of the innovation behavior of the industrial companies that is often considered as the crucial component of the national innovation system (Hart, 2012).

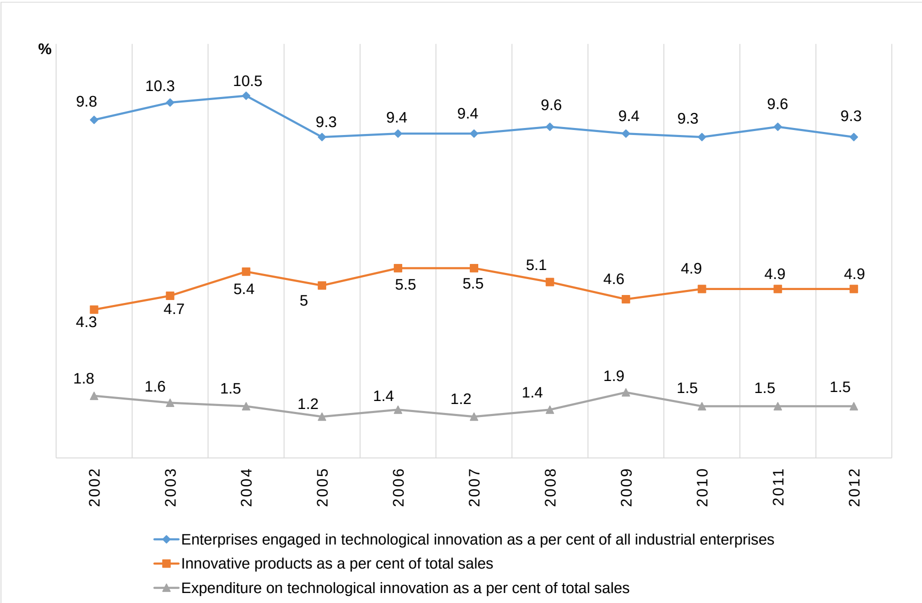
Figure 1 and Figure 2 provide key macro-level tendencies for the industrial enterprises (NACE rev. 1.1 C, D, E).

Figure 1. *Performance of the industrial enterprises: total sales, innovation sales and innovation expenditure*




Source: authors' estimates based on HSE, 2014.

Figure 2. *Innovation activity, intensity of expenditure and share of innovative sales of the industrial enterprises*




Source: HSE, 2014.

For the recent decade, total intensity of innovation expenditure nearly doubled (in the constant prices), while the sales of innovative goods and services grew even faster. The great deal of that increase took place after 2009. At the same time, all the relative indicators, including the total share of innovation companies, shares of innovation expenditure and innovation sales in the sales total, appear to be stagnant at rather modest levels. Less than 10% of the industrial enterprises engage in technological innovation, total innovation spending comprises around 1.5% of total volume of sales while the share of innovative products and services fluctuates around 5%. These indicators frame the very limited magnitude of the innovation as an economic activity.

Observed disparity of dynamics between the absolute and the relative indicators testifies for the specifics of the changes that take place within the Russian national innovation system. On the one hand, the scale of the innovation effects increases over time, following the general ideas of economic development and the accumulation of capabilities and opportunities. On the other, the fraction of actors engaged in innovation as well as their principles of the resource allocation appears to be stable over longer periods, showing minimal sensitivity to the macroeconomic shocks (both positive as in case of higher oil prices in 2004 and negative after the crisis of 2008-2009).

These findings can hardly be elaborated further with the help of solely macro-level indicators. The skewness of the distribution of innovation activities within the economy (expectedly unequally expressed along different dimensions) justifies the necessity of utilizing methods that are more rigorous. Next section considers applying longitudinal meso-level taxonomy-based innovation trends analysis in order to deepen the understanding of innovation processes within the Russian NIS and to address the methodological issues formulated in the previous section.

## 4. Innovation trends at meso-level

Following Peneder's (2003) discussion of the industry-level taxonomy construction principles one can distinguish three methodological approaches for constructing the modes: (i) *one-dimensional cut-off* that implies choosing a single variable (such as R&D intensity) and constructing the classes based on the value of this variable within the predefined set of boundary levels; (ii) *top-down mixed classification*, based on the initial selection of the dimensions (e.g. availability of intramural development activities, operation at the international markets); (iii) *data-driven taxonomies* produced through the specific statistical manipulations with the broad range of dimensions.

