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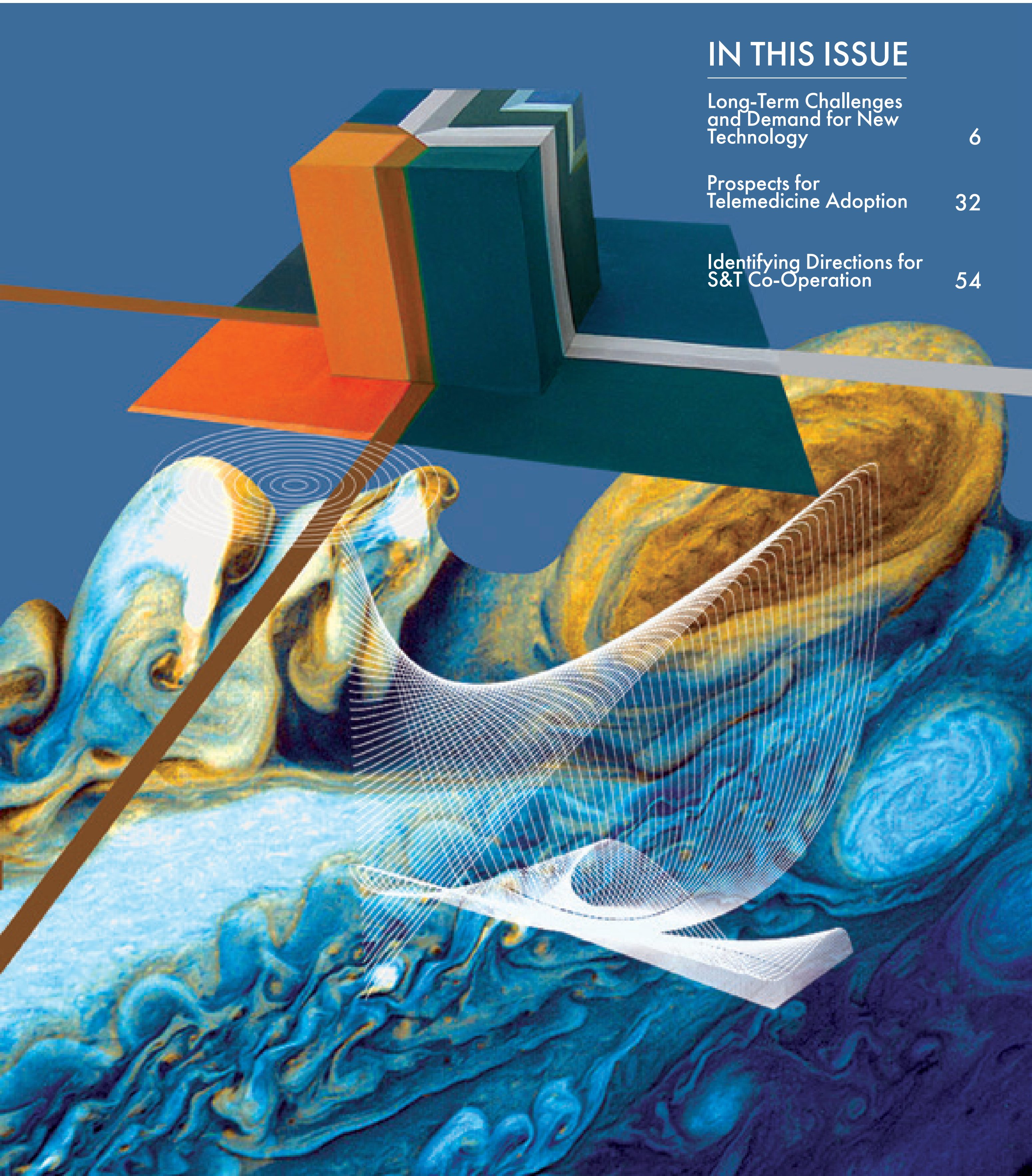

## IN THIS ISSUE

# Foresight and STI Governance

National Research University
**Higher School of Economics**

Institute for Statistical Studies
and Economics of Knowledge





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**Foresight and STI Governance (formerly Foresight-Russia) — a research journal established by the National Research University Higher School of Economics (HSE) and administered by the HSE Institute for Statistical Studies and Economics of Knowledge (ISSEK), located in Moscow, Russia. The mission of the journal is to support the creation of Foresight culture through dissemination of the best national and international practices of future-oriented innovation development. It also provides a framework for discussing S&T trends and policies.**

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## References

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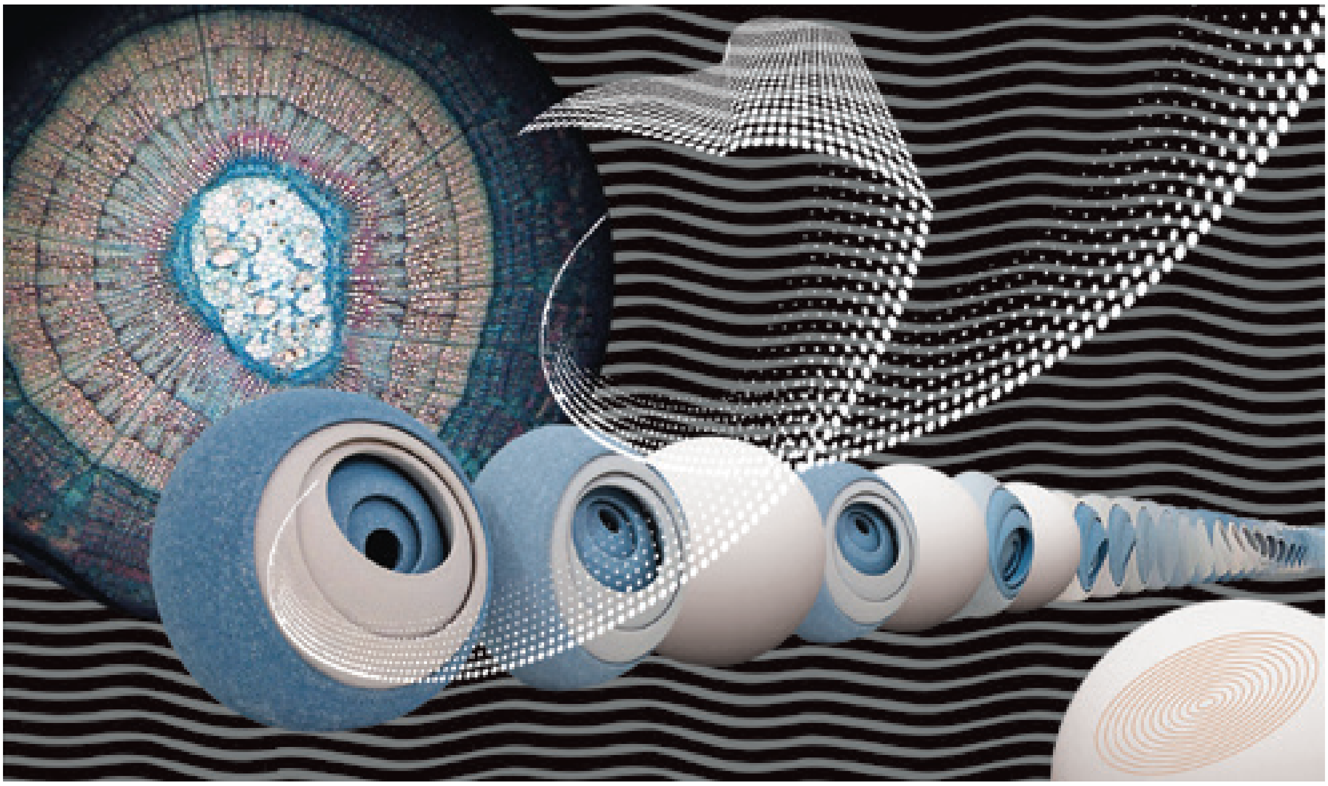
**Vol. 9 No 4 2015**

# Long-term Socioeconomic Challenges for Russia and Demand for New Technology

Alexander Apokin[I], Dmitry Belousov[II], Vladimir Salnikov[III], Igor Frolov[IV]



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## Abstract

**The primary long-term socio-economic challenges facing Russia – both global and country-specific in nature — drive demand for a range of technologies. We explore several groups of challenges, namely urbanization, demographic, socio-economic, the consequences of ageing, geopolitical, restricted access to key technological competences, climate change and its ecological consequences, as well as technological challenges largely associated with risks in ICT and biotech development, and the emergence of so-called 'killer technologies' that induce structural transformation in the economy.**

**We identify four groups of key factors influencing demand for new technology. First, those factors that strengthening Russia's role as a provider of key natural resources for the global economy. Second, of equal importance are those factors that support import substitution of various products of the global market, including electronic components, chemicals, and food products. Third, developing centres of technological competences plays a significant role, especially in export-oriented, manufacturing, and services sectors. These include nuclear energy, software, weapons and military equipment, military aircraft, and energy machinery. Finally, technological advancement would occur by integrating Russia within global technological value chains with external system integrators in pharmaceuticals, machine-building, petroleum products, and some ICT sub-sectors.**

**Keywords:** long-term socioeconomic challenges; demand for technology; technological development; S&T policy

DOI: 10.17323/1995-459X.2015.4.6.17

**Citation:** Apokin A., Belousov D., Salnikov V., Frolov I. (2015) Long-term Socioeconomic Challenges for Russia and Demand for New Technology. *Foresight and STI Governance*, vol. 9, no 4, pp. 6–17. DOI: 10.17323/1995-459x.2015.4.6.17

Defining the factors that shape demand for technological innovations is the most important aspect of developing a long-term socio-economic development strategy on any level or scale. To solve this problem recent research proposes a variety of instruments [*Granger*, 1980; *Molnar*, 2010] involving textual analysis [*Gokhberg et al.*, 2014] and expert surveys as part of the Foresight studies [*Landeta*, 2007; *Popper*, 2008]. The methodology used for this research paper has been described in detail in *Belousov et al.* [2012]. We consider technological development as the primary solution to the long-term challenges facing Russian socio-economic development. Therefore, when analyzing demand for innovation, it is important to define the nature of specific challenges by projecting global dynamics onto the domestic situation. We have opted for the most topical and widespread groups of challenges in academic writing: demographic, urbanization, geopolitical, climate and technological. Comparing these with the development conditions of the domestic economy will allow us to identify industry challenges and opportunities.

Long-term socio-economic development challenges are in many ways shaped by the global context, i.e. global trends. However, a number of specific features of the current state of the Russian economy play no small role in determining Russia's course. Among others, the work [*Gokhberg et al.*, 2014] is devoted to an in-depth analysis of the characteristics of global-level factors. Based on the results of this study and other research, we will carry out our own evaluation of some of the most important trends, risks to global development, and opportunities for Russia. It will analyze the industry-specific features of technological challenges.

The methodology used was developed as part of the preparation and update of the coordinated long-term socio-economic and science and technology (S&T) development forecast for Russia [*Abramova et al.*, 2013; *Gokhberg*, 2014]. This was carried out by the Centre for Macro-economic Analysis and Short-term Forecasting (CMASF) in collaboration with the Institute for Statistical Studies and the Economics of Knowledge (ISSEK) at NRU HSE.

