foresight

A dynamic and adaptive scenario approach for formulating science & technology policy

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Abstract

Purpose – *Dynamic changes in the world bring challenges for making long-term future-oriented policy and strategy. A number of recent developments like drops in oil prices, increasing global conflicts, mass immigration and economic stagnation have had disruptive effects on long-term policies and strategies. The purpose of this paper is to provide a dynamic and adaptive Foresight approach as required by the fast-changing global landscape.*

Design/methodology/approach – *The scenario approach presented in the paper aims to develop multiple time horizons by bringing together short-term forecasts and long-term exploratory and visionary scenarios. Each time horizon allows for re-considering and dynamically changing drivers and assumptions of scenarios and thus builds not a single linear, but multiple and dynamic pathways into the future. Following the presentation on the background and description of the methodology, the paper illustrates the proposed approach with a case study on science and technology (S&T) development in Russia.*

Findings – *The flexible scenario approach allows developing and strategies with similar adaptability and flexibility.*

Practical implications – *The scenario approach presented in the paper may be applicable for Foresight exercises at all levels of governance, including national, international, regional and corporate.*

Originality/value – *A novel scenario approach is presented for the formulation of S&T policy with an illustrative case study.*

Keywords *Russia, Forecasting, Foresight, Scenario planning, Backcasting, Science and technology policy*

Paper type *Research paper*

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1. Introduction

Future-oriented technology analyses in the form of Foresight, futures and forecasting are all crucial for a prosperous, sustainable and resilient future. However, rapid and unprecedented changes in the world bring challenges for long-term policy and strategy-making. A number of recent developments like sharp drops in oil prices, global conflicts, mass immigration and economic stagnation have had disruptive effects on long-term policies and strategies. This new fast-changing environment requires approaches and tools, which may help to practice a "dynamic" and "adaptive" Foresight for a rapidly changing global context.

Scenario planning is a commonly used technique for future-oriented technology analysis, including Foresight, forecasting and technology roadmapping. Scenarios help decision-makers and managers in building policies and strategies by providing a set of alternative outlooks for the future under complexity and uncertainty (Miles *et al.*, 2016). They have been used extensively as part of national, regional and corporate Foresight exercises. The extensive literature on scenarios describes numerous ways of developing scenarios (Bishop *et al.*, 2007). Amer *et al.* (2013), Wodak and Neale (2015) and Borjeson *et al.* (2006)

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provide an account of the scenario method through reviews. The others describe processes for scenario development in strategic management, for instance through expert procedures (Konno *et al.*, 2014). There is also work on suggesting new approaches for scenario planning with the use of new methods as well as by integrating existing methods for the purpose of scenario planning. Saritas and Aylen (2010) combine two frequently used methods, scenario planning and roadmapping in their study. Tourki *et al.* (2013) suggest using a meta-analysis approach for scenario planning. Stelzer *et al.* (2015) describe the use of bibliometrics in scenario planning. Other research concentrates on the applications of scenarios, for example planning for ecosystem development (Chang, 2015). There are also a number of applications for specific industries (Alizadeh *et al.*, 2016).

The present paper suggests a new methodological approach for "dynamic" and "adaptive" scenario planning. The dynamic and adaptive approach utilizes multiple time horizons by bringing together short-term forecasts and long-term exploratory and visionary outlooks. Each time horizon allows for re-considering and dynamically changing drivers and assumptions of scenarios and thus builds not a single linear, but multiple and dynamic pathways into the future. The flexible scenario approach allows developing strategies with similar adaptability and flexibility. The process combines qualitative and quantitative methods for scenario development. The originality of the work lies in the selection and combination of those methods and their use for planning science and technology (S&T) priorities, policies and strategies by considering long-, medium- and short-term developments; generating plausible pathways of future development and transformations; and benchmarking them and the strategies slated for adoption.

The methodology developed considers future scenarios with multiple time horizons. Scenarios for each time horizon are constructed considering the differences in terms of the level of change and uncertainty involved (Bos and Teulings, 2013). Scenarios developed for different time horizons are used in a complementary way to portray transformation pathways from the present to the future. In this respect, long-term scenarios allow exploring alternative futures under conditions of high uncertainty and complexity. Within this period, major transformations can be seen in Society, Technology, Economy, Environment, Policy and Values/Culture (STEEPV). Developments in such a distant future, say beyond 10 years, are hard to predict and therefore cannot always be quantified. Major trends and developments, such as demographics, can be used as guidelines to provide a framework for alternative scenarios. The relationships between STEEPV systems are captured within scenarios with plausible and internally consistent narratives. A cross-impact analysis may help in the exploration of cross-linkages between different system elements.

The short term typically covers the next 5 to 10 years, where uncertainty is relatively low compared to the longer term. Therefore, this term represents a more forecastable future. The medium term is the meeting point of the long- and short-term scenarios. This will mark the milestone for transformation from the predictable futures into transformative futures. Medium-term scenarios will be obtained through "backcasting" (Dortland *et al.*, 2014) from the long term-scenarios as well as "forecasting" from the short-term scenarios.

Another important feature of the proposed scenario process is the distinction between the "external" and "internal" conditions. External conditions refer to the framework factors, which create the context for scenarios. There is usually no or limited power to influence changes in the external conditions. Meanwhile, the internal conditions refer to the responses toward the external conditions in the form of policies and strategies. The combination of multiple time horizons and external and internal conditions allows for exploring multiple policy and strategy options for responding to fast-changing conditions. Policies can be represented as a portfolio of real options (Vilkkumaa *et al.*, 2015). Hence, scenarios with embedded real options could reflect policy decisions along evolving trends and changing factors. In this case, the process scenario planning becomes closely linked to decision-making analysis (Ram *et al.*, 2011). The proposed methodology allows switching between policies across to reflect the presence of strategic options, in other words, real options. The real option analysis has become a very popular approach that accounts for managerial flexibility in the time since Myers introduced it back in 1977 (Myers, 1977). Research mostly concentrates on application of real options for the evaluation of projects (Pendharkar, 2010) or portfolios of projects (Huchzermeier and Loch, 2001). Within the context of the proposed scenario methodology, the real option method is used to identify and benchmark policy and strategy responses. It is assumed that the real option approach may allow policymakers to adapt to changing external and internal factors as well as reach desired objectives (Dortland *et al.*, 2014). The proposed process is applicable for Foresight exercises at all levels of governance, including national, international, regional and corporate.