The analysis within this section exploits the firm-level data on the innovation activities of enterprises collected from the Russian Innovation Survey, the annual mandatory exercise performed by Russian Federal Statistics Service (Rosstat) since 1994. It covers innovation activities of medium and large enterprises in industrial sectors and the selected services (specifically – NACE rev 1.1. C, D, E, 64, 72, 73, 74). Survey design is based on the Oslo Manual (OECD, 2005) and is generally accepted as compatible with the Eurostat/OECD

Community Innovation Survey programme[1]. Anonymized firm-level data for this study is organized as the pooled cross-section that covers the Russian industrial companies (NACE rev 1.1 C, D, E) of more than 20 employees for 2002-2012, for the approximately 260000 total observations, of which more than 25000 are innovative.

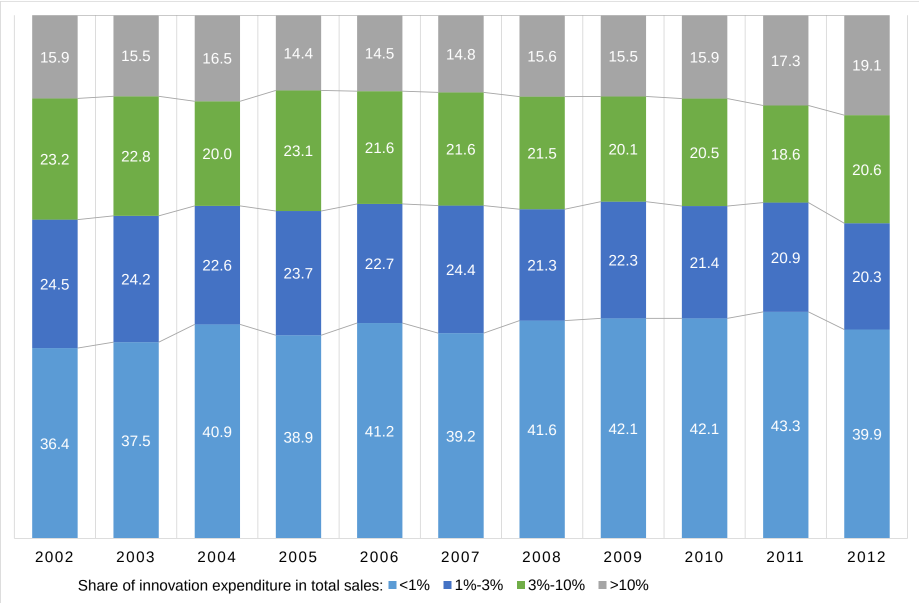
The *cut-off* taxonomies are the most straightforward to implement (not considering the effort on the data collection and harmonization) and interpret as well. The most notable example here is the OECD classification of industries' technological intensity (Hatzichronoglou, 1997) that practically explores the role of R&D expenditure in the economic performance of the specific industrial sectors. Although subject to broad criticism (referenced by a number of the authors as the 'high-tech myopia'), this taxonomy contributed greatly to both the scientific and the political discussions in this field and is still the subject of further elaboration (see Peneder, 2010).

For the present analysis, we construct two *cut-off* based taxonomies, one classifying the companies along with the intensity of the innovation expenditure as a share of total sales and the other – in line with the share of the sales of the innovation products and services in the total sales. Figure 3 shows the composition of innovation intensity classes over time. Commitment to the specific models of resource allocation proves to be extremely persistent in line with (Peters, 2009) findings. During the last decade the stable group of roughly 40% of the innovation companies maintained their spending at less than 1% of their total sales. Intermediate expenditure groups (with the expenditure being 1-3% and 3-10% of total sales) comprise jointly another 40% of enterprises. The share of the most intensive investors (more than 10% of their total sales) has been growing marginally, increasing from 16% to 19% over the observed period.

[1] See further comments in (OECD 2011, p.133). Key innovation indicators are distributed via the series of databooks (e.g. Innovation Indicators, 2015) and are partly available at the Rosstat website:
http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/science_and_innovations/science/

Figure 3. *Intensity of innovation: meso-level trends*

*(% of companies with the specific innovation mode in total innovation companies)*