## Main global challenges to long-term socio-economic development

Russia's socio-economic development challenges are directly dependent on long-term global trends, where such global trends are largely unaffected by the state of the domestic economy. In the period up to 2030, we can expect the following global socio-economic and S&T challenges to persist:

- waning population growth;
- intensification of international conflicts;
- worsening environmental and climate problems, which would also be linked to the supply of resources for growth;
- new risks connected to technological development, primarily linked to bio- and information and communication technologies (ICT).

### Waning population growth

A key factor in the growth of developing countries over the coming decades will be the second demographic transition, accompanied by a fall in mortality resulting from modernized health care, improved nourishment and better public health conditions. In these societies, the persistently high (albeit gradually falling) birth rate is combined with rapidly decreasing mortality, especially among babies and children. As the birth rate drops as a result of urbanization, the spread of consumer culture and other modernizing tendencies, the demographic situation in developing countries will start to approach that of developed countries, characterized by low, near-zero population growth [UN, 2012]. It goes without saying that this is a projected trend, one which we can hardly expect to take root fully before the middle of this century.

An important, although not decisive in terms of its effects, global demographic factor might be the renunciation of the 'one family, one child' policy in China with the possible transition to a policy directed towards stimulating growth in the birth rate. At the same time, the next wave of the country's industrialization, in particular its urbanization, will likely bring about a fall in the birth rate to less than two children per woman of reproductive age.

The continued waning population growth will give rise to two groups of effects. The first group of effects are reflected in the majority of forecasts (for example, in the World Population Prospects forecasts published by the UN [UN, 2012]) that include the urbanization process, an ageing population, and the continual and possible increase in migration processes.

In less developed countries, urbanization goes hand in hand with the process of industrialization and, more widely, the modernization of society and economy. Urbanization processes will intensify further primarily in states undergoing industrialization (China and others), where a group of post-industrial global centers (such as Shanghai) emerge as modern technological and financial metropolises alongside growth in traditional industrial cities.

Ageing populations is a steady trend for developed countries and a comparatively new one for developing countries. While the population of developing countries continues to be relatively young (due to high mortality and a current gradual decline in mortality), in future their age structure will become comparable with that in developed countries.

Migration trends are characterized by a degree of uncertainty in the long-term. Today, migration trends are largely supported by the demographic imbalance between developed (labor-deficient and wealthy with ageing population) and developing (labor-abundant and poor with young population) nations. Technological changes in the labor market, especially in terms of automation, can significantly alter the situation. It would seem that the challenges brought about by this trend have the greatest long-term impact.

The less obvious effects of the second group resulting from migration from developing to developed countries relate to the growing importance of technologies intended to address the deficient nature of pension systems and poor access to 'long-term money' for the elderly; spread of new forms of education, transition to 'urbanist' consumption; and the spill-over of social, international, and interfaith conflicts.

The development of technologies intended for the elderly is primarily attributable to the spread of specific illnesses that require long-term treatment among this age group. According to data from [*Alemayehu, Warner*, 2004], roughly half of all expenditure on medicine by US residents are incurred after the age of 65, and roughly one third after the age of 85. This includes biomedicine, ICT and transport for the elderly and disabled, and on the educational, financial and other infrastructure geared towards them [*Peine et al.*, 2015]. Current policy in the field mentioned above significantly undervalues the market outlook of global ageing and the inevitable transition to a socio-material constitution of later life.

Growth in the elderly population creates shortcomings in pension, and more broadly, financial systems, making it harder to access 'long-term money'.[1] The shift in the balance between the proportion of employed and those incapable of work in the economy will lead to a reduction in savings rates in developing countries (e.g. in the Pacific Rim, Russia, and a number of Arab states). This shift occurs irrespective of effective pension system in these countries or the dependence of essential support services for the elderly on voluntary savings and intergeneration transfers. In turn, this wreaks havoc on the ability of such economies to finance deficits (and therefore overconsumption) in developed countries. Another possible effect is a general tension in the venture funding market for high-risk innovation projects.

The falling demand for unqualified labor globally is leading to guaranteed economic competitiveness, not through a demographic or emigrational inflow, but rather through the continuous modernization of existing human capital. This increases the importance of lifelong learning and technology-oriented education in general. Simultaneously, in developing countries we are seeing a transition to 'urbanist' consumption with demand for high-quality food products (in particular, for beef in China and in Arab states), environmentally-friendly produce (predominantly in the West) and for clean water[2]. The electrification of consumption alongside the overall trend of increasing energy efficiency is contributing to intensive growth in the consumption of electricity and a fall in demand for hydrocarbon energy sources, especially oil products.[3]

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[1] On average, in OECD countries [OECD, 2013a] the work force retires from the labor market when it reaches the official pension age. In Asian countries (South Korea, Japan, etc.) people actually take their pension 5–10 years after the legal age, and in Latin American countries (Mexico, Chile, etc.) — 3-5 years after. Cultural and regional idiosyncrasies in developing countries with regard to retirement tend to prevail over economic factors.

[2] This poses a challenge for a large number of Russian industries, especially agriculture, as the lag in water management technologies is reaching a critical level. Of course, in many developing countries, in particular in China, the problem of water pollution is even less favorable.

[3] Rapid development is expected in non-hydrocarbon (electrical) energy technologies (nuclear, solar, wind, etc.). We can expect to see intensive research and development (R&D) in thermonuclear energy, which is likely to be rolled out commercially after 2030.

### Intensifying international conflict

This trend can be caused by new centers of economic, and consequently, technological strength coming into direct competition with one another, combined with a crisis in existing international institutions that follow a monocentric model. The growing migration from developing countries in recent decades is already leading to the spillover of social, international, and interfaith conflicts into developed countries.

This trend, and not simply its military and political aspect, is discussed extensively in the literature [National Intelligence Council, 2013]. The financial and economic side of the problem, also defined as global imbalances, causes structural risks in relationships between developed debtor countries and developing creditor countries [*Mendoza et al.*, 2009]. Despite the fact that the last five years have halted successfully the intensification of these imbalances, the disparity continues to have an impact on the global economy. An explanation for this phenomenon has not yet been offered in the academic literature.

### Realization of environmental and climate problems, including linked to the supply of resources for growth

A general trend in recent years has been the growing demand for environmentally friendly products as well as an environment shaped partially by progress in urbanization on a global scale. As a result, there is the intensifying specialization of regions globally, including in identifying land for global environmental/resource reserves and, partly, the excessive environmental load in a number of developing countries, including in the Pacific Rim. The deficit of a number of vitally important resources such as clean drinking water and fertile land is increasing amid ground water pollution, soil erosion, and landscape degradation, which have all been significant factors behind the deteriorating quality of life in China and other developing countries.

By the early 2030s, the question of adapting to long-term and very long-term processes, including climate change, will be firmly rooted on the global political and technological agenda. Among other things this means global warming[4] irrespective of the causes (man-made or long-term natural factors), and changes in the power, water salinity, temperature and other characteristics of major oceanic flows (El Niño, the Gulfstream), similar atmosphere processes, and rising ocean levels.

One trend that is observable clearly and is linked directly to those outlined above is the rising prices for natural resources, especially hydrocarbons, uranium, and certain types of metal. Although there is no physical shortage of some of these resources, the extraction methods are growing increasingly complicated and expensive, in particular for shale gas, oil sands, and hard-to-extract heavy, viscous oils dispersed through metal deposits. The technological landscape of the next decade [*Gokhberg et al.*, 2014] suggests that price formation in the energy market will be dependent on the following situation. We will either witness a consistent increase in prices for conventional hydrocarbons, or an intensive transition to new forms of energy capable of significantly cutting down oil prices in the market (at least in the second half of the forecast period).

## Risks connected with technological development

Technological development gives rise to a separate group of risks, especially the rapid obsolescence of existing technology and the increasing complexity of new solutions and platforms. At the same time, these risks open up opportunities in niche areas, which can supplement existing technologies.

### The exponential development of information and communication technologies as a 'super factor'; the information society, economy, and science

Long-term and intensive development in ICT is attributable to the accumulated inertia of technological development and large-scale investment in this field. The unique feature of ICT is its total penetration into all areas of social life, including

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[4] 'Current climate change in Russia should on the whole be characterized as persistent warming at a rate exceeding the rate of global warming by more than two and a half times. According to observation data, the average rate of warming on the Earth's surface was 0.17°C/10 years for 1976-2012, while in Russia it is warming at a rate of 0.43°C/10 years. The most rapid warming is seen in the northern latitudes. 2013 was very warm: sixth among the warmest years since instrumental observations began in 1886. The average temperature for the year in Russia was 1.52°C above 1961-1990 norms, while the average global temperature for 2013 only exceeded the norm by 0.50°C. However, the trend of slowing warming, witnessed globally since the start of the 21st century, has not yet been detected on Russian territory' [HydroMetCentre Russia, 2014].

the production of goods and services, which results in an uneven impact on developing and developed economies. While developing economies have the chance to gradually strengthen their position on the global technological map, which includes developing the production of electronic components, software, and content, developed economies face the prospect of reindustrializing and maintaining their technological leadership through personalization and customization of goods and services, including traditional manufacturing [OECD, 2013b].

Alongside the general characteristics of ICT noted above, a clear trend in this sphere is the growing role of the software component in the added value of end products. The bulk of the profit is now generated not by the manufacturers of components and hardware (processors, electronics, etc.), but by owners of the intellectual property which shapes the unique properties of the finished article. This fundamentally changes the structure of the ICT market, which would shape its dynamics in the medium-term until the emergence of radically new processor manufacturing technologies [WEF, INSEAD, 2014].

This field is characterized by a high risk of 'failure' of an ordinary surge in development with the revolutionary and extremely intensive; while the evolutionary trajectory is as a result of insufficient investment or the existence of fundamental technical or scientific problems (quantum effects, etc.). Such a reduction in growth results from reduced R&D in energy. Some of this research, linked to making use of quantum effects, is dependent on the development dynamics of new ICT, while at other times research serves as a prerequisite for opportunities to arise such as in the case of adaptive power grids. Moreover, a slowdown in the development of a number of closely related technological fields is inevitable:

- biomedicines, where studies, in particular genomics and proteomics, use cutting-edge ICT;
- new materials — nanotechnologies, composites, biocompatible polymers;
- new energy — nuclear and thermonuclear synthesis, adaptive energy systems, nanophotonics, etc.

A failure in the development of new ICT drastically increases the likelihood of a general cooling of S&T development [Ernst & Young, 2014].

### Biomedical technologies as the core of the new technological lifestyle

The technological base of the new mode of life will, according to forecasts, form over the next 15 years right up to the 2030s, which will witness the rise of biomedicine as a key and promising area of economic development. Developments in genetic diagnostics and therapy, artificial organs and tissues, treatment biosynthesis, and cell therapy hold great potential during this phase. Cross-disciplinary fields such as bioinformatics and new areas of bioengineering will give a new impulse to development [DHHS, 2014].

One of the most important medico-technological fields in scientific research is pharmacogenetics, which is the study of the relationship between disease, genes, proteins, and pharmaceutical drugs. A new area has in fact arisen in medicine: the development of targeted treatments based on genome mapping results [DHHS, 2013].

In the main, the risks associated with technological development give rise to the following long-term effects and trends:

- saving resources — energy, water, certain types of metals — this trend will peak by 2030, by accelerating efforts to reduce the man-made load on our natural environment and developing closed production cycle technologies; more importance will be paid to establishing and adhering to environmental standards — these will become an important factor allowing access to markets, primarily in developed countries;
- increasing price volatility for natural resources as a result of simultaneous growth in the cost of extraction and tighter regulations regarding the efficiency of energy technologies used;
- the growing intensity of existing and new migration flows, caused by the exhaustion of natural resources / deterioration of the environmental situation; the spread of conflicts over resources in developing countries (for access to water, fertile soil, etc.)