Thus, the second section of the chapter begins with a further elaboration of the scenario approach proposed in the present work. Following the presentation of the conceptual framework, the main steps for the implementation are presented. The methodology is then demonstrated in the third section with a case study on S&T development in Russia. First, key socioeconomic trends for Russia are analyzed and then these scenarios are developed following the key methodological steps. The paper is concluded in the fourth section.

2. Methodology

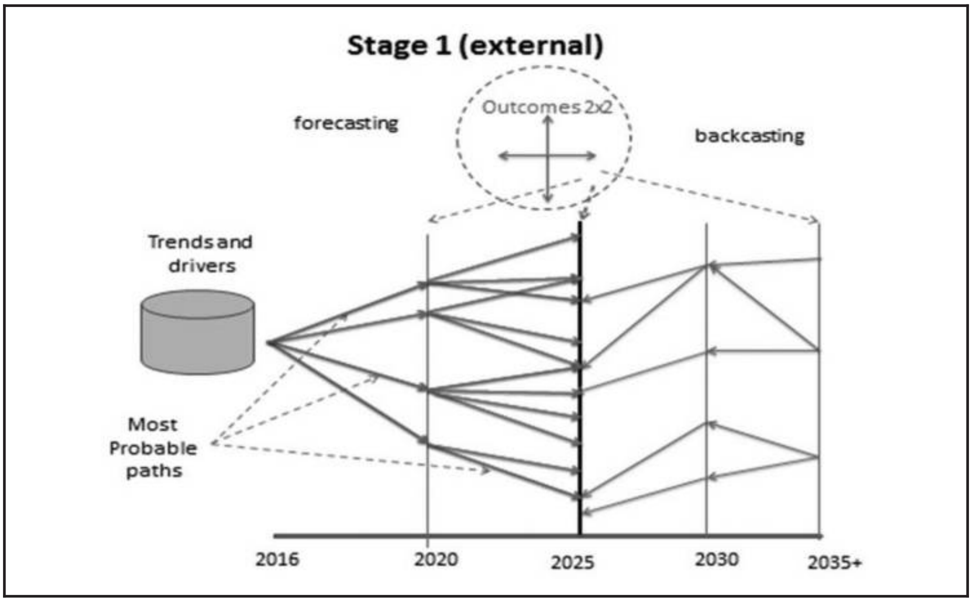
The proposed scenario approach has two key assumptions as its main pillars:

1. *Assumption 1*: When planning scenarios, short- and long-term time horizons should be dealt with differently, as there are considerable differences regarding the level of uncertainty and amount/magnitude of transformations to take place. In the short run, developments are more predictable; for instance, economic and technological changes are more foreseeable. In the long run, major socioeconomic and cultural developments are expected to play a transformative role leading to new paradigms, hence uncertainty is higher. The scenario development process involves a combination of exploratory and normative approaches. Short- to medium-term scenarios are developed based on forecasts under lesser uncertainty. Scenarios toward the long term are considerably more explorative, given the fact that uncertainty is higher. The normative approach is used to build pathways for eventual scenarios, which will eventually help to formulate policy options. How this is done is explained below.
2. *Assumption 2*: When planning scenarios, external and internal conditions should be distinguished. External conditions are generated by factors, which are beyond control or there is a limited scope for influencing them. Internal conditions are the ones which are relatively under control and can be used proactively to change, or as a response to changing external conditions. These include structural elements like internal, processes, procedures, equipment and technologies as well as behavioral elements like culture, politics, skills, motivation, power and management (Saritas *et al.*, 2007). Thus, scenario-building and decision/policy-making are integrated with each other in the process.

Based on these two assumptions, the proposed scenario planning process consists of two stages. The first stage involves the construction of the external conditions across the short and long terms. Then, the second stage is concerned with the development of the internal conditions and description of the pathways of transformation from the present into the future. Figure 1 illustrates the first stage of the scenario work.

The figure illustrates a short-term time horizon (by 2025) and a long-term time horizon (by 2035). In the present example, 2025 is considered the medium-term meeting of the two. Thus, it brings together short-term forecasts and long-term scenarios, which are carried back through backcasting across time. An event tree is built by the alignment of short-term and long-term scenarios with each other in the medium term. These create several plausible evolutionary pathways from the present

Figure 1 Stage 1 of the scenario development process



into the future. To increase the sensitivity of the time horizons, both the short and long terms are divided into two further sub-horizons of five years.

Stage 2 of the process is concerned with policy analysis for each period (Figure 2).

In this stage, the event tree built for the external conditions is used for the planning of evolvement of internal conditions and the determination of scenario pathways. Then, alternative policy responses are formulated considering the internal conditions and outcomes. Generated policy responses are analyzed and benchmarked through the real option analysis method.

Figure 3 illustrates key steps of the methodology in each stage. Each step of the methodology is described next.

2.1 Construction of external contextual scenarios (Stage 1)

The process begins with a focus on the short to medium term.

2.1.1 Identify global trends in the medium term (Step 1.1). External conditions in the medium term evolve according to global trends. A STEEPV framework can be used to explore the trends in