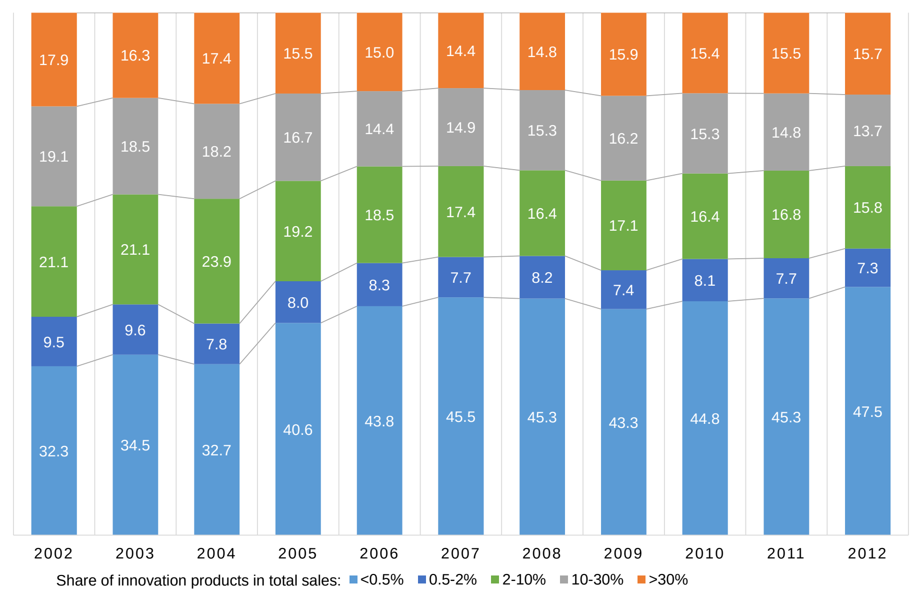



Source: authors' estimates.

Meso-level trends of the intensity of innovation sales (Figure 4) express more volatility. The clear tendency is the growing (from 32% in 2002 to 47.5% in 2012) share of the companies for which innovation sales appears to be increasing share of the process-driven innovators, for which the potential volume of sales of the novel goods and services is somewhat secondary compared to other effects of technological innovation. Another sound finding is the relative stability of the more innovation-driven company classes (e.g. those that account for 10-30% or more than 30% of innovation sales) – together they account for nearly 30% of all innovation firms. Interestingly, their share is the least volatile with regard to the economic crisis which somewhat supports the findings of higher sustainability of the well-established innovation-driven strategies

Figure 4. *Intensity of innovation sales: meso-level trends*

*(% of companies with the specific innovation mode in total innovation companies)*




Source: authors' estimates.

The *top-down mixed modes* approach is the logical development of the cut-off principle. It implies selecting a set of dimensions that allow accounting for the desired space of innovation heterogeneity. Resulting classes typically are constructed as mutually exclusive subsets of the values of the selected dimensions. One notable example of this type of studies is presented in (Arundel and Hollanders, 2008) and later in (OECD, 2009). These studies construct the taxonomy of the innovation modes that jointly capture input and output characteristics of the innovation performance. The predefined top-down procedure ensures repeatability of the analysis with regard to different national contexts, thus providing the opportunities of international comparisons.

In this study we explore three top-down innovation taxonomies, one describing the sophistication of innovation strategies, another capturing the information sourcing model pursued by the company and the last replicating the original output-based innovation modes described above.

Sophistication of innovation strategies in this procedure implies the availability of the expenditure on the particular innovation activities at the firm (Table 1. Sophistication of the innovation strategy). Major dimensions include availability and the localization of the R&D activities. Purchase of the machinery and equipment is considered as the simplest strategy, while the 'Cooperative R&D' mode that combines intramural and extramural activities can be thought of as the most sophisticated.

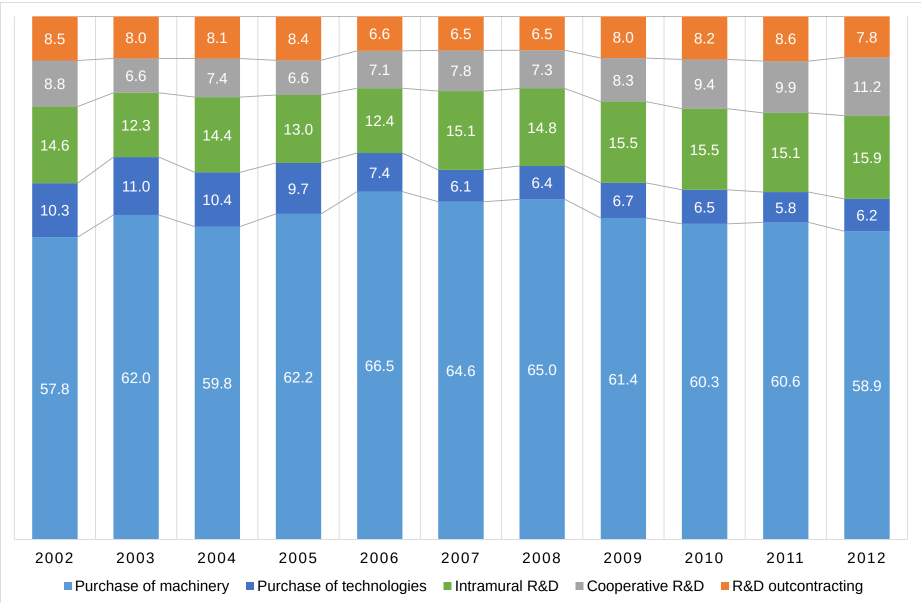
Table 1. Sophistication of the innovation strategy