## Key challenges facing the long-term development of the Russian economy

The long-term challenges and risks for the Russian economy and society can be broken down into several groups, which only partly reflect global trends. In the period up to 2010, we can expect challenges to emerge or intensify in such socio-economic areas as:

- demography;
- secondary urbanization;
- ecology: risks of ecosystem deterioration;
- supply of resources: growth in the cost of extracting minerals amid stabilizing global hydrocarbon prices;
- technological development: 'closing' technologies and new de facto standards;
- social stability: new conflicts and intensifying inequality;
- geopolitics: conflict and access to key technological expertise.

### Demographic challenges

Like other industrially developed countries, Russia is facing the problem of an ageing population and the end of the second demographic transition. Birth rates came close to less than two children per woman of reproductive age while mortality among the working population (including non-medical reasons such as work or transport-related trauma, violent causes, etc.) also dropped. The contribution of these factors to the increase in life expectancy maybe traced to progress in medicine. As a result, the number and share of elderly people among the Russian population is steadily growing. Thus, by 2030 the level of demographic burden (the number of elderly citizens per 1,000 citizens capable of work) will grow from the current 400 to 510 (Figure 1).

The demographic dynamics described give rise to the following economic and financial risks:

- a reduction in budgetary stability as a result of the increase in pension liabilities, demographic burden ratio, and health care spending;
- an imbalance in the financial system when savings rates fall and the pension and social budgetary burden rises due to changes in the demographic burden ratio;
- social tension caused by a mass influx of migrants amid a shortage in labor resources: growing conflict within and between different ethno-social groups, growing state spending on rehabilitation of migrants, etc.;
- conservation of excess labor intensity in certain sectors of the economy (residential construction, trade, etc.), resulting in lowered standards in comparison to developed economies.

### Challenges of secondary urbanization

The post-industrial stage of economic and social development is characterized by the concentration of the population in megalopolises, especially in so-called global cities (such as Moscow and St. Petersburg in Russia) in a close network. This type of agglomeration allows for a higher standard of living and offers fundamentally different opportunities for self-fulfillment in areas of human capital development, choice of career path, lifestyle, etc., when compared with average-sized cities.

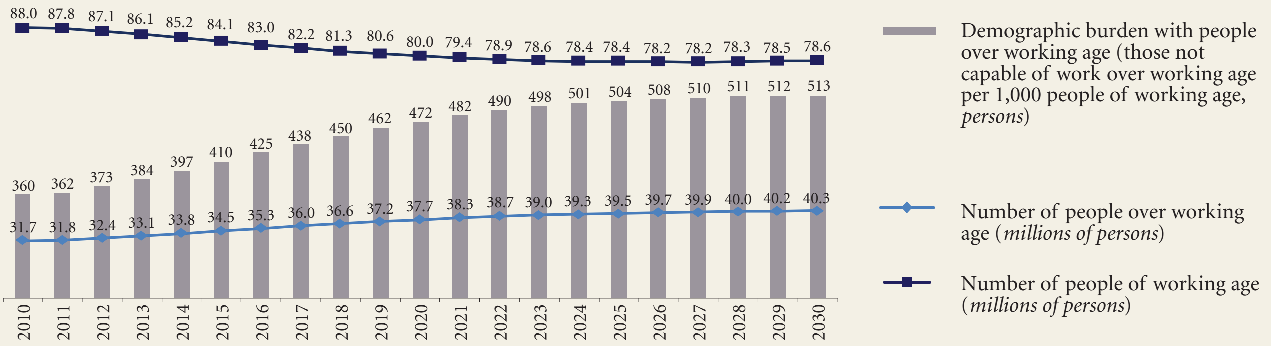
The risks of secondary urbanization are linked to the degradation of human capital in average-sized cities and the emergence of 'backwardness zones' as a result of the outflow of qualified specialists. A more direct structural economic risk lies in the fact that the crisis in average-sized cities could bring about substantial losses for a number of traditional industries located in them — car manufacturers, for example.

### Risks of deterioration of the natural environment

Russian territory has suffered significant pollution from industrial waste and transport emissions, especially in old industrial regions and areas of metal or chemical production. According to data from Rosgidromet, the Russian Hydrometeorology and Environmental Monitoring Agency, in 123 Russian cities, in which 52% of the urban population reside, the level of air pollution is classified as high or very high. These cities are primarily old industrial cities with older technology of manufacturing which is harmful to the environment (e.g. in Yekaterinburg, Volgograd, Arkhangelsk, or Ufa). A lot of the present day's mass production cause environmental pollution, which is characteristic of regions with high concentrations of industrial capacity (e.g. Norilsk, Magnitogorsk, Cherepovets, Kyzyl, Kurgan, Nizhny Tagil, Chita, and Salekhard).

In view of the growing public demand for a decent quality of life, intense pollution of the environment could become an additional factor contributing to

Fig. 1. **Demographic burden dynamics in Russia**




*Source*: compiled by the authors based on Rosstat demographic forecast data, average variant. Available at: http://www.gks.ru/free_doc/new_site/population/demo/progn1.htm, accessed 25.01.2015.

the outflow of population from industrial regions. As a result of deteriorating environmental conditions, especially in the Pacific Rim countries and, perhaps, Central Asia, Russia faces the threat of uncontrolled immigration.

### Resource challenges: growth in production costs and the stabilization of global hydrocarbon prices

As new tight mineral extraction regions open up and the industry re-orients itself towards new forms of hydrocarbons, the cost of extraction in Russia will steadily rise. Oil and gas production in Russia is already one of the most expensive in the world and is showing further signs of cost pressures (Figures 2, 3).

Combined with the highly likely stabilization of dollar prices for hydrocarbons because of technological re-equipment of production companies, growth in the cost of extracting Russian oil and gas will pose a high risk of crisis in the industry, caused by a shortage of financial resources among the major players. In any event, we should not expect a surplus of funds in future. In contrast to the mid-1990s, the sector has once again started to meet the growing demand for financial resources thanks to other industries.

This in turn poses macroeconomic risks of losing budgetary stability and disruption of the balance of payments, as they are highly dependent on commodity exports. At the same time, the inflow of direct foreign investment, loans, and lending is also determined to a degree by the state of the oil and gas markets. The limited opportunities to manage and redistribute oil and gas revenue are fraught with systemic crises for the domestic economy.

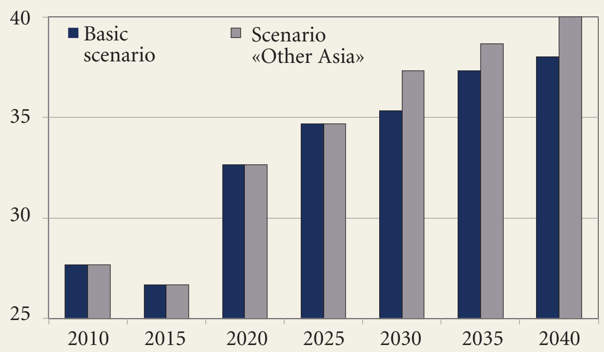
### Technological challenges: 'closing' technologies and new de facto standards

Current technologies have the potential to radically change the industry structure of the Russian economy either by fully liquidating ('closing down') certain markets or creating barriers to Russian products penetrating into developed countries, i.e. replacing it with low-profit and/or high-risk emerging markets. Five areas of technological development can be identified which have the potential to bring about significant risks in certain sectors (industries): ICT, personalized medicine, technologies allowing bespoke production of mass-market products, new energy, automated vehicles, and armaments. A more detailed typology of these technologies and the associated risks is given in Table 1.

The greatest risks from this perspective come from the following technological areas:

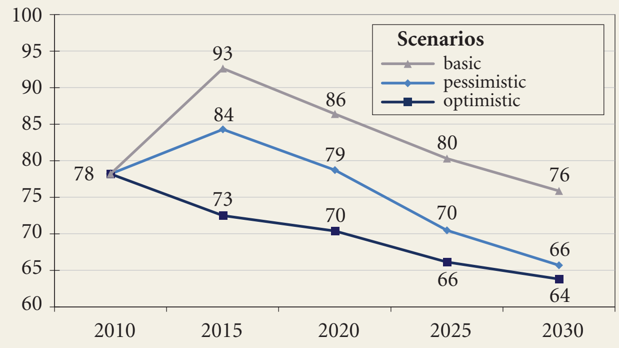
- ICT (including modern electronic components, the transition to new principles in physics, etc.), including their combination with cognitive technologies, which involves ousting 'traditional', and therefore obsolete, ICT products and associated medium-tech goods and services from the production market, and the defense and general engineering industries, and forming new de facto standards;
- personalized medicine radically transforming the pharmacology and medical services market on a scale comparable with the emergence of antibiotics or mass remote monitoring practices;

Fig. 2. **Capital-output ratio of the Russian fuel and energy sector in 2010** (dollars/t.o.e.)




*Source*: Russian Energy Agency.

Fig. 3. **Global Urals crude oil price dynamics in 2010** (dollars per barrel)




*Source*: CMASF.

- advanced 3D printing, which makes it possible to produce heterogeneous articles, in terms of their density, thickness, and other characteristics, and automated production of mass bespoke products (for example, using RFID assembly methods). These technologies place significant pressure on the automotive and other traditional industries (especially those with high labor costs) and contribute to reshoring, i.e. the reverse transfer of production from developing to developed countries, thereby further complicating the potential competition conditions for Russian companies;
- new energy, energy saving technologies, batteries, and adaptive energy system management technologies are capable of removing domestic hydrocarbons from the market, which involve high production costs. On the other hand — and even more importantly — the development and spread of super batteries and adaptive energy technologies will allow us to reduce the amplitude of day-to-day fluctuations in energy demand and supply in the general economy by reducing peak loads, which could be an additional factor in the reduction of demand for Russian energy products;

Table 1. **Relationship between new technologies and the forms of activity 'closing them down'**

| New technology | 'Closing' technologies or activities |
|---|---|
| Modeling of human intellect, cognitive consciousness and behaviour models | A broad spectrum of standardized analysis and forecasting in business (including financial markets), meteorology, medicine (even as far as an individual digital doctor), education ('distance student'), military, etc. |
| Evolution of the Internet: semantic web, Internet of Things | Revolution in intellectual activities (semantic web), new de factor consumer standards, possibly investment (Internet of Things) and military products |
| Radical transformation in the ICT market as a result of changes in electronic component base production technology (the end of Moore's Law, the development of new materials, photonics, etc.), the creation of breakthrough quantum technologies. | Obsolescence and 'closing down' of traditional ICT, replacement of de facto standards in associated fields |
| Transition to personalized 'health medicine', radical increase in life expectancy, control of human cognitive abilities | Crisis in traditional mass medicine, differentiation of 'old' health care for the poor and 'new' for the well-to-do, break-up of previous business models geared towards mass production of drugs |
| Stricter environmental standards and safety standards for production, transport, food products, consumer goods, buildings and structures, waste; customization of consumption | New de facto standards closing markets to traditional goods |
| Advanced 3D printing technology | Crisis in labor-intensive medium-tech automotive and metal manufacturing industries; emergence of new business models in high-tech sectors (including the high-quality expansion of outsourcing, in part through small and medium companies); reverse transfer of manufacturing into developed countries as a result of the leveling out of costs |
| Development of new energy, battery systems and energy network management systems | Gradual move away from the use of more costly hydrocarbons in favor of alternative energy sources; rise in car energy efficiency; trend of rapid expansion of the electric and hybrid car market |
| Development of automated transport and armaments | Ousting of standardized equipment and services from the market (for example, in rail transport); shrinking of regular military technology and armaments markets |
| Development of flexible automated production allowing for customized mass production output | Domestic crisis in traditional labor-intensive industries; automated automotive industry, possibly, production of mass consumer electronic and electrical goods; increased opportunities to transfer production |

*Source:* compiled by the authors.