Figure 2 Stage 2 of the scenario development process

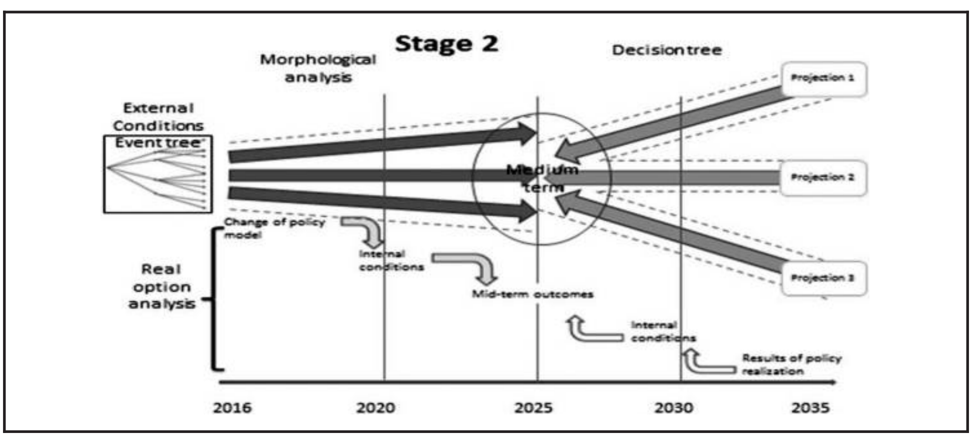
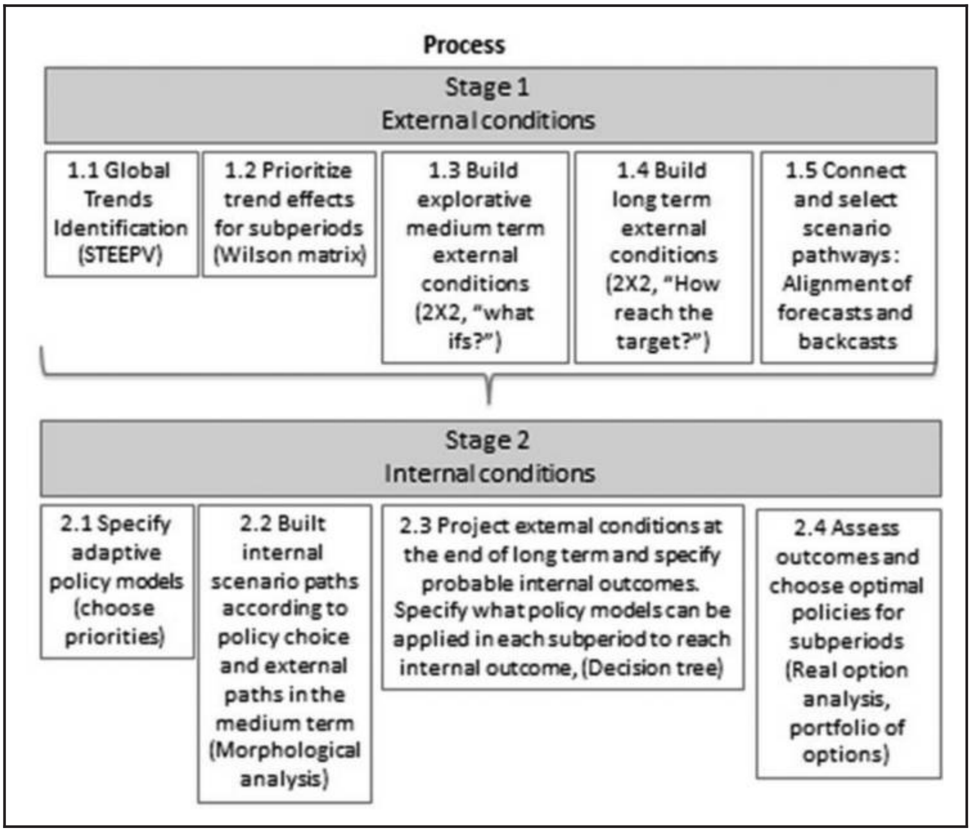


Figure 3 Key steps of the methodology



respective systems. Qualitative methods such as reviews, interviews and workshops, as well as semi-quantitative and quantitative methods like Delphi, bibliometric or sematic analysis, can be used for identifying and monitoring trends (Saritas and Burmaoglu, 2015). Academic publications, news and blogs and reports by international and other acclaimed parties can be used as information sources for analyzing trends (Ena *et al.*, 2016; Bakhtin *et al.*, 2017).

2.1.2 Describe and prioritize different possible impacts of identified trends (Step 1.2). In this step, the expected development directions of trends are described with qualitative and, where available, quantitative values. This input will be used to develop predictions for the developments in STEEPV systems. Key factors which may potentially shape the short- to medium-term future will be assessed at this stage. A cross-impact analysis can be used to explore possible systemic relationships between the trends, and hence helps to produce scenario narratives.

Within this period, it is expected that social and environmental trends will be more stable compared to economic and technological trends, where faster developments and changes are witnessed. Therefore, scenarios will consider the most important trends to create alternatives, and policy responses will be formulated accordingly. Furthermore, discovered key effects can be different depending on the purpose of the study. For instance, in a technology market-oriented study, socioeconomic and technological trends can be further narrowed to important technology-push and market-pull effects. If a technology trend has a greater impact on key socioeconomic trends in the short to medium run, then a technology-push effect can be mentioned. The demand-side impacts on technology can be considered within market-pull effects.

2.1.3 Build external forecasts for the mid-term (Step 1.3). This step is concerned with the construction of mid-term scenarios. A typical 2 × 2 matrix can be used for building scenarios at this stage (Ramírez and Wilkinson, 2014). Despite some drawbacks of the 2 ×

2 method (Varho and Tapio, 2013), the framework allows portraying and mapping four alternative scenario trajectories for the future. The axes of the scenarios will be based on the most important developments in the short to medium term. To identify the key axes, a prioritization scheme may be introduced into the process. Forecasting models, expert workshops and/or other more structured prioritization tools can be used. Two key factors with the potential for the most diverse outcomes will be chosen to form the axes for scenarios. Because of the shorter time range, the scenarios at this stage can be based on forecasts of more predictable developments, and therefore, their variety will be relatively lower compared to longer-term scenarios with higher uncertainty, and stronger wild-card effects. Most likely and relevant scenarios from the set can be selected for analysis.

As illustrated in Figure 1 earlier, the short to medium term, which is considered to be up to 10 years, can be further divided into two sub-periods of five years. The scenario process based on forecasting could be first done for the first period, and can be repeated for the second sub-period toward the medium term. As an approach, scenarios for the second sub-period can be developed by using a similar 2 × 2 approach. In this case, each of the first initial four scenarios can be further forecasted for the next period. The result is an event tree with a growing number of variations from the short to the medium term, as shown in Figure 1. Among these pathways, the most plausible, relevant and/or distinct ones can be selected for further elaboration. This completes the forecasting part of the proposed scenario process.