| Mode | Definition |
|---|---|
| Purchase of machinery | Company's innovation expenditure consists solely of purchase of novel machinery and equipment |
| Purchase of technologies | In addition to machinery and equipment acquisition, company purchases technologies (e.g. licenses and patents) |
| Intramural R&D | Company performs R&D activities in-house. |
| Cooperative R&D | Company combines intramural and extramural R&D competences |
| R&D outcontracting | Company outsources R&D (no in-house activities) |

Figure 5 presents the meso-level trends based on this taxonomy. Most of the innovation companies (nearly 60%) follow the least sophisticated strategy of implementing innovation through the purchases of the novel machinery and equipment. Intramural R&D-based modes of innovation account for 12-16% of the whole innovation population, while the share of usual outsources of the R&D changes between 6.5 and 8.5%. The most advanced strategy of the cooperative R&D seems to be gaining popularity. In the recent years, it accounts for 9.4-11.2% of the innovation enterprises.

Figure 5. *Sophistication of the innovation strategy: meso-level trends*

*(% of companies with the specific innovation mode in total innovation companies)*




Source: authors' estimates.

Patterns of usage of the information sources represent another dimension of innovation strategy. The classification (Table 2. Sources of information for innovation) distinguishes the companies only relying on the internal sources of information, those dominated by the suppliers, market-driven and facilitated by the knowledge providers. The most sophisticated mode implies combinations of various types of information sources.

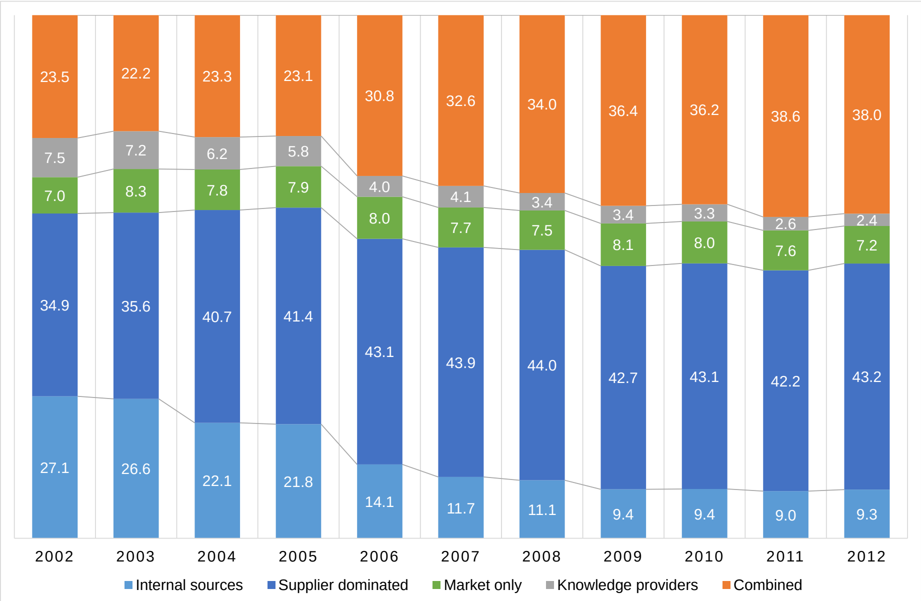
Table 2. Sources of information for innovation

| Mode | Definition |
|---|---|
| Internal sources | Only internal sources of information were marked as important |
| Supplier dominated | Among the external sources, only suppliers were recognized as highly relevant innovation driver |
| Market only | Innovation activities rely on the information collected from the market actors: clients, competitors and suppliers |
| Knowledge providers | Innovation activities rely on the information collected from universities and research organisations |
| Combined | Company combines market- and science-based sources of information |

The observed intertemporal patterns (Figure **6**) exhibit more explicit structural shifts in the distributions the innovation modes. One general tendency is the gradual decrease of isolated strategy of implementing innovation (from 27.1% of innovation companies in 2002 to 9.3% in 2012) accompanied with the dissemination of the combined networking (from 23.5% to 38%). The most popular type of behavior however remain to be the supplier-driven innovation (up to 43% of innovation firms). Interestingly, companies that solely focus on the market environment account only for 7% of total innovation firms.

Figure 6. Sources of information for innovation*: meso-level trends*

*(% of companies with the specific innovation mode in total innovation companies)*




Source: authors' estimates.