- automated transport and armaments preconceiving new de facto standards and involving the liquidation ('closing down') of a number of significant Russian manufacturers in market niches (railway engineering, military aircraft engineering, etc.).

### Social challenges: conflicts and new inequalities

The development of personalized medicine, the radical increase in life expectancy, the control of cognitive abilities, and the improvement of 'brain-computer' interfacing technologies signify a fundamental increase in the abilities of individuals. In Russian terms, however, this growth is inevitably uneven due to the significant social inequality that reflects the income structure of the economy: in recent years, the income ratio has fluctuated between 16 and 17.

At the same time, the continuing socio-economic imbalance and consolidation of the class structure in society will cause a significant deterioration in the situation. However, the necessary tools to overcome this situation are currently lacking.

### Geopolitical challenges: the struggle for access to key technological expertise

A number of global development scenarios make assumptions about the intensification of international conflicts, which could make it more difficult for domestic companies to access key technological expertise in economics and security, as was the case in 2014. This turn of events in particular presupposes significant growth in the scale of the problems facing the Russian S&T complex.

## Industry specifics of challenges to long-term socio-economic development

Industry analysis allows us to outline the current challenges to the development of certain sectors of the Russian economy that are already experiencing certain weaknesses (Fig. 4).

First, *we can expect a steady decline in the global situation*: according to most existing assessments, in future, commodity prices will remain relatively low and are unlikely to rise significantly above the 2015 levels. Another negative factor is the growing cost and falling accessibility of technologies and funding. Both of these factors are responsible for the low value of the national currency since 2015.

Second, *we should expect a negative impact on business income from the increasing cost of basic resources and factors of production.* This problem, to a certain degree, confronts all industries. A comparably new, but no less dangerous factor may be

Fig. 4. **Reality of risks and threats to key industries in the real sector of the Russian economy**

| | Global risks | Fall in income | Deficit of labour resources | Lack of access to credit | Backwardness of technology | Loss of skills | Closing of markets |
|---|---|---|---|---|---|---|---|
| Agriculture | low | medium | high | maximum | high | low | high |
| Extraction and processing of hydrocarbons | maximum | high | low | medium | medium | low | medium |
| Extraction of other minerals | medium | medium | low | medium | medium | low | minimal |
| Food manufacturing | minimal | medium | medium | high | medium | low | maximum |
| Fruit and vegetable production | minimal | high | medium | high | high | high | low |
| Timber industry | low | medium | medium | high | medium | low | medium |
| Chemical industry | medium | high | medium | medium | medium | high | maximum |
| Engineering industry | high | maximum | maximum | maximum | maximum | maximum | maximum |
| Power industry | low | medium | low | medium | medium | low | minimal |
| Construction | medium | high | high | high | high | low | minimal |
| Transport | medium | medium | medium | medium | high | low | low |
| Communications (ICT) | high | low | medium | high | low | medium | low |
| Trade | medium | medium | high | maximum | medium | medium | minimal |

**Degree of urgency**: minimal, low, medium, high, maximum

*Source:* compiled by the authors..

the sharp fall in incomes in the oil industry due to growing capital expenditure and limited access to modern technologies amid the stabilization or even fall of global hydrocarbon prices. In turn, this causes problems in a wide range of associated industries such as the oil refining, chemical industry, engineering, and so on.

Third, *the deficit in labor resources is forecast to intensify*, especially qualified labor, which will further increase workforce costs. This risk is caused by a combination of negative demographic trends and the lack of specialists with a specific profile, attributable to the shrinking incomes of a number of manufacturing companies. As a result, the major players refrain from bringing in qualified and highly paid personnel or break the 'breeding' cycle for specialists at the companies themselves.

While in the early 2000s, the situation in the labor market was in part successfully mitigated by attracting specialists from post-Soviet countries (engineers and qualified workers — from Ukraine and Belarus, partly — from Transcaucasia, low-qualified workers — from other former Soviet republics), today this resource has been virtually exhausted, in part due to the reorientation of the migration flows towards EU countries. Labor-intensive industries such as engineering, construction and the service sector, find themselves in a particularly vulnerable position.

Fourth, in view of the nature of the policy conducted by the Bank of Russia, *access to credit resources for non-financial companies is expected to remain difficult.* Price uncertainty and reduced income in the global commodity markets are forcing players in the banking and financial sector to revise their risks upwards, which means that corporate lending is more expensive.

Fifth, *the backwardness of the technological equipment at production facilities will grow.* In the post-crisis period, there was clear trend of fading investment activity despite the relatively favorable overall climate in 2010–2012 and positive consumer dynamics. The worsening of the situation, combined with the increased risks in 2013–2014, further weakened the incentives for long-term capital investment and thereby suppressed technological development in the domestic economy and increased the dependence of key sectors of the economy on other countries.

Sixth, *a skills crisis as a result of a change in traditional business models* is starting to develop. In recent years, a number of high-tech industries (for example, aircraft engineering — the *Sukhoi Superjet*) have developed the 'high-tech designer' model, involving global outsourcing of virtually all, including key skills, excluding systems integration. With the active expansion of exports (and the conformity of the foreign currency structure of sales to the spending structure), this model is highly dependent on the strength of cooperation with external partners. While the formation of networks of global 'power centers' will in fact be accompanied by more conflicts, critical skills in high-tech industries will require far stricter control than today.

Seventh, *a liquidation of markets (especially in developed countries) is taking place due to changes in de facto standards and the introduction of 'closing' technologies.* This challenge, posed by changes in technological and environmental standards, could affect virtually all industries and forms of production. It poses the greatest threat to the pharmaceutical and medical industry, power engineering, construction materials production, and the production of a broad range of engineered consumer, investment, and defense products.

The challenges and risks described bring to the fore an additional administrative problem: the reduced effectiveness of existing (resource-intensive) state support instruments for technological development such as special federal and state programs. The majority of R&D funding provided by these programs is geared towards high-tech industries — aerospace, nuclear, defense — and the resources themselves are concentrated in central coordinating organizations and are issued to support technological development through existing business models. At the same time, the evolution of production technologies is accompanied by the emergence of new business models with the redistribution of the influence across the whole chain of centers of excellence.

At present, traditional high-tech engineering industries are facing these very problems. However, the most indicative example is the space industry. Thus, in the USA private space technology manufacturers such as SpaceX (which manufactures the Falcon 9 rocket and Dragon freight capsule), Virgin Galactic, or Boeing are actively increasing their share of the industry, not only for satellites, but rockets and freighters that intend, among other things, to put astronauts into orbit. Private companies offer far lower prices for orbital services than traditional state players, thanks largely to optimized production chains. The globalization of this model allows for efficient savings through outsourcing and poses a threat to the competitiveness of domestic producers with a high level of vertical integration and relative cost of rockets. The situation in the Russian space industry is being intensified by the transition to a new technology platform – the 'Angara' family is due to replace the 'Soyuz' series, the foundations for which were laid back in the 1950s, which helped to maintain low costs.

In the future, the transition to new business models may also be initiated in other high-tech industries in which Russian players would retain some degree of competitiveness.

## Conclusion

An analysis of the challenges facing Russia's socio-economic development has allowed us to make several important conclusions relating to technological modernization and long-term national development strategy.

The Russian economy is set to face two waves of strategic challenges in the near future, which would demand market flexibility and adaptability. The first wave (in roughly 2020 or slightly later) will likely be linked to the end of economic growth as part of the 'energy pole' model. We cannot be certain today as to which of the new technologies in the fields of energy, energy saving (super batteries), adaptive networks, unconventional forms of hydrocarbons, and so on, will come to define the global agenda. There can be almost no doubt that the energy markets may undergo a drastic and irreversible transformation within the next 5–10 years. For Russia, the situation is complicated further by the growing capital intensity of energy resource extraction at newly developed and old sites.

Another factor is the possible revolution in de facto standards linked to the development of all-pervading ICT (the Internet of Things) and new materials. Those companies which have not subscribed to the new standards will likely find themselves ousted from the market. The expanding demographic and environmental crises and increased security risks will serve as the general backdrop for this.

The second wave (roughly 2030–2035) is expected to be linked to fundamental changes in medico-biological technologies and in ICT. The corresponding shifts are capable of causing large-scale negative social effects — the emergence and intensification of new social inequalities, such as asymmetry in access to pharmacological and genome technologies to control human abilities. Combined with the formation of a global educational and cultural network and the increased security risks, this could undermine the stability of the social structure in Russia and its sovereignty.

Global and internal Russian challenges will affect different industries to differing degrees. However, all industries, even the most low-tech, will exhibit persistent demand for modernization. In the case of basic industrial sectors, modernization is capable of encouraging the development of a whole range of medium- and high-tech chain-based production; for example, the extraction and initial processing of raw materials — oil and gas engineering, transportation of raw materials — transport engineering, etc.

From an import substitution perspective, a small group of industries in three sectors hold the greatest potential:

- electronic components, medical technology, machine tool and engine engineering, oil and gas engineering, ship building, agricultural equipment and forestry;
- chemical complex — extraction of rare metals, production of composite materials, dyes and varnishes, plastics, cleaning and polishing products, articles made from resins and plastics, pharmaceuticals;
- food industry — production of meat and fish products, preserved fruits and vegetables.

Long-term growth opportunities are linked largely to the development of existing strong centers of excellence, including those in foreign markets. In industries such as software development, nuclear energy, and partly the production of armaments, military technology, aircraft, energy equipment, certain classes of lorries, and so on, Russia is capable of acting as a technology donor and center of excellence on a global scale. For pharmaceuticals, engineering, motor fuel production, and certain types of ICT, a rational strategy is perhaps getting embedded in global production chains, including through outsourcing with external systems integration (importing skills)

The development of new technological skills is vitally necessary to maintain Russia's national competitiveness and security. Such a task, however, requires a relatively strict prioritization of efforts in this sphere in the absence of adequate financial (various forms of revenue) and human resources in simultaneous 'frontal' modernization.

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# Technological Innovation as a Factor of Demand for Energy Sources in Automotive Industry

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## Abstract

**The issue of forecasting demand for liquid fuels has become particularly significant in recent years with technological development and much tougher inter-fuel competition in the transport sector. In future, these developments could radically transform the oil, gas, and electricity markets. Therefore there is a greater need for improved forecasting methods that take into account the dynamics of market factors, primarily those related to the use of new technologies.**

**We analyse the difficulties of forecasting demand for liquid fuels in conditions of uncertainty related to future technological developments in car transport. We classify the technologies driving demand for motor fuels by the nature of their impact on the demand for petroleum products: technologies aimed at improving the energy efficiency of traditional cars, as well as drivers of inter-fuel competition, both in terms of direct and indirect substitutes for petroleum products. To resolve the problem of limited input information, the methodology incorporates clustering instruments, which enable us to group countries according to certain criteria. The use of economic and mathematical tools with optimizing units enables us to make integrated calculations that model the market for liquid fuels and assess its interactions with the markets of other energy resources.**

**Our proposed system for forecasting demand for liquid fuels, including petroleum products, can be used as an instrument to assess the future impact of technological innovation on the development of the oil industry when carrying out Foresight studies.**

**Keywords:** oil products; alternative fuel; automotive transport; forecast of demand; technology; energy efficiency

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Liquid fuels, including oil and petroleum products, among of the most important components of the energy balance. According to data from the International Energy Agency (IEA) [IEA, 2014], oil alone accounts for roughly 31% of total global energy consumption and 93% of energy consumption in the transport sector.