2.1.4 Build external exploratory scenarios for the long term (Step 1.4). Following the construction of the scenario pathways through forecasting of short- to medium-term developments, the next step deals with the medium to long term. Focusing on the longer term, this period entails a higher level of uncertainty and complexity, which cannot be simply predicted (Loveridge and Saritas, 2012). The key characteristic of the scenarios developed at this stage is their exploratory nature. Longer-term trends and uncertainties are considered to be within the context of broader STEEPV systems. Major transformations can be expected during this period. A 2 × 2 scenario framework may be suitable at this stage as well. Following the analysis of the trends, the most uncertain and critical ones can be used to constitute key scenario axes, and scenarios can be formulated accordingly. After the construction of the scenarios, a “backcasting” approach can be used to describe transformational pathways leading to the emergence of long-term scenarios from the medium term.

2.1.5 Connect and select scenario pathways: alignment of forecasts and backcasts (Step 1.5). Following the completion of the “forecasts” from the short to medium term and “backcasts” from the long to medium term, the purpose of this stage is to “align” forecasts and backcasts and build plausible pathways from the present into the long-term future. Scenarios, forecasts and backcasts may be fine-tuned as necessary to increase the plausibility of the pathways.

With this step, the first stage of the process, which described the external/contextual/framework conditions, is completed. The second stage will be concerned with the development of “responses” in the form of policies and strategies. Among all the pathways, several of them can be selected by considering those that are the most plausible, probable, possible and/or preferable. Ideally, three or four diverse and distinguishable pathways can be considered for formulating policy responses.

2.2 Construction of internal response scenarios (Stage 2)

Policy responses to changes and developments can also be various. These will depend on the external as well as internal conditions. Therefore, the second stage will begin investigating policy conditions, and then internal conditions will be generated accordingly. The steps of the second stage are described below. In terms of chronological order, the process follows the steps in Stage 1.

2.2.1 Formulate policy instruments and responses (Step 2.1). As underlined by Schubert *et al.* (2015), policy models are affected by feasibility as well as a broad range of social issues. Those models reflect policy responses to scenarios (Inayatullah, 2008). The present study suggests three possible policy models:

1. steady state and conservative protectionism (conservative);
2. continued growth within existing frameworks (modernization); and
3. transformative and breakthrough development (breakthrough).

Policy models can be also considered as strategies (Capello *et al.*, 2015). They can be reconsidered by policymakers after every sub-period. The choice of model depends on the projected external and current internal conditions. Policy responses for each period and sub-period might be different, for instance steady at one stage, and transformative when the right point of time comes with enough resources (skills, time, money, etc.). This gives a more flexible, sensitive and customized approach across time.

The next two steps are concerned with the construction of the internal conditions through policy models. Internal conditions for one sub-period will depend on previous internal conditions, external conditions, policy model implementation and its success. The execution of policy models at each node of the external conditions event tree form the internal conditions for the next stage. The decision on the shift between policy models will be determined by external and internal conditions at the end of each period. Hence, several alternative development paths will be provided to form internal conditions.

2.2.2 Build internal conditions based on "what if?" policy responses (Step 2.2). This step starts from the present and moves toward the mid-term. Initial internal conditions are already given at the present stage. Therefore, the process begins with the development of policy models for the first sub-period (i.e. 2016-2020) under the given external conditions toward 2020 ("what if?" policy responses). Next, internal conditions for 2020 are set up. Then, policy models are developed considering the external conditions for 2025. Following which, internal conditions for 2025 are generated.

2.2.3 Build internal conditions through "where to?" policy models (Step 2.3). At this step, the process starts from the long term and comes back to the medium term. For this purpose, the analogue of the real option approach can be introduced into the process. Looking at the target internal conditions, policy options for the latest sub-period can be determined. Thus, first, the internal conditions for 2035 are considered within the context of the external conditions at the same period. Then, the backcasting approach is used to consider what sequence of policy models in 2030 may have led to the internal conditions in 2035 ("where to?" policy responses). Based on the external conditions and backcasted policy responses, internal conditions for 2030 are specified. A similar process will be repeated to backcast policy responses for 2025, and understand internal conditions in the same period. As the process moves back to the mid-term, the use of options will allow switching between policies in line with the changing external and internal conditions in each sub-period.

2.2.4 Build and assess scenario paths and policy options (Step 2.4). The outputs from Step 2.2 and Step 2.3 are aligned with each other in the medium term. Here, the paths that correspond to conditions, which were obtained for the end of the medium term, are considered. This way scenario paths for the medium term into the long term can be constructed. Again, out of all possible paths of internal conditions, the most probable ones with diverse outcomes can be selected for analysis. The process is repeated for each of the scenario pathways, and then pathways for internal conditions and policy models leading to them are designed. There is no one single policy model for a set of dynamically changing external and internal conditions. Therefore, switches between policy models can be considered, which will become real options for policymakers at each stage of future development. If a policy model is considered as a portfolio of real options, then the switch between policy models becomes an option. To enhance the precision of scenarios and policy pathways, they can be explained in qualitative and quantitative terms. The involvement of quantitative data may make the optimization procedure more complicated, but it will certainly provide a more evidence-based input for informative decision-making.

Following the presentation of the methodology with its key stages, the next section aims to demonstrate the basic outline and key points of the methodology with a case study on S&T development in Russia. The case will not aim at providing a full-fledged analysis, but will present an outline of the proposed approach.

3. The case of Russia

Before immediately embarking upon the scenario planning process, first, it is important to understand the current S&T landscape in Russia. This will be explained briefly for the purpose of providing a context for the scenarios as the first step of the proposed methodology.

3.1 External conditions (Stage 1)

3.1.1 Global trends affecting Russian S&T development in the medium term (Step 1.1). Regarding overall contextual trends and challenges, various internal and external drivers can be considered, which shape Russian S&T. Among them, the following ones can be highlighted:

- Russia relies mainly on an oil- and gas-based economy with low industrial diversification, and thus few globally competitive areas, such as the energy, defense and space sectors.
- The country is not completely integrated into the global economic system owing to its different standards and regulations.
- Russia exports human capital and research outputs while importing technologies and high-tech products, which increases the technological dependence on developed countries.
- Russia’s S&T development is mostly financed by the government sector, while the business sector has no or low motivation for investing in S&T development.
- Recently, Russia’s development has faced several setbacks owing to economic and political factors such as the drops in oil prices, political and economic sanctions and partial isolation from financial markets.