Output-based innovation modes follow the original definitions (Arundel and Hollanders, 2008; OECD, 2009) presented in Table 3. One key idea behind this taxonomy is to distinguish the strategic potential of different types of innovators that includes the degree of novelty of innovations developed, markets of operation and the capabilities for the in-house development of innovation.

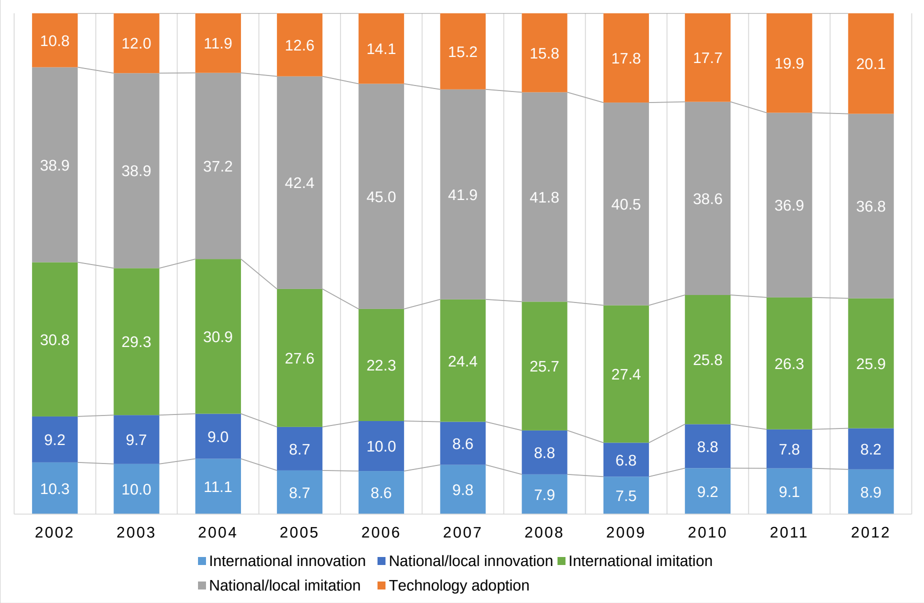
Table 3. Output-based innovation modes

| Mode | Definition |
|---|---|
| International innovators | Companies act at the international markets, engage in intra-mural innovation development activities and implement new-to-market technological innovations. |
| National/local innovators | Companies act at national/local level, engage in intra-mural innovation development activities and implement new-to-market technological innovations. |
| International imitators | Companies act at the international markets, develop innovations in-house or mostly in-house but resulting products and processes are similar to already existing ones. |
| National/local imitators | Companies at national or local markets only, develop innovations in-house or mostly in-house but resulting products and processes are similar to already existing ones. |
| Technology adopters | Innovations are developed by the means of external organizations (irrespective of resulting novelty) |

The distribution trends derived from this taxonomy express high degree of stability (Figure 7). Major part of the companies follows the least sophisticated regimes of innovation, either adopting the technologies developed by the others or focusing at the imitative activities on the local markets. Moreover, the total share of the companies executing these modes is gradually increasing (from 50% of all innovation companies in 2002, to 57% in 2012). This expansion happens by the cost of the advanced modes, and the 'international imitation' mode at most. The present share of this strategy is 26% of the total innovation enterprises. The most sophisticated core of 'innovators' remains relatively stable (around 9% for the innovation at international and national markets), showing only minor decrease.

Figure 7. Output-based innovation modes*: meso-level trends*

*(% of companies with the specific innovation mode in total innovation companies)*




Source: authors' estimates.

The *data-driven typologies* can be traced up to the influential Pavitt's taxonomy of innovation (1984). In the original approach, 2000 documented cases of the influential innovation development were carefully grouped in order to produce four base types of innovation behavior, namely – supplier-dominated, suppliers of capital goods and equipment, science-based and scale intensive strategies. This study was largely inductive, while the emergence of novel data sources made possible the large scale statistically driven analyses, such as the extended firm-level cluster analysis of innovation strategies across 18 countries (Lambert and Frenz, 2012). Resulting modes included 'intellectual property/technology innovators', 'marketing-based innovators', 'process modernizers', 'wider innovators' and 'networking innovators'. The distribution of the modes varied greatly across the countries although the authors managed to capture some stability of this allocation across two periods of observation.