In view of the acute significance of liquid fuels for the global energy sector and economy as a whole, the future development prospects of this market are the subject of detailed studies by both the expert community and representatives from business circles and government bodies. Development forecasts for the liquid fuel market (often called the oil market due to the dominance of oil as an energy resource) are compiled annually by the US Department of Energy [DOE, 2014a], IEA [IEA, 2014], the Organization of Petroleum Exporting Countries (OPEC) [OPEC, 2014] and the Energy Research Institute of the Russian Academy of Sciences [*Makarov et al.*, 2013]. One of the most important aspects of these studies is their evaluation of long-term trends for energy demand (in particular for oil-based fuel), and it is this demand that in many ways shapes the future configuration of the oil market, including prices. However, the prospect of a change in demand for liquid fuel is becoming increasingly uncertain, due to significant technological changes which are taking place in today's oil market, in particular in terms of technological developments in the transport sector, which now accounts for 64% of global oil consumption.

Active diversification of the fuel basket, expansion of inter-fuel competition between petroleum products and other energy sources and innovative developments in the technologies used in the consumption of the oil products themselves (especially in the transport sector) all require the modernization of existing and the development of new methods to forecast demand for liquid fuels while taking current and future technological changes into account.

In order to guarantee the quality required of the calculations using oil demand forecasting methods, we need a tool kit that can account for all three of the identified technology groups. However, existing approaches do not fully meet these requirements. Methods based on forecasting demand solely from macro-parameters ('top-down') do not offer tools for explicitly taking the technologies into account, although they are noted for their simplicity and accessibility to a wide range of experts. The other category of methods ('bottom-up') involve a similar tool kit, but in practice require access to large data arrays, which is often not possible. Moreover, such methods are particularly sensitive to the accuracy of the initial data and scenario conditions.

The demand forecasting system proposed by the authors is an original approach combining the advantages of various existing methods, which will ultimately make it possible to form multi-factor scenarios and evaluate the impact of energy and industrial policy on the demand for motor fuel.

To account for the effects of technologies, the forecasting system provides for special 'technological' blocks and, in addition, evaluates demand from the perspective of inter-fuel competition between petroleum products and direct substitutes through data exchange with an optimized model of liquid fuel markets. The problem of the lack of information, which is characteristic of the 'bottom-up' model, has been eliminated by the use of clustering instruments, which make it possible to draw well-founded analogies between units and to establish values in correlation with countries (regions) exhibiting similar characteristics. As a whole, the entire system covers economic, demographic and technological factors.

## Key technological changes in motor fuel consumption

We are seeing a relatively wide range of areas in which technology is developing, which is capable of having a significant impact on liquid fuel consumption in the transport sector. From the perspective of fuel expenditure, improvements to vehicle transport will have two opposing effects. On the one hand, the consumer properties of transport will improve, leading to an increase in fuel expenditure (increase in power, introduction of air conditioning systems, hydraulics, automated mechanisms, massage systems, additional media devices, etc.). On the other hand, technologies capable of increasing the energy efficiency of transport are being introduced. In sum, trends are geared towards reducing fuel expenditure. Looking at demand for petroleum products, it is also important to bear in mind the development of inter-fuel competition technologies, which allow for a reduction in petroleum product consumption in the transport sector by including other types of fuel in the energy basket.

Despite more than a hundred years of the automotive industry, modern vehicles still have significant energy-saving potential. According to estimates by the American Physical Society [APS, 2008], modern vehicles running on traditional fuel only effectively transfer 20% of the fuel's potential energy from the tank to the wheels, and this is bearing in mind that it was only from the early 1990s to 2010 that vehicle power globally increased on average by 42% and fuel expenditure fell by 37% [*Makarov et al.*, 2013]. This was achieved through the development and mass introduction of an entire range of technologies: turbochargers, direct fuel injection, cylinder deactivation and valve timing systems, improved gear boxes, reduced weight and increased vehicle aerodynamics, and hybrid vehicles.

This development and diffusion of energy-efficient technologies was helped in no small part by government measures to increase the efficiency of road transport. In the US, for example, reinforced Corporate Average Fuel Economy (CAFÉ) standards have been in effect since 1975, which oblige vehicle manufacturers to ensure that their products meet fuel economy standards, expressed as the minimum number of miles that a vehicle can travel on one gallon of fuel. In 1995, the European Union adopted standards (which are regularly reviewed) to limit carbon emissions from cars. Similar, but far stricter standards were adopted in 1999 for vehicle manufacturers in Japan, and in 2004 in China. All of these standards are continually adapted and tightened as vehicle manufacturers develop new fuel-efficient technologies. Furthermore, it is this expectation that standards will inevitably become more exacting that encourages producers to improve their technologies. According to data from the US Environmental Protection Agency, long-term CAFÉ target figures assume a reduction in average fuel expenditure for light vehicles by 60% and for heavy goods vehicles by 30% over the period 2014-2025.[1] Such targets are not only set for road transport, but the aviation industry as well: the International Air Transport Association (IATA) has adopted a target of increasing civil aviation fuel-efficiency by 25% by 2020 compared with 2005.[2]

An analysis of technology development areas shows that further increases in vehicle fuel-efficiency will mainly come about as a result of the improved and higher energy conversion efficiency of all components (including the engine), developments in hybrid vehicles, active use of intelligent control systems and use of composite materials in the cabin and bodywork for weight reduction.

Inter-fuel competition technology will also have a significant impact on petroleum product consumption. Alternative energy sources are gradually starting to occupy a niche in the transport sector and can be classified into:

- direct petroleum product substitutes – types of fuel not requiring serious changes in the construction of engines and consumer infrastructure (these might include biofuels and liquid petroleum products produced from gas and coal using *coal-to-liquids* (CTL) and *gas-to-liquids* (GTL) technologies);
- fuels which are indirect substitutes, and their use in transport directly involves a need to modify vehicles and set up the corresponding consumer infrastructure. Indirect substitutes include: natural gas-based motor fuel, electricity and fuel cells.

It is worth noting that direct substitutes have a far greater diffusion than indirect, which is linked to their availability for consumers. However, their share in the transport sector as of 2015 is extremely small (roughly 2% of total transport energy consumption), which can in part be explained by the relatively high production costs. According to IEA calculations, biofuels (with current production

[1] Available at: www.epa.gov, accessed 16.09.2015.

[2] Available at: https://www.iata.org/whatwedo/ops-infra/Pages/fuel-efficiency.aspx, accessed 16.09.2015.

technologies) become efficient when oil prices range from 70 to 150 US dollars per barrel (depending on the location and method of production), synthetic coal-based fuels from 45 to 105 US dollars per barrel, and gas from 60 to 105 US dollars per barrel. The direct unit costs of extracting all accessible and technically possible conventional oil supplies globally (excluding deposits in the Arctic circle and deep-sea oil) vary between 15 and 70 US dollars per barrel (including the cost of processing into petroleum products) [IEA, 2013].

It is important to stress that all of these figures are highly conditional and in reality could sit within a far wider range depending on the cost of gas and coal, the tax burden and other factors. However, even such 'conditional' assessments point to the fact that direct substitutes are in fact competing with petroleum products produced from oil obtained from marginal deposits (deep-sea deposits lying in complex reservoir conditions) and from unconventional sources: oil sands, shale deposits and kerogen (for more cf. [*Makarov et al.*, 2013]) which, according to IEA data, could be involved in the economy with oil prices between 50 and 100 US dollars per barrel. Nonetheless, this competition is being won by unconventional oil sources, which can be explained, among other things, by the trend in recent years for significant reductions in production costs. For example, the development of shale oil extraction technologies has made it possible to reduce total extraction unit costs in the US by more than 40% over the period 2006 to 2010 [*Grushevenko, Grushevenko*, 2012), while the unit costs of setting up businesses to produce synthetic fuel derived from coal and gas have, on the contrary, risen.

Aside from the relatively high production costs, the emergence of new oil substitutes on the market is being held back by a number of other restrictions. For biofuels it is being shaped by production capabilities, which (with existing technologies) are limited by the amount and condition of fertile soil and arable fields, as well as the needs of the global food industry. This restriction can in theory be removed through the commercial development of second-generation biofuel production technologies[3], which, according to IEA experts, are capable of supplying 700 million tonnes of oil equivalent of this energy resource [OECD, IEA, 2010] or roughly 17% of global oil demand in 2014.

Other direct petroleum product substitutes, or rather the raw materials to produce them – gas and coal – also have their own restrictions: the resource base of each of these materials is not unlimited and demand is steadily growing. There then is the question of how to make efficient use of these resources.

Large-scale use of synthetic coal-based fuels is limited by the energy-efficiency of the processes used to produce such fuels. Often, the normalized EROI (Energy Return on Investment) is used to evaluate the energy efficiency of energy resource production, defined as the amount of energy derived from the raw energy material relative to the amount of energy used to produce it. For petroleum products – petrol and diesel – this figure is 25 on average [*Cleveland, O'Connor*, 2010], but for fuels produced using CTL technologies, the figure varies between 0.6 and 6 [*Kong et al.*, 2015]. For comparison, burning coal at power stations gives an EROI of 40-80 [*Raugei et al.*, 2011], which is clearly more efficient than converting it to liquid fuels.

Synthetic gas-based fuels (under current technological conditions) are more efficient from the perspective of energy-conversion efficiency than coal-based fuels. However, we have not seen widespread distribution of industrial GTL facilities, which can be explained not only by the relatively costly production compared with oil-based fuels, but also the fact that the natural gas itself coming into such projects is an extremely efficient indirect substitute for petroleum products without the need for additional costly processing.

In spite of the existing price and volume restrictions, further reductions in the cost of technologies to produce full petroleum product substitutes or the formation of a favorable market climate for them (high oil prices) are both capable of having an impact on demand for motor fuel, which means that it is essential that the factor of inter-fuel competition with these types of energy resources be

[3] For more on the different generations of biofuel cf. [*Makarov et al.*, 2013].

taken into account when forecasting demand for petroleum products.

At the current stage, indirect petroleum product substitutes are losing the competition with petroleum products not only due to the price and costliness of production (often a directly alternative resource, for example, natural gas, is cheaper for consumers than petroleum products), but also due to the less appealing consumer qualities of the transport and the lack of infrastructure. For some forms of transport, in particular electric cars, their higher sale cost is also significant. And in the case of refitting, for example, a petrol car with gas-cylinder equipment, the corresponding costs fall to the consumer. In addition, in most countries there is no developed infrastructure to service and refuel vehicles running on alternative fuels, which makes running such vehicles inconvenient and reduces their consumer appeal. The infrastructure itself is not appealing to business as an investment, as demand for the corresponding services is limited to a small number of consumers. Weak demand holds back even the strongest automotive concerns from mass production of these types of vehicles [*Mitrova, Galkina*, 2013].