Several other broader trends can be mentioned, which are likely to affect Russian S&T development. On the social side, demographic trends like aging population, growth of international migration and urbanization are expected to play a role. The effects of these trends are expected to be limited in the short to medium term owing to the predictability of demographic figures in Russia. However, in the long run, this trend may be an important one, as it has the potential to affect human capital for economic and S&T development in the country.

Developments on the S&T side provide additional opportunities and threats for Russia. The country has relative competitive advantages in the defense and nuclear energy technologies. However, the emergence and adoption of technologies and concepts like industry 4.0 and renewables as well as other energy storage and battery technologies may create barriers for Russia to catch up with S&T advancements.

Transformation into a new technology-enabled economic system will bring additional challenges for Russia. The country’s conventional energy-based economy is the main source of Gross Domestic Expenditure on Research and Development (GERD). Therefore, the price of oil and gas will have a major impact for S&T development in Russia, at least in the shorter term, until the economic system is diversified in the long run. Another traditionally important aspect related to the global economy and energy system is the environment. However, in the short to medium term, no environmental constraints are expected to occur in Russia. The country currently has sufficient water and land as well as other natural resources in place.

3.1.2 Possible impacts of trends (Step 1.2). In this phase, the scenario planning process begins with the short term, i.e. starting from 2016 to 2020. During this term, several political, economic and technological trends will affect Russian S&T development spending. One of the main drivers of development of the overall economy, and S&T in particular, in the current to near term, appears to be oil supply and demand. Budget constrains after collapsing oil prices bring challenges for development.

According to the International Energy Outlook 2016 (IEO2016)[1], worldwide consumption of petroleum and other liquid fuels will increase from 90 million barrels per day (b/d) in 2012 to 100 million b/d in 2020 and 121 million b/d in 2040 mainly owing to the growing demand from emerging economies. The uncertainties result in big differences in price projections of IEO2016 even for the short period. Contradictions among OPEC (Organization of Petroleum Exporting Countries) members and increasing supply from the USA will most likely keep oil prices at low levels. A shift toward changing role of oil and gas in global energy supply balance will also be crucial. By the end of this period, whether demand for conventional energy sources will pick up at all or conventionals will be gradually replaced as energy sources will be clearer. The increasing supply of oil and reduced oil prices combined with economic sanctions affect government spending on R&D (as the major part of total R&D investments) as well as innovation activities of the industry, including major Russian oil and gas companies. The oil industry in Russia has just gone through a major modernization and the production volume has been increasing since. Consequently, in the near future, a reduction in exports combined with high oil prices is very unlikely.

A possible global systemic crisis during this period will not affect Russia only through oil prices. Major Russian companies are not very active borrowers on foreign financial markets, and a large part of foreign capital has already left the country owing to sanctions and the economic slowdown. The dollar value of exports has dropped significantly after low oil prices. Further decreases are arguable after the Ruble's depreciation.

The structural improvements in Russian S&T development can also be affected by other external trends, such as the developments in industry and technology. For instance, the aircraft and space research programs, which account for a large percentage of Russian R&D spending, face challenges owing to new technologies developed in the USA and Europe as well as growing competition from China and India. The new industrial revolution may spread into Russia, at least through the adoption of technologies even under difficult economic conditions. Well-educated IT specialists in Russia may lead to a shift toward the development of Information and Communication Technologies (ICTs) in areas like Big Data Analysis, Artificial Intelligence (AI) and the Industrial Internet of Things. This trend may continue toward the 2020s and beyond, and may be supported mostly by the domestic demand.

On the other hand, advancements in S&T may be hindered by new challenges and threats like cybersecurity issues, environmental concerns and more strict regulations. Depending on the speed of global S&T development progress and shifts in its structural components, Russia will need to choose to develop its own technologies or will rely on imports and fast adaptation of required technologies – or a suitable mix of the two options depending on needs and technological competence. Whatever option is to be opted for, it is clear that in the short run, oil prices and the speed of transformations in the global S&T ecosystem will be among the key determinants of Russian S&T development.

3.1.3 External forecasts for the medium term (Step 1.3). Two main drivers of change for the Russian R&D system, namely, oil prices and global S&T development, will be used to build scenarios for the medium term. Four scenarios based on the extremes of the two drivers can be represented in a 2×2 matrix, as illustrated in Table I. Each scenario will be described briefly below.

Table I	Scenario matrix for 2020	
Drivers	*Gradual Global S&T Development*	*Major Shifts in Global S&T Development*
Higher oil prices	Scenario 2020.1	Scenario 2020.4
Low oil prices	Scenario 2020.2	Scenario 2020.3

The 2020.1 scenario for 2016-2020 may happen in the case of easing conflict in the Middle East and if an agreement between OPEC and non-OPEC regarding oil production is reached. At the same time, a large number of shale oil producers in the USA could face financial difficulties as the cost of capital for them becomes very high, especially if there are rising interest rates. Iran will increase production slowly because of the lack of investments. Despite rising tensions, Europe will continue to rely mainly on Russian gas. Rising demand from China will also be observed. This scenario considers rather slow progress with the global S&T development owing to regulatory pressures. For instance, cyber-security concerns for the growing use of the internet and ICTs, as well as ethical considerations for the use of genome-related technologies, may become restrictive factors for major advancements.

Scenario 2020.2 suggests a slow S&T development owing to similar concerns observed in the previous scenario. However, in this case, the tensions between OPEC remain, with geopolitical issues forcing Iran to rapidly increase its oil production as well as the US shale oil companies quickly recovering and significantly decreasing the cost of oil production using government support.

The third scenario, 2020.3, suggests gradual escalation of political tensions, which may result in technological cooperation and a breakthrough all over the world during 2016-2020. High technology-based and cleaner industrial growth will cause drops in carbon fuel demand.

Fast S&T development along with higher oil prices scenario (2020.4) is considered to be a wild card given that advances in transportation, manufacturing and other energy-dependent sectors would result in the replacement of oil in global value chains by more environmentally friendly and sustainable sources of energy.