We construct two *data-driven* taxonomies one exploring the patterns of the complementarity between the effects of innovation and the other – outlining the perception of key factors hampering innovation activities, both according to the companies' self-estimates. In both cases we use similar data (vectors of binary variables that express whether the particular effect is relevant for the company, or whether the specific factor is perceived as the significant obstacle to innovation) and procedure. We employ latent class analysis (Hagenaars and McCutcheon, 2002; Langseth and Nielsen, 2009; Magidson and Vermunt, 2004) in order to produce clusters of similarity. The clusters are interpreted according to the within distributions of the variables used for the classification procedure. The clustering and the interpretation had been performed for the pooled dataset while the distributions of these clusters were later traced on the yearly basis.

The classification procedure derived six major profiles of the innovation effect complementarity (Figure **8**): 'no significant results', 'modernization in line with regulation', 'new products for market demand', 'innovation for quality, flexibility and efficiency', 'product-driven expansion' and the 'synergic effects of innovation'.

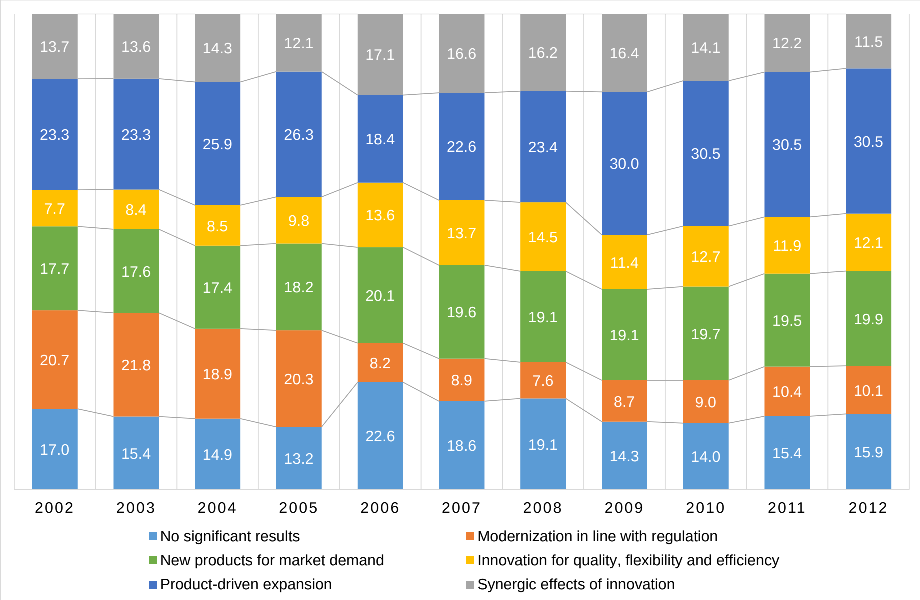
Figure 8. *Complementarity of the effects of innovation: cluster profiles*

| **Results of innovation activities** | Profiles of innovation effects | | | | | |
|---|---|---|---|---|---|---|
| | No significant results | Modernization in line with regulation | New products for market demand | Innovation for quality, flexibility and efficiency | Product-driven expansion | Synergic effects of innovation |
| Reduction of labor costs | 0.0 | 26.6 | 2.2 | 26.4 | 11.9 | 71.9 |
| Reduction of material and energy costs | 0.1 | 64.2 | 5.7 | 45.5 | 26.6 | 96.1 |
| Increase in flexibility | 0.0 | 21.8 | 19.5 | 65.3 | 59.6 | 80.5 |
| Expanding to national market | 0.0 | 5.8 | 49.0 | 4.5 | 97.7 | 91.6 |
| Expanding to international markets | 0.0 | 2.3 | 14.4 | 0.5 | 45.0 | 52.6 |
| New products | 0.2 | 6.1 | 82.8 | 72.9 | 93.3 | 93.3 |
| Increase in quality | 0.2 | 37.1 | 63.2 | 94.8 | 89.2 | 94.3 |
| Reduced pollution | 0.0 | 42.8 | 3.3 | 35.6 | 32.7 | 76.8 |
| Increase in scale | 0.1 | 40.4 | 16.5 | 60.6 | 57.7 | 86.9 |
| Compliance with standards and regulation | 0.2 | 62.2 | 38.6 | 78.0 | 75.9 | 89.7 |
| Total share of companies within the cluster (% of pooled crossection 2002-2012) | 16.4 | 13.2 | 18.9 | 11.3 | 25.9 | 14.4 |

Source: authors' estimates.