The use of electricity in vehicles is restricted by the size of the service infrastructure and certain technological improvements in modern electric cars, primarily the low energy capacity per charge, short journey length and cost of the electrical equipment, which all have an impact on the cost of the vehicle and therefore the appeal of such transport for consumers.

Nonetheless, innovations in indirect petroleum product substitute technologies and associated marketing and PR programs are making them more and more competitive on the market. The Tesla electric car produced in the US, for instance, is even becoming more attractive than traditional cars for some of its consumer characteristics – acceleration, noise, not having to regularly replace the engine and transmission oil, etc. It is getting ever closer to its competitors in this class, not only in terms of price, but journey length without recharging too. One of its main advantages is the lack of exhaust gases, ignoring of course the emissions from the power station producing the electricity. This market cue suggests that potential technological innovations could, in the not too distant future, have a significant impact on demand for oil and petroleum products by displacing them from the transport sector in favour of indirect substitutes.

These changes in vehicle manufacturing innovation and improvements to energy consumption technologies in the transport sector in turn require flexible mechanisms to take all of these technological factors into account in modern petroleum product demand forecasting systems.

## Review of petroleum product demand forecasting methods

Far from all existing forecasting methods are capable of taking into account technological development factors. Often these factors are not examined at all or are evaluated in a generalized, implicit form through changes in energy and oil capacity.

As shown in a study by the World Bank [*Bhattacharyya, Timilsina*, 2009], two approaches tend to be used to forecast demand for petroleum products:

- 'top-down', when the forecast is based on macro-parameters;
- 'bottom-up', when the situation with specific types of fuels is analyzed, which can include technological parameters.

Forecasting methods adopting the 'top-down' principle have seen the most widespread use. These methods are based on the fundamental dependence between demand for petroleum products and economic and demographic indicators (GDP and population figures)[4]. The correlation between macro-economic variables and energy resource consumption is usually attained using regression models [*Makarov et al.*, 2013], but heuristic search algorithms [*Behrang et al.*, 2011], genetic programming [*Forouzanfar et al.*, 2012] and other methods can also be used. Often these models analyze the oil capacity (petroleum product capacity) of GDP (the ratio of GDP to demand for petroleum products).

[4] The nature of these correlations is described in more detail in [*Grigoryev, Kurdin,* 2013].

The technological factor of increasing energy-efficiency is generally taken into account in models using a 'top-down' method by shifting the forecast oil capacity (petroleum product capacity) dynamics more rapidly downwards (if the scenario assumes substantial technological developments) or slowing the downturn (if, on the contrary, technological developments come about at a more moderate pace). To evaluate technological improvements from the perspective of inter-fuel competition, the model includes the elasticity of demand for petroleum products by price [*Nakanishi*, 2006; *Bobylyov et al*, 2006].

From the perspective of technological forecasting, key shortcomings in the 'top-down' approach are the difficulty in taking into account the impact of specific innovations on future demand, the lack of flexibility in specific scenarios and the lack of transparency in the actual procedure used to evaluate technological factors. Moreover, [*Cleveland et al.*, 2000] casts doubt on the relevance of tying demand for petroleum products in with GDP dynamics. The authors of this work point to the recent loss of close correlation between GDP dynamics and energy resource consumption, which makes it all the more important that we search for alternative approaches to forecasting demand for petroleum products.

Models based on the 'bottom-up' principle are often used to evaluate demand for energy resources in the transport sector. They involve developing a forecast for demand for motor fuels by including various data in the calculation – data on the size of the fleet, its structure, rate of renewal and retirement and technical and economic figures. These approaches are used in the models adopted by the IEA [IEA, 2011], US Department of Energy [DOE, 2014b], World Energy Council [World Energy Council, 2011] and other researchers [*Wang et al.*, 2006; *Bouachera, Mazraati*, 2007; *Braginsky*, 2012]. They also allow for flexible scenarios and evaluation of the effects of developing new technologies on demand. Demand calculations based on the scale, make-up and characteristics of a fleet allow both improvements to traditional technologies and new technologies (including those based on alternative forms of energy) to be taken into account.

The main problems in the 'bottom-up' approach are the need for high detail in the input data and difficulties in coordinating demand calculations in the transport sector with evaluations in other sectors. The difficulties in forecasting demand with insufficient data are explored in the work [*Bhattacharyya, Timilsina*, 2009]. In order to overcome these problems, some researchers have tried to group countries according to certain characteristics [*Button et al.*, 1993].

There are however some shortcomings characteristic of the existing methods:

- 'Top-down':
  - taking account of a limited number of factors, which is insufficient for variable-based calculations and scenarios allowing an impact assessment of S&T progress, energy policy, etc.
- 'Bottom-up':
  - the need for a large set of initial figures and high level of detail in the figures;
  - the lack of transparency in calculations where there is a shortage of initial data;
  - inadequate consideration of marketing factors affecting demand (consumer preferences, fashion, accessibility of infrastructure and services);
  - lack of a direct mechanism to indicate errors when using incorrect initial data or premises.

The method that we have proposed looks to solve these very problems.

## System of forecasting demand for liquid fuels

The method developed by the authors of this study to forecast demand for petroleum products and other liquid fuels (biofuel, synthetic fuels made from gas and coal) combines various forecasting approaches and involves elements to eliminate the shortcomings of existing approaches and to make effective use of their strengths (Table 1).

As noted above, we can identify the following advantages of the method developed by us, compared with previously adopted methods:

Table 1. **Comparative analysis of methods to forecast demand for liquid fuels**

| Problem | 'Top-down' method | 'Bottom-up' method | Proposed method |
|---|---|---|---|
| The dependence of the forecast on a limited number of macro-economic indicators, the inability to take technological development factors into account | Characteristic of such methods | Solved by including multiple indicators in the calculation | Covers multiple indicators |
| Shortage of statistical data | By taking a small number of required input parameters into account, this problem is generally not characteristic of such methods | A key problem of applying such methods | Application of multi-criteria clustering of countries to search for common characteristic patterns, allowing the problem of insufficient information to be partly eliminated |
| Taking demand by sector into account | Does not make it possible to identify individual sectors or base calculations exclusively on the economic indicators of an economic sector (gross value added of a sector) | As a general rule, used to forecast demand only in a particular sector (transport); needs 'links' with other consumer sectors to define aggregate demand in other models | Combination of the 'top-down' approach when assessing aggregate demand for petroleum products and the 'bottom-up' approach when assessing demand for motor fuels, followed by interlinking the assessments |
| Taking marketing factors into account | Not taken into account | Taken into account partially, depending on the parameters set by the authors | Taken into account |
| Lack of transparency in mechanisms to take account of inter-fuel competition | As a general rule, this is done as a formality, by assessing 'price elasticity'; requires additional 'extras' to take account of inter-fuel competition | Can involve technical and economic indicators which are used to take account of inter-fuel competition; as a general rule, requires the use of additional calculation systems | Proposes the use of a method closely linked to the 'resource block' imitating the functioning of the market, including aspects of inter-fuel competition |

*Source*: compiled by the authors.

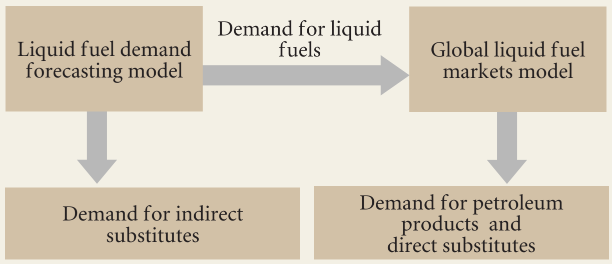
- the application of multi-criteria clustering to eliminate the problem of insufficient data for certain countries;
- the combination of 'bottom-up' and 'top-down' approaches to solve the problem of linking forecasts of demand for petroleum products in the transport and other sectors, and to indicate calculation errors resulting from the use of incorrect initial data and assumptions;
- a detailed analysis of marketing factors affecting demand. These include consumer preferences and fashions (when buyers are prepared to buy vehicles with worse economic indicators thanks to other attractive characteristics or due to the influence of advertisements and the accessibility of infrastructure and services);
- the drafting of forecasts as part of a comprehensive system of forecasting for the global energy industry, which make it possible to take account of the impact on demand for petroleum products of various factors in neighbouring industries, as well as any adverse effects.

In general terms, forecasting using this method involves carrying out calculations in two inter-related model blocks: in the demand forecasting model for liquid fuels, where demand for liquid fuels is calculated taking into account technical and economic factors and inter-fuel competition with indirect petroleum product substitutes, and in the global model of liquid fuel markets, where demand for petroleum products is calculated by taking into account inter-fuel competition between petroleum products and direct substitutes (fig. 1).

In order to calculate demand for liquid fuels in line with the standard fractional composition of oil and the consumer characteristics of the individual distillates and their direct substitutes, the following petroleum product groups have been identified for use in the model:

1. Liquefied oil gases including ethane and propane-butane fraction. From the perspective of the market, this group combines all gaseous petroleum products used in the transport sector as motor fuels, in the household and commercial sectors as fuel for small-scale heating and electricity generation, and in petrochemicals as a raw material.

Fig. 1. **Structure of the demand forecasting system for liquid fuels**




*Source*: compiled by the authors.

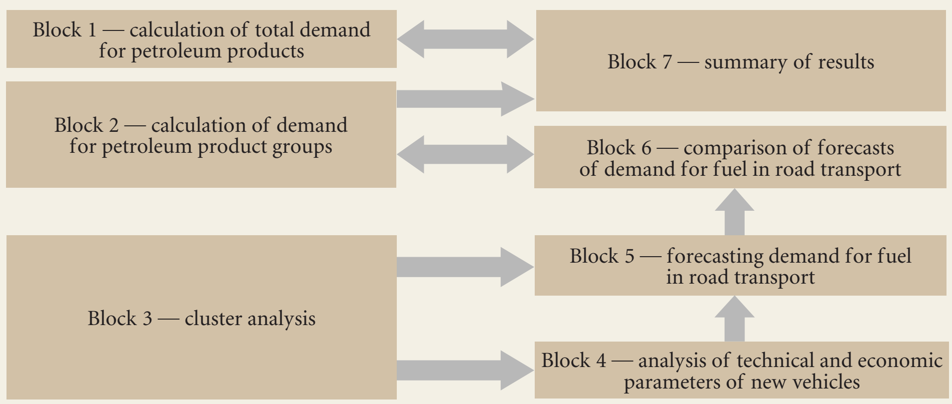
2. Straight-run petroleum (naphtha), which are light petroleum distillates not suitable for use as fuel and often used as a solvent or raw material in the petrochemical industry.
3. Vehicle petrol – a multi-component mix of straight-run naphtha, secondary and enhanced petrol and chemical additives suitable for use in petrol-fuelled vehicle engines. Substitutes include petrol produced from coal, gas and biomass.
4. Aviation kerosene – fuel for jet engines.
5. Diesel fuel – diesel distillates having gone through hydro-treatment and other petroleum product refinement processes, used in road and rail transport, as ship fuel, in diesel generators, etc. Substitutes include biofuel and fuels produced from coal and gas.
6. Fuel oil and other heavy petroleum products – a broad group of dark, high-density petroleum products, including naval and furnace fuel oil, tar, bitumen, vacuum gasoil and other heavy petroleum processing residues. The products in this group are used in various sectors: in water-based transport, in heating and electricity production, and construction.