During 2021-2025, no significant changes are expected in the scenario factors for the 2016-2020 period, but their effects on the Russian S&T development can be different. From 2021 to 2025, it is expected that policies toward emissions will be among the main factors shaping demand for oil and affecting prices. This is also supported by the International Energy Agency scenarios in the World Energy Outlook[2]. Besides that, S&T advancements will be still playing the key role for socioeconomic prosperity.

Thus, two key external factors for Russian S&T development in 2021-2025 will be shaped by hydrocarbon policies and scientific and technological developments. Accordingly, the scenario matrix is shown in Table II.

In Scenario 2025.1, scientific and technological breakthroughs will be more frequent and widespread all over the world, which will require new strategies for research and innovation (Amanatidou *et al.*, 2016). Rapid developments in S&T will require the quick adoption of new key and enabler technologies for Russia such as ICTs, additive manufacturing and bio- and nanotechnologies. Advanced petrochemical products may become widely used as materials in the new industrial revolution. This scenario could be implemented if the policies for reducing greenhouse gas emissions remain the same (to support economic

Table II	Scenario matrix for 2025	
Drivers	*Gradual Global S&T Development*	*Major Shifts in Global S&T*
Current policies for carbon emissions	Scenario 2025.2	Scenario 2025.1
New policies for carbon emissions	Scenario 2025.4	Scenario 2025.3

growth) with the low popularity of electric cars, while more efficient gasoline or diesel engines for transportation and manufacturing are developed.

In Scenario 2025.2, the energy balance will remain mostly unchanged. Developed countries will still mostly rely on traditional gasoline and diesel cars. Electric mobility technologies will develop gradually and remain a niche area during this period. A significant increase in demand for oil and petroleum products may be observed. The rise in demand may be supported by high growth rates in developing countries. Oil will be used for traditional fuel production in industry as well as gasoline for growing car penetration in those regions. Current policies for carbon emissions will still be in place, without much progress. Ecological standards will be adopted rather slowly, particularly by the developing countries. However, a technology breakthrough is not expected with economic development mainly relying on conventional technologies.

Scenario 2025.3 offers a transformed world. New carbon emission policies are implemented in parallel with growing demand for renewable sources of energy and increasing environmental and quality of life expectations both in developed and developing countries. These trends provide greater effects with a global consensus and widespread policy adoption. The intensity of regional conflicts and related sanctions are expected to decrease with the greater manifestation of this trend. Alternative energy sources will be given more weight owing to growing considerations for resource independence, ecological sustainability and increasing energy efficiency. A possible S&T breakthrough in life sciences, for example, where Russia is currently lagging, may be another area, which can quickly affect the S&T development agenda and priorities for the country.

Scenario 2025.4 can be considered to have a very limited impact owing to the fact that only marginal progress can be made with the adoption of new carbon policies without significant progress in S&T. Therefore, it is less likely, and is not a particularly desirable scenario.

3.1.4 Exploratory scenarios for long term (Step 1.4). Following the development of short- to medium-term predictions, this stage represents the exploratory aspect of the study. In this more uncertain and complex period, economic growth and S&T development will still be expected to play a major role. They are expected to be more closely connected with each other.

In the long run, among the key drivers of change considered are capital, labor, S&T and economic growth. Relationships between these key factors will shape the global (external) context in the long term, such as the role of human capital in S&T development (Moriarty and Honnery, 2014) as well as the effects of demographic and societal shifts on economic growth (Choi and Shin, 2015). Current trends indicate that S&T developments are likely to hollow out the global middle class. The concentration of the labor force is moving toward the low and high ends of the employment spectrum (Saritas, 2015). This imbalance may generate a number of consequences, including increasing unemployment, and, thus, a growing social burden owing to an aging population. Therefore, two important drivers for the long term are the human–machine balance in socioeconomic value generation and overall advancements in S&T. Considering the extremes of each drivers, the scenario matrix can be constructed as illustrated in Table III. This generates four distinct scenarios for 2035 (and beyond), which will constitute diverse contexts for future developments in Russia.

Scenario 2035.1 assumes that the human capital continues to be a major asset in economy and its cost increases significantly compared to the financial capital. New industrial revolution will come true, but the roles of machines and AI are more supportive than mainstream with data analysis, decision support and assistance in manufacturing. Humans will remain highly qualified and well-paid decision-makers. In this world, the consumption growth rate will significantly increase. Hence, inflation pressure may remain high for a long time. Large global projects such as space exploration or earth transformation may be started as well. This world will require more closely linked and cooperating countries with borders eliminated. The level of urbanization may decrease, as the wealthy population may be spread over rural areas

Table III Scenario matrix for 2035

Drivers	*Gradual Global S&T Development*	*Rapid global S&T development*
Human-driven	Scenario 2035.2	Scenario 2035.1
AI/Machine-driven	Scenario 2035.4	Scenario 2035.3

especially in the case of growing communication and transport connectivity with the extensive use of distant working in a digital era. The development of life science increases the span and capacity of human life. Decreasing birthrates will maintain a more stable, healthy and relatively more wealthy global population. Efficient policies and regulations taking account of major risks may impose restrictions such as the ones on the environment, but not to the extent of creating barriers for S&T developments. They can rather aim to create cleaner environments for human communities while adopting advanced S&T.

Scenario 2035.2 suggests a rather negative picture. It highlights imbalances in the economies of developed countries and rising anti-globalism that will slow the growth rate of S&T development. Manual labor will continue to be dominating production, particularly in the economies of the developing countries. Therefore, productivity growth will be very slow and incremental. Offering more of a business-as-usual case, this scenario considers that growing social inequalities will lead to regional instabilities, terrorism and global security concerns. Thus, the emergence of new blocks and a multi-polar world is very likely. Costs for social care and the burden of diseases are expected to grow.

Scenario 2035.3 may be considered as the age of smart machines with a growing role of AI. The S&T development rate is very high owing to the increasing role of smart and connected machines. People are replaced by robots in many sectors, both high- and medium-skilled ones, in highly intellectual and sometimes complicated tasks like basic software development, financial service provision, all kinds of transportation and even some research activities. The unemployment rate will rise significantly. In parallel, it is expected that income inequality will also rise. This may cause a reverse immigration pattern across the world. On the positive side, high levels of economic growth are achieved owing to jumps in productivity. Economic growth allows for supporting the social system of most countries and even helps to decrease the level of poverty. The costs of basic healthcare will drop but advanced treatment will be available only for high-income individuals. Consumption will remain at a low level, as will the inflation rate. The globalization trend will still be very important. The level of urbanization may fall because the jobless but socially supported population will tend to live in a less-costly environment.