Meso-level trends constructed using this taxonomy also prove to be quite robust (Figure 9). The two advanced modes associated with massive effects of innovation, including expansion on the international market ('synergic effects' and 'product-driven expansion') account for nearly 40% of the strategies. Annually, 13-22% of companies admits that their innovation activities fail to produce significant effects. There is a declining share of firms (20% in 2002 to 10% in 2012) that relate innovation with the modernization activities targeted at fulfilling standards and regulation. Flexibility and efficiency is the conventional combination of the effects for 7-12% of enterprises. The rest (roughly 20%) of companies relate innovation to novel products possibly with the increase of quality and the consequent expansion on the markets within Russia

Figure 9. *Complementarity of the effects of innovation: meso-level trends (% of companies with the specific innovation mode in total innovation companies)*




Source: authors' estimates.

As opposed to the cases mentioned above, the taxonomy of perception of the obstacles to innovation was constructed on the whole population of the companies including the non-innovation ones (Figure **10**). The basic dimensions for the taxonomy were taken from the questionnaire section devoted to the companies' perception of obstacles to innovation. These questions were included into the questionnaire (similarly to the Eurostat's design) in the form of the closed list of factors grouped along several larger groups (e.g. external and internal factors). For each factor the companies were to define its applicability and significance for hampering the innovation processes. For this study, a set of binary variables was constructed, each indicating "1" if the factor was marked as significant (or highly significant) by the respondents. Direct frequency analysis reflects the general company-level perception of the innovation-related problems: three most commonly indicated obstacles include "Lack of available financial resources", "High economic risks", "Lack of state support". These answers appear to be ultimately popular across all types of innovation firms. At the same time, the diversity-oriented taxonomy approach allows to go further these general references of poor and contra-innovative business environment by drawing more detailed portraits of perception of the innovation system flaws.

Base types derived from the clustering exercise include: 'Total hostility of environment and the enterprise's interior', 'Deattachment from innovation networks and markets', 'Anti-innovative organisational culture, shortage of the human capital', 'Shortage of funds, higher and unleveraged risks', 'Flaws of the existing policy mechanisms/infrastructure' and the 'not relevant' option.

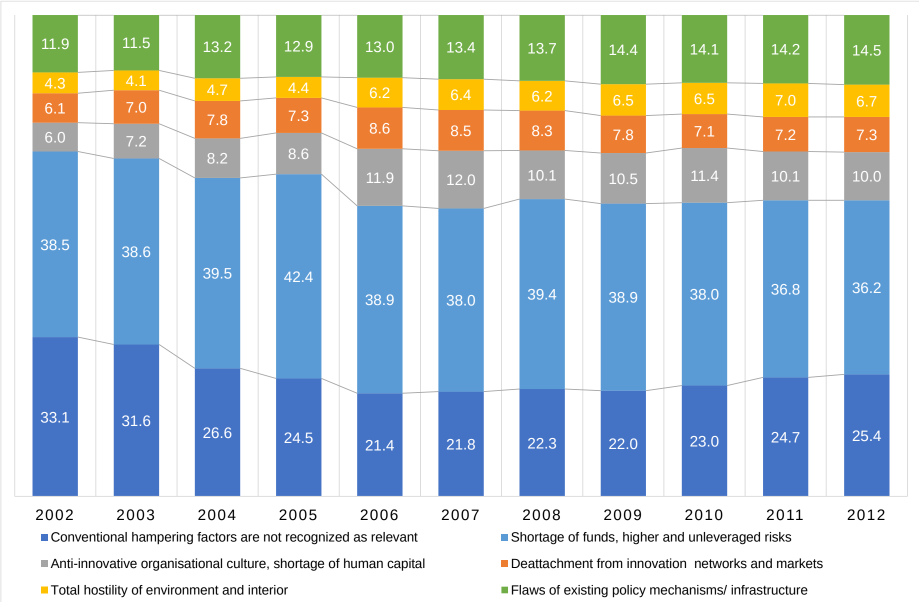
Figure 10. *Perception of the obstacles to innovation: cluster profiles*