The demand forecasting model for petroleum products has seven interdependent blocks (fig. 2): three blocks for forecasting demand for petroleum products, differing in their methodological approaches (blocks 1, 2 and 5), two preparatory research blocks (blocks 3 and 4), and two aggregating blocks (blocks 6 and 7).

Each block of the model is dedicated to specific tasks.

Block 1 involves calculations of total demand for petroleum products based on correlation dependencies between demand and fundamental macro-economic indicators: GDP and population figures. Based on retrospective dynamics of petroleum product consumption figures relative to GDP (oil capacity) and popu-

Fig. 2. **Integrated forecasting model**




*Source*: compiled by the authors.

lation (per capita consumption), future values are forecast by constructing various types of trends, after which the total demand for petroleum products in the future period is determined.

Block 2 is dedicated to forecasting total petroleum product consumption by aggregating forecasts of demand for individual petroleum product groups. Assessments are based on GDP forecasts and population figures by building trends from retrospective GDP capacity figures and per capita consumption for each petroleum product group. Another methodological feature of block 2 was dictated by the specific way in which initial data is presented by consumption of individual petroleum products, which are as a general rule recorded statistically in metric tonnes, rather than in their energy equivalent. This means that conversion ratios need to be applied, calculated using the calorific value of the fuel, to compare the results of the forecasts in blocks 1 and 2.

Block 3 makes preparations for the calculations in blocks 4 and 5. This block aggregates the units into clusters using the *k-means* method. A more detailed mathematical description of the algorithm and the way in which it is used are presented in [*Hartigan, Wong*, 1979; *Telgarsky, Vattani*, 2010]. Indicators describing a unit from economic and energy perspectives are used as criteria in the calculation: GDP, net oil and petroleum product exports, composition of the fuel basket in the transport sector, etc. The results of the analysis are then used to cluster the units under study (amalgamating them into groups). The results of this aggregation of units into groups are used when determining the individual members of the cluster-specific, average-cluster indicators, information on which may be difficult to access for certain units. These indicators could include, for example, average annual mileage of vehicles or their service length. It should be noted that the number of clusters, make-up of units and set of characteristics used to create the clusters can be changed depending on the preferences of the researchers or research objectives. A special case of clustering countries based on three characteristics – GDP per capita, net oil exports and the ratio of petrol to diesel consumption – carried out to test the described demand forecasting system is examined in the article [*Grushevenko, Grushevenko*, 2015].

The results of the distribution of geographical units by cluster are used in blocks 4 and 5. If the researchers have problems in accessing any information required on a particular unit for the forecast, the values characteristic of the cluster to which the unit belongs are to be used.

Block 4 involves preparatory calculations to forecast demand for fuel in the automotive transport sector. In particular, it takes into account the technical and economic indicators of vehicles using various types of fuels, makes scenario assumptions regarding the technological development of automotive transport, and evaluates consumer preferences when acquiring particular vehicles. All of these parameters are defined by calculating vehicle appeal coefficients for each type of fuel (taking into account the potential for technology to be modernized) based on the cost of ownership and factors describing clearly economic, but not formalized consumer preferences (access to infrastructure, 'fashion' for a specific type of transport) which have no clear economic characterization.

The most important task in block 4, and later in block 5, is taking account of inter-fuel competition. The model calculations allow competition with indirect petroleum product substitutes to be taken into account, including with fuel types used on transport and requiring significant changes to the consumer infrastructure. These include electricity and compressed natural gas, the use of which is considered to involve significant modifications to the vehicle's construction and the construction of refuelling and service infrastructure to guarantee their appeal to a wider consumer base. By analyzing the technical and economic indicators and prospective development trends of technologies using these fuels, block 4 makes scenario assumptions which are then formalized in corresponding coefficients for subsequent calculations.

It should be noted that inter-fuel competition between petroleum products and direct substitutes (i.e. types of fuel which can be used in existing vehicles with existing infrastructure) – bioethanol and biodiesel, as well as diesel and petrol produced using GTL and CTL technologies – are taken into account after the transfer of results from the liquid fuel demand forecasting model into the global liquid fuel markets model.

The output parameters from the calculations in block 5 are:

- demand for petroleum products and their direct substitutes by type – petrol (bioethanol, GTL and CTL petrol), diesel (biodiesel, GTL and CTL diesel), liquefied hydrocarbon gases;
- demand for indirect petroleum product substitutes by type – compressed natural gas, fuel cells, electricity used in the transport sector.

Block 5 covers calculations of forecast demand values for fuel for automotive transport based on the size and structure of the vehicle fleet of each unit, consumer preferences and technological development trends in the sector, as examined in block 4. Block 5 establishes a forecast of the demand for automotive petrol and diesel (including fuel produced from coal, gas and biomass), liquefied hydrocarbon gases and indirect oil-based fuel substitutes equivalent in their make-up to those taken into account when forming the appeal coefficients in block 4 (electricity, compressed gas, hydrogen).

The forecast demand values obtained in block 5 for petroleum products are then transferred to block 6 for comparison with the forecast demand from block 2. The GDP capacity and per capita consumption trends for automotive petrol, diesel and liquefied hydrocarbon gases from block 2 are then adjusted on this basis.

Block 7 summarizes the results obtained in block 2 (taking into account the adjustment in blocks 5 and 6) and the results of block 1 following adjustment after switching over to the alternative indirect petroleum product substitutes in blocks 4 and 5.

The results from block 1 are adjusted by reducing the obtained total demand for petroleum products by the amount of demand for indirect motor fuel substitutes (electricity, fuel cells, compressed gas) expressed in their energy equivalent (from block 5).

The demand from block 1, adjusted by the amount of demand for indirect petroleum product substitutes, is compared with the results of the calculations in block 2. These results are entered into block 7 in the form of summary demand for all petroleum products, expressed in their energy equivalent (to allow for comparison between results). In this case, the comparison serves as an indicator of serious errors which may have emerged in the calculations.

Where necessary, if there are serious discrepancies between the results, following expert analysis of the causes, calculations can be reverted to blocks 3-6 for secondary analysis of the set parameters or to the algorithm in block 1, where the adjustment of GDP oil capacity or per capita petroleum product consumption trends is carried out. Based on the expert assessment of the quality of the calculations, the results of the comparison in block 7 can call for an adjustment in the calculations of per capita consumption or GDP capacity trends for specific product groups (block 2).

The final results of the model are estimates of the demand for liquid fuels. The output parameters are broken down in the same detail by geographical characteristic and are intended to solve a wide range of analytical problems. The model therefore allows a definition of:

- Total demand for liquid fuels (including petrol and diesel produced from gas, coal and biomass) taking into account technological factors and adjusted for inter-fuel competition with energy resources which are indirect competitors with petroleum products in the transport sector. This figure can be applied in systematic studies of the future legitimacy of energy developments, the formation and adjustment of forecast energy balances and to determine the role of oil-based fuels in these balances.
- Demand for specific petroleum product groups: automotive petrol and diesel (including fuels produced from gas, coal and biomass), liquefied hydrocarbon gases, aviation kerosene, straight-run petroleum (naphtha) and others. The forecast demand for petroleum product groups is expressed in energy and metric units and serves as a basis to analyze the corresponding markets, solve modelling problems and for forecasting in oil refinement sectors.

- The breakdown of demand for liquid fuels: liquefied hydrocarbon gases, automotive petrol and diesel (including fuels produced from gas, coal and biomass) used as motor fuels (in the automotive transport sector). These are expressed in metric tonnes or in energy equivalent and can be used when analyzing transport sector development trends and forecasting specific petroleum product markets.
- Demand for non-oil-based fuels which are indirect competitors for petroleum products in the transport sector and require fundamental changes to the structure of the vehicle fleet and servicing infrastructure (electricity, fuel cells, compressed natural gas). Demand for such fuels is expressed in their energy equivalent. These data are needed to analyze innovative paths to develop the energy industry, inter-fuel competition, forecast the markets of these fuels and petroleum products, and form and adjust energy balances.

The assessments of total demand for liquid fuels (including petrol and diesel produced from gas, coal and biomass) adjusted for inter-fuel competition with energy resources which are indirect competitors with petroleum products in the transport sector are used in the global liquid fuel markets model, where it is adjusted and stripped from demand for direct petroleum product substitutes. This is a statistically optimized model of complete equilibrium with the target function to satisfy demand in six petroleum product groups taking into account minimum total expenditure across the entire oil and petroleum product supply chain, from deposit to consumer.

The production chain presented in the model covers:

- The extraction block, which selects the deposits to be commissioned, taking into account the cost of extraction and potential future volumes. These are forecast for the largest deposits and oil and gas regions, based on data on supplies, depletion dynamics and extraction profiles. For existing or confirmed extraction projects the extraction profile for the forecast period is determined on the basis of data from the operator companies, and for the remainder by building a forecast extraction profile using Hubbert's linearization method [*Hubbert*, 1962] and more modern modifications [*Hook*, 2009; *Michel*, 2010].
- The transport block, which links the production and consumption of oil and petroleum products, simulating the transportation of energy resources by pipeline, rail and water transport.
- The oil refining block, which contains information on 872 oil refineries in different countries and regions around the world. This imitates petroleum product production operations with minimal restrictions and expenditure on processing. The minimal restrictions on petroleum product output are set on the basis of the potential selection of oil distillates, taking into account their chemical make-up and current processing possibilities.
- The inter-fuel competition block takes account of competition between petroleum products and biofuels and synthetic fuels produced from coal and gas. It is in this block that the liquid fuel demand indicators entered into the model are disaggregated into demand for oil-based fuels and their full substitutes.

To calculate the different scenarios and carry out a quantitative assessment of the expected changes in the fuel market climate, the liquid fuel market model allows the amount and structure of potential oil extraction and processed oil to be varied, transport capacity and supplies to be adjusted, and scenario conditions under which petroleum products are replaced with direct substitutes to be changed.

In terms of taking inter-fuel competition between petroleum products and direct substitutes into account, the model looks at the possibility of displacing a portion of petroleum products. This is based on information regarding the price of switching over and potential maximum production volumes for alternative fuel types. When assessing the scale of the displacement, the potential volume and full estimated cost of supplying petroleum products to the consumer market (including the cost of the oil extraction, transportation and processing) are taken into account, together with the potential volume and full estimated cost of supplying a competing energy resource to the same market (biofuel, fuel produced using GTL and CTL technology). At first, the market is supplied with the cheapest competing energy resources, and later, if volumes are insufficient to cover demand, energy resources with higher supply costs.

Analysis of the scenario-specific changes regarding the volumes and prices of a potential switch to alternative energy resources allows different development scenarios to be formulated for bio- and synthetic fuel production.

Combining the liquid fuel demand forecasting model with the global liquid fuel market model serves as a basis for forecasts of oil and petroleum product demand taking into account scenario-specific assumptions regarding future technological changes related to increases in the energy-efficiency of transport and changes to technologies used to produce and consume energy resources competing with petroleum products, both existing and future.

## Opportunities for practical application of the developed method

In practice, the method has been tested in the context of liquid fuel demand forecasting system which is part of the global SCANER modelling and information complex (fig. 3) [*Makarov et al.*, 2011]. It was included in the 'Population – GDP – Energy consumption – Electricity consumption – Liquid fuels consumption' module and is closely linked in with balance and resource oil modules [*Makarov et al.*, 2013]. The resource module is a model of the liquid fuel markets, described in [*Goryacheva et al.*, 2013].