In this case example, Scenario 2035.4 is omitted owing to the fact that smart machines and AI substituting human and labor is most likely with rapid developments in the S&T landscape.

3.1.5 Connecting scenario pathways (Step 1.5). When an overall assessment of the scenarios is made, it can be seen that there are four different pathways (the scenarios are numbered to reflect the pathways). For the present case, the pathways are named as follows:

1. Preferable pathway, which shows some improvements compared to the present state of development including Scenarios 2020.1, 2025.1 and 2035.1.
2. Business-as-usual (BaU) pathway, which considers the continuation of the present developments or slight changes across time, including Scenarios 2020.2, 2025.2 and 2035.2.
3. Transformative pathway, which offers dramatic changes and shifts from the present state, including Scenarios 2020.3, 2025.3 and 2035.3.
4. Unexpected pathway, which brings together less probable developments as an alternative outlook, including Scenarios 2020.4, 2025.4 and 2035.4.

Each scenario pathway explains a specific context for the internal conditions, which are elaborated in the next stage of the proposed methodology.

3.2 Internal conditions (Stage 2)

In the Law of Strategic Planning for the Russian Federation[3], three areas are identified as critical for the development of Russian S&T. These are:

1. macroeconomic conditions, with effects on R&D and innovation expenditures;
2. structural factors related to key areas of S&T development; and
3. institutional factors related to R&D organizations and support institutions, which will be mostly determined by internal policy shifts.

Among the three macroeconomic conditions are those which are mainly determined by the external conditions. Responses will vary according to the external scenarios described above. Regarding structural and institutional transformations, the level of control at the domestic level is higher and internal policy instruments can be considered for them. The paper will continue discussing how the structural and institutional factors combined with macro conditions suggested by external scenarios may bring different policy responses on the agenda.

3.2.1 Policy instruments (Step 2.1). In the description of methodology, three policy models were suggested, including:

1. steady state and conservative protectionism (conservative);
2. continued growth within existing frameworks (modernization); and
3. transformative and breakthrough development (technological breakthrough).

How structural and institutional factors can be considered under each of these policy models is summarized below.

1. Conservative model
   - Structural characteristics:
     - preserve traditional priorities of S&T development, support as many of them as possible;
     - S&T development focuses on domestic market and national security in the general sense; and
     - import substitution of crucial technologies for national security and the development of some export-oriented sectors of economy.
   - Institutional characteristics:
     - slow modernization of S&T infrastructure;
     - increase in efficiency of current S&T institutions and programs;
     - development of standards for technologies for the domestic market; and
     - depending on available resources, government support is provided at each stage of innovation: from S&T development to technology commercialization.
2. Modernization model:
   - Structural characteristics:
     - technology development for niches in global value chains; and
     - focus on sectors with rapid commercialization opportunities such as ICT.
   - Institutional characteristics:
     - liberalization of the S&T regulations and open market;

- government support for building infrastructure for international cooperation;
- adjustment of infrastructure, standards and business processes in key economic sectors to international standards and requirements;
- import of technologies accompanied by foreign direct investment, providing necessary favorable conditions; and
- increasing cooperation with foreign companies, organizations and scientific centers on all stages of innovation and S&T development.

3. Technological breakthrough model
   - Structural characteristics:
     - support for the development of new technologies for globally competitive high-tech production with high added value; and
     - development of "risky" technologies in the areas such as bioscience, AI and fintech (and standards for them), that are currently not supported in other countries but could be adopted in the future.
   - Institutional characteristics:
     - stimulating large companies to enter new global markets using competitive advantages and government support of hi-tech exports;
     - invitation of leading researchers and experts from abroad (including incentivizing the return of Russian-born scientists) for technology development localization and creation of new research platforms;
     - stimulation of international patent activity including appropriate intellectual property regulation;
     - preferences for domestically invented technologies;
     - international cooperation at the early stages of S&T development; and
     - support of development institutions and venture funds – investors in early staged STI.

The success of the aforementioned policy models will depend on the availability of funds, speed of reforms and opportunities and barriers for entering new markets. Similar to the scenario pathways, switching between policy models is also possible through a process of transformation across time, which may take effect during the described sub-periods. This is where the proposed methodology becomes more sensitive to changes and transformations across time with a focus on multiple time horizons and pathways with dynamic drivers of change and policy responses.

The next section will combine external scenario pathways and policy instruments, and will build short- and long-term responses within the discussed periods.

3.2.2 Short-term responses (Step 2.2)

3.2.2.1 Period 2016-2020. Current external and internal conditions in Russia leave only one choice, which is the conservative policy model. The growing budget deficit prevents the adoption of a "technological breakthrough" policy, and severe sanctions contradict the modernization policy toward an open market. The conservative policy model forces Russia to mainly remain a commodity source in global value chains. Government-controlled companies will be key consumers of innovative products. Technological exports will remain concentrated in the aerospace and defense sectors, while most of the planned projects will be implemented. Trends toward digitalization and growing demand for the ICTs will positively affect younger populations in Africa, the Middle East and developing Asia. However, in Russia, the population is relatively conservative and aging. With poor domestic infrastructure and rigorous regulations in Russia, the development of ICTs will mostly follow a “catching up strategy” and will not pave way toward a leadership in S&T development in this and many related areas.

Higher oil prices and gradual S&T development may create a preferable case for Russia in this period. However, this will prolong the adoption of a conservative policy model after 2020, and may postpone the steps taken toward a more modernized and S&T-based socioeconomic system. The failure of the conservative policy during this period in terms of structural and institutional reforms may lead to a loss of competitiveness even in the defense sector, extended project realization times, difficulties in imported technology substitution and continued dependence on external technologies, the massive loss of researchers and nearly frozen S&T development in Russia for several years. Causes of the failure could be either external (i.e. systemic crisis) or internal (i.e. ineffective decisions) or both. The probability of failure will be higher in the case of low oil prices and will be very likely in the case of rapid global technological development.