| Factors significantly hampering innovation activities at your enterprise | | Profiles of perception of obstacles to innovation | | | | | |
|---|---|---|---|---|---|---|---|
| | | Conventional hampering factors are not recognized as relevant | Shortage of funds, higher and unleveraged risks | Anti-innovative organisational culture, shortage of human capital | Deattachment from innovation networks and markets | Total hostility of environment and interior | Flaws of existing policy mechanisms/ infrastructure |
| Economics | Lack of availble financial resources | 7.21 | 93.82 | 98.52 | 95.87 | 99.53 | 96.75 |
| | Poor demand on innovation | 1.36 | 19.09 | 26.92 | 46.13 | 68.17 | 37.96 |
| | High economic risks | 0.42 | 37.55 | 54.69 | 66.14 | 88.05 | 70.35 |
| Internal factors | Low innovation potential of the enterprise | 0.75 | 22.01 | 85.48 | 65.09 | 85.68 | 30.83 |
| | Underdeveloped cooperation linkages | 0.12 | 4.13 | 15.63 | 46.07 | 79.13 | 25.61 |
| | Lack of information on markets | 0.21 | 5.75 | 0.02 | 92.52 | 84.05 | 22.08 |
| | Lack of information on technologies | 0.13 | 7.59 | 32.64 | 68.60 | 87.08 | 21.29 |
| | Shortage of qualified personnel | 0.51 | 13.36 | 80.79 | 68.91 | 86.90 | 26.70 |
| Institutional environment | Flaws of innovation infrastructure | 0.22 | 4.38 | 20.75 | 19.95 | 93.27 | 70.17 |
| | Flaws of legislature | 0.48 | 10.35 | 18.67 | 15.24 | 91.29 | 80.30 |
| | Lack of state support | 0.07 | 49.81 | 66.47 | 59.60 | 85.52 | 68.21 |
| | Total share of companies within the cluster (% of pooled crossection 2002-2012) | 28.36 | 34.33 | 10.28 | 7.68 | 5.63 | 13.73 |

Source: authors' estimates.

Meso-level trends in this case describe the distribution of these types of perception among all the companies in the industry sector, beyond the innovation-active subsample (Figure 11). The most expressive structural shift captured within this taxonomy surprisingly concerns the decreasing share of the mode 'Conventional hampering factors are not recognized as relevant'. It dropped from the extreme 33% in 2002 to the modest 25% in 2012. The possible interpretation here is that the 'not relevant' mode appears to capture general disattachment from the conventional innovation discourse, possibly describing the companies which never seriously consider innovation activity as an option, thus, not choosing any of the widely accepted hampering factors as relevant. Nearly 7% of companies is convinced in the total innovation-related hostility of the environment and the enterprises' internal assets as well. One interesting mode of perception communicates specifically the unsatisfactory of the existing innovation policy mechanisms, broader regulatory framework or infrastructure. It accounts for 11-14% of all the industry enterprises.

Figure 11. *Perception of the obstacles to innovation: meso-level trends (% of companies with the specific mode in total companies)*




Source: authors' estimates.

The foregoing analysis of the longitudinal meso-level trends derived from the seven firm-level taxonomies has been provided novel information on the dynamical performance of the Russian NIS. The population of innovation companies is dominated by the entry-level strategies, while the sophisticated types usually comprise not more than 10% of all innovation actors. There is an evidence for the multidimensional persistency of engagement into innovation activities: not only the overall propensity to innovate appears to be relatively constant, but also the specific types and formats of this engagement are robust. All in all this evidences for the inconspicuous structural shifts in the overall systems of incentives and rent distributing mechanisms within the Russian economy during the observed period. Institutional changes of the specific sectors fail

At the same time, the system demonstrates certain signs of the learning processes. Companies' strategies move towards the intensified networking as well as overall better recognition of the innovation-related challenges and opportunities.

## 5. Conclusions

This paper has considered the potential of the firm-level innovation taxonomies to produce extended evidence on the genesis of the national innovation systems. The proposed meso-level trends allow to capture the dynamic allocation of the specific actor types, bringing together two generally accepted ways of understanding the path-dependence: the institutional change (both revolutionary and 'bounded'), perceived by the stability or evolution of the incentive systems, and the firm-level persistency of activities, hereby embodied into the specific heterogeneous modes of innovation behavior. Intertemporal distribution of the particular types of innovation behavior on the one hand reflects the arrangement of incentives within the socio-economic environment, and on the other to some extent predetermines the response on regulation and the accumulated capabilities for the development.

Applying this approach for the case of the Russian Federation demonstrated considerable robustness of the meso-level trends constructed from the firm-level classification exercises. The observed tendencies allowed expanding the knowledge base on the development of the Russian national innovation system, emphasizing (i) the absence of the radical changes in the overall system of stimuli and rewards, that reflect the overall limited efficiency of the ongoing innovation policy models, (ii) but also the processes of learning and the accumulated sophistication of the innovation strategies (specifically, increased networking).

With this regard, firm-level taxonomies prove to be the valuable instrument for both diagnostics of the processes of structural change and the diagnose-based policymaking (in line with Edquist, 2011). Observed robustness of the innovation modes in the times of relative stability makes them an appropriate components of the STI governance architecture, while the embodied functional meanings can be the source of proper objectives definition while reacting on the greater socio-economic and political shocks.

**Acknowledgements**

The financial support from the Government of the Russian Federation within the framework of the Basic Research Program at the National Research University Higher School of Economics and within the framework of implementation of the 5-100 Programme Roadmap of the National Research University Higher School of Economics is acknowledged.

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