The co-dependency between the liquid fuel markets model and the liquid fuel demand forecasting model is achieved as follows: the calculations of demand for liquid fuels obtained using the forecasting method described above serve as input data for the former model. Aside from the calculations of production indicators, it allows for the assessments of liquid fuel demand to be adjusted to take into account inter-fuel competition (the model can contain information on additional volumes of alternative fuels) and to break it down into petroleum products and direct substitutes.

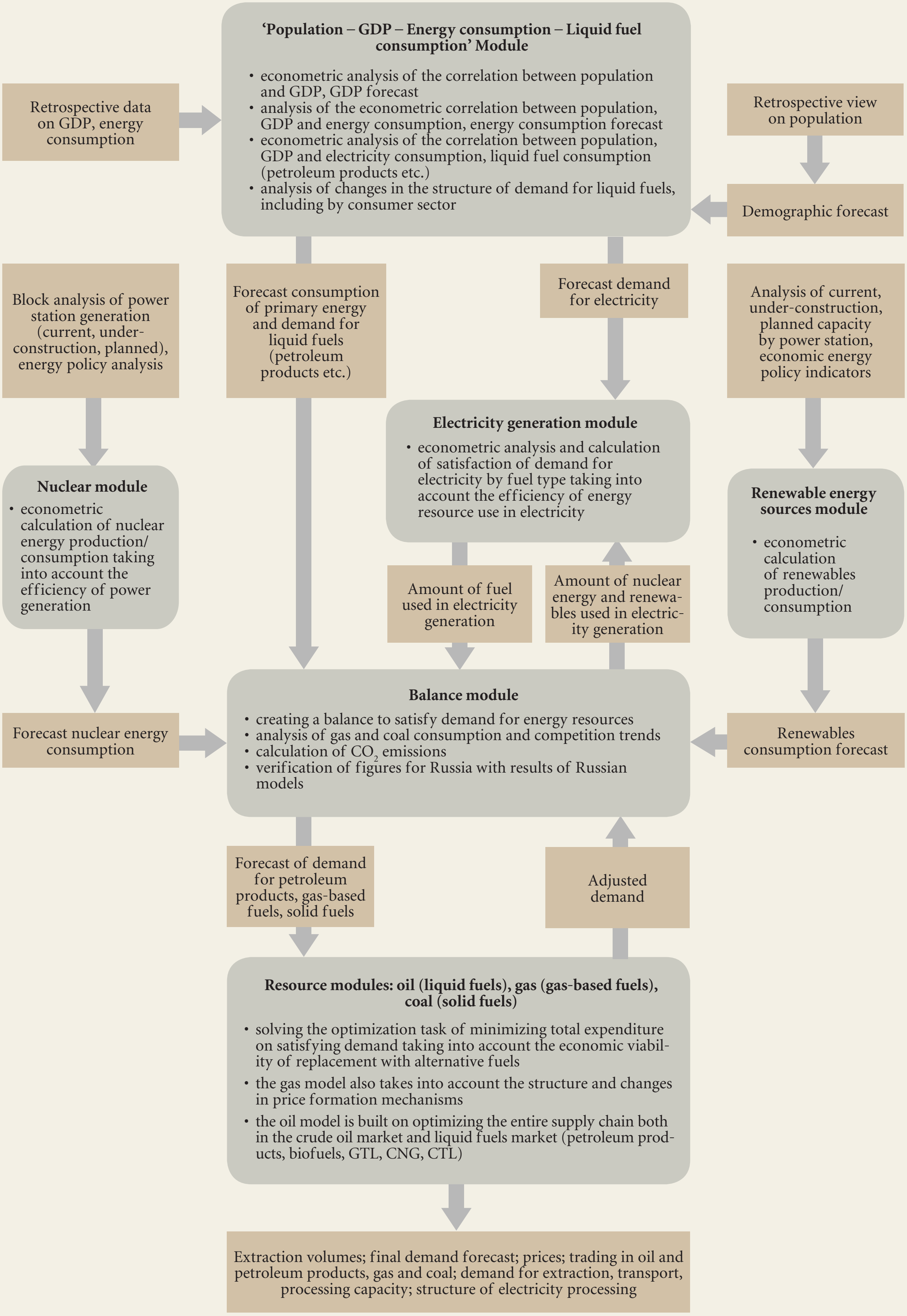
Breaking down demand into petroleum product groups makes it possible to use this system to solve a wide range of scientific and practical purposes: from forecasting the market of a specific petroleum product in a particular country or region to systematically studying the development prospects of the global oil market or the role of oil in the global energy balance. The existence of such a tool kit allows foresight studies to be carried out on the development of the oil complex taking into account prospective technological changes, and to evaluate the effect of developing already developed technologies on future demand for oil and petroleum products and identifying the most promising technologies that are capable of having the greatest impact on reducing demand. Analyzing how effective the impact of different variants of energy and technology policy on market development is also growing in importance.

## Conclusion

Innovative technologies in the automotive transport industry are capable of having and are already having a significant impact on the petroleum product market. From the perspective of impact on demand, these technologies could be classified as energy-saving or energy-efficiency technologies bringing about a reduction in the growing demand for oil by improving conventional vehicles and inter-fuel competition technologies allowing petroleum products to be replaced with alternative fuels.

The signs – which are already becoming clear – of a slowdown in demand for petroleum products under the influence of innovation require in-depth study, including through economic and mathematical modelling. Analyses of future demand for petroleum products taking into account technological developments require modernization of the existing evaluation methods.

Fig. 3. **Block diagram of the calculations in the SCANER modelling and information complex**




*Note.* The calculations in each block are by country (unit). The resource modules contain a more in-depth breakdown.

*Source*: [*Makarov et al.*, 2013].

The systematic tool kit proposed by the authors of this study makes it possible to combine the advantages and eliminate the disadvantages of different petroleum product demand forecasting methods by combining the advantages of the corresponding approaches into a single algorithm. This ultimately helps to markedly increase the quality of energy development forecasting to take account of the impact of technological progress.

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# Prospects for Telemedicine Adoption: Prognostic Modeling as Exemplified by Rural Areas of USA

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## Abstract

**Experts predict that in the majority of countries state healthcare expenditures will continue to rise. Usage of telemedicine applications — the use of information and communications technologies (ICT) in order to provide clinical health care at a distance — will help optimize the costs of healthcare in the long-term.**

**The main advantages of telemedicine include reducing the number of doctor's errors, saving both patients and physicians time, and improving the efficiency of healthcare organizations. It also ensures timely and high-quality services for large segments of the population living in remote territories with difficult socio-economic conditions, particularly rural areas.**

**The paper forecasts the adoption rate of telemedicine in US rural areas by using the Bass Model. The model is considered quite versatile as it can be used across a wide range of products and services. Nevertheless, the Bass model has some limitations related to how it estimates missing data. Calculation errors can be related to numerous barriers, which affect the adoption rate of telemedicine. These barriers include: high costs of production and exploitation of hi-tech equipment; physicians insufficiently prepared to adopt and use the latest technologies in their daily work; as well as possible concerns of patients about the quality of remote healthcare service.**

**Keywords:** telemedicine; remote areas; remote medical services; information and communication technologies (ICT); healthcare expenditures; the Bass model

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Healthcare is one of the most important sectors in any country for two main reasons. First, this is because it is related to people's health and their lives. Second, because medical care costs are high in both developed and developing countries. According to the Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group; the US Department of Commerce, Bureau of Economic Analysis; and the US Bureau of the Census, in the US, national health spending in 2011 was just over USD2,700bn. This was about 17.9% of the country's Gross Domestic Product (GDP), which was USD15,076bn [CMS, 2012].

US national expenditures on health is expected to rise. According to the Center for Medicare and Medicaid Services, it will reach USD4,638bn by the end of 2020, comprising about 20% of US GDP (will be USD17,775bn) by the same year [*Ibid.*]. Therefore, we need healthcare to take advantage of Telemedicine applications that reduce the cost of healthcare in the long-term. In addition, Telemedicine helps reduce doctor errors, and saves time for both patients and physicians. The US population has been annually increasing; during the last decade, it increased from 282 million in 2000 to 311 million in 2011, which is an increase of more than 9%. Meanwhile, healthcare expenditures increased almost double in the last 30 years, from 9.2% in 1980 to 17.9% in 2011. These data are plotted in Figure 1 below.

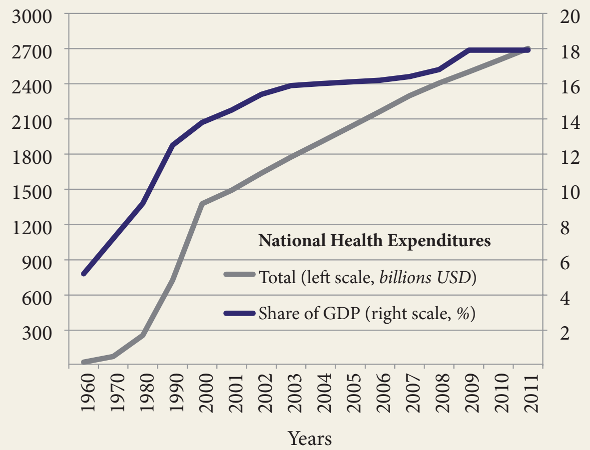
## History and Background of Telemedicine

Distance healthcare services have been in vogue for centuries, with healers using available resources to communicate with patients. For example, postal mail was one of the first tools of communication that was used followed by the telegraph, first used during the American Civil War [*Craig, Patterson,* 2005]. Soon the radio was used in healthcare for long distance international communication [*Stanberry,* 2000].

In 1924, science recorded one of the first conceptions of telediagnostic and televisit where a distance diagnostic examination of children was conducted using direct imaging [*Ramos,* 2010]. During the 1920s, Telemedicine was very useful, where physicians at the coast station assisted ships with medical emergencies in the middle of the ocean by using radios. Further, in April 1924, the 'Radio News' magazine included an article about telecare and put it on its cover page [*Ibid.*]. We can summarize the phases of telemedicine developments as shown below in Table 1.

Telemedicine introduced as an implementation tool to improve and support healthcare services will cause huge changes in healthcare organization [*Hu,* 2000]. The impact of telemedicine will reach all levels of healthcare organization from physicians and nurses to the bottom level. Physicians play a primary role for telemedicine users and their decision to adopt a new technology is the first step for the emergence and sustainability of telemedicine networks [*Cagnon et al.,* 2003; *Croteau, Vieru,* 2002].

Fig. 1. **The percentage of gross domestic product (GDP) on national health expenditure, and total national health expenditure, 1960–2011**




*Source*: [CMS, 2012].

Table 1. **Phases of Telemedicine development**

| Time Scale | Technology used | Examples/Description |
|---|---|---|
| Mid-19th century | Postal | Prescriptions and diagnosis exchanged between patient and physician by post. |
| 1835 | Telegraphy | Used during American Civil War to send casualty lists and order supplies |
| 1906 | Telephone | Electrocardiograms sent using telephone networks |
| 1920 | Radio | Seaman's Church Institute of New York — first organization to provide medical care using radio |
| 1950s onwards | Television and Space Technologies | Two way closed circuit television correspondence between Nebraska Psychiatric Institute and Mental Hospital in Norfolk |
| 1967 | Video conferencing | Station established at Massachusetts General Hospital/ Logan International Airport to provide emergency medical care to airport employees and travellers |
| 1990s onwards | Internet | Used in