3.2.2.2 Period 2021-2025. Unlike the short term with the most probable adoption of the conservative model, Russia may have a choice of all three policy models in the 2021-2025 period. The decision on the model will depend on external conditions and outcomes of the previous period.

Technological breakthrough will unlikely follow a protectionist policy but may still be realized in the case of Scenario 2025.2 of strong demand for petrochemical products and high growth rate of developed countries which provide financial resources for Russian S&T development. Russia will quickly catch up with the technologies of the developed world. However, the country will of course face strong competition of human capital from China and some other developed countries. Losing this competition may lead to a failure in this risky policy model. The slowing growth rate in developing countries increases the chance of policy failure for Russia as well.

The 2025.2 scenario for the period of 2021-2025 may be used by Russia as an opportunity for occupying a moderate place in global value chains. This is, of course, impossible without easing sanctions and an open market policy. Russia may become a leader in the production of advanced materials or a major IT service provider applying the less-risky modernization model. Russia can also provide transportation services for the rest of the world.

The 2025.3 scenario may leave Russia the choice of a conservative model. Russia will keep the role of commodity producer for the rest of the world and concentrate on the domestic market but will be able to catch up with several important rapidly developing technologies. In this case, Russia will move to produce basic materials, which are more advanced than raw materials. Thus, the reliance on the export of raw materials will be lower and products with more added value will help diversify economic output as well as exports.

3.2.3 Long-term responses (Step 2.3). S&T development in Russia in the long run will be discussed in this section. Several visions can be formulated regarding country’s role with respect to the aforementioned future external conditions. In the 2035.1 scenario, Russia will be integrated in the global S&T development. This requires a strong international cooperation and rapid catching up in key S&T areas. The realization of a technological breakthrough in the 2025-2030 period allows for taking a leading role say in major space or life science projects. This will require a modernization model starting from 2020 till 2025; i.e., if Russia is to be one of the leaders in advanced materials by 2025, a breakthrough in the coming years becomes much more plausible.

In the 2035.2 scenario, Russia has little chance to sustain the modernization policy for a long time. The conservative model is much more likely in this case for the long term. Favorable conditions and a successful breakthrough in the medium term may allow Russia to make another jump in S&T and increase its role as a leading aero-defense producer in the world.

The technological breakthrough for Russia in the 2035.3 scenario will be difficult to attain. Russia must implement a modernization model as early as possible. If the country is unable to find a growing niche in S&T development, it will remain a resource provider with an insignificant and very dependent role in global value chains. This is the most negative scenario for the development of S&T in Russia.

3.2.4 Assessment of scenario pathways and policy options (Step 2.4). The optimal choice of policy model across scenario pathways at each time interval allows for building internal policy trajectories. In this case, the policy model can be considered as a portfolio of real options under budget constraints for S&T development. The execution of each option will require financing one or a set of specific S&T projects. The decision about option implementation can be made after an optimization procedure as described by Dortland. For example, if Russia wants to achieve an economic growth of 1 per cent higher than the growth of the world economy in 2030-2035, it might require an additional GERD of 1 per cent of GDP every year starting from 2025. If the external scenarios in 2030-2035 are favorable, this goal may be achieved. However, in the case of a negative scenario, Russia will lag behind, despite major R&D investments.

4. Conclusions

Most of the scenario approaches provided thus far have fixed trends, drivers and assumptions for the time horizon they look into, such as next 10, 20 or 30 years. However, there is the fact that change is dynamic, and may occur at any time across the way, and may invalidate the key assumptions of the planned scenarios. For instance, a number of Foresight and scenario works have missed the recent dramatic drop in global oil prices. The key premise of the proposed approach lies in the fact that it brings together long-term exploratory and visionary scenarios with short-term forecasts, and builds plausible pathways into the future. Besides developing linear pathways, the value of the methodology lies in the fact that it considers shifts from one pathway to another over time considering the disruptions in the way trends and developments unfold. Several milestones across different timeframes combine short-term predictable forecasts and longer-term exploratory futures. The construction of a scenario tree helps to describe several probable, plausible and preferable pathways, which might be either a specific pathway (in the case study described above, these were named as BaU, Preferable, Transformative or Unexpected), or a combination of them (e.g. BaU in first period with a shift to Preferable or Transformative in the next period, or any other combinations).

Similar to dynamic and adaptive scenarios, the proposed methodology allows for building policy pathways, which may be aligned with the scenarios. The strategies and actions are considered for each scenario pathway through the assessment of options across time. If the economic effects of S&T developments can be analyzed (Dranev and Chulok, 2015), then an optimal choice of preferable pathway can be determined. Further qualitative analysis may be used to provide a foundation for quantitative research and the determination of favorable policies for S&T development. For instance, the choice of appropriate S&T projects for implementation can be determined through expert procedures. The proposed approach may be applicable for Foresight exercises at all levels of governance, including national, international, regional and corporate. The advantage of this approach is that it can be used for the qualitative assessment of adequate policy making decisions for each period. The introduced methodology does not provide an explicit policy choice but rather supports an informative decision-making. To enhance the precision of scenarios and policy pathways, they can be explained both in qualitative and quantitative terms. The involvement of quantitative data may make the optimization procedure more complicated, but may also provide a convenient input for informative decision-making. As a point of caution, it should be mentioned that failures may still be expected at the policy implementation stage due to different factors in external and internal conditions, such as social and cultural issues (Wijck and Niemeijer, 2016) or other factors like wild cards. Failing to implement any policies, or inaction, may end in a collapsing scenario trajectory, which should also be counted in the process.

The paper described a case on the development of S&T policies and strategies in Russia for an illustration of the proposed methodology. The reliance on mainly qualitative data and methods is a limitation of the case presented in this study. Future work will benefit from more elaborated cases to illustrate all features of the proposed dynamic and adaptive scenario planning methodology with the use of quantitative as well as qualitative data. A demonstration of how shifts occur between scenario trajectories with the combination of qualitative and quantitative tools is planned in a more elaborated case-based study.

Notes

1. www.eia.gov/outlooks/ieo/liquid_fuels.cfm
2. www.iea.org/publications/scenariosandprojections/
3. http://economy.gov.ru/minec/activity/sections/strategicPlanning/regulation/20151113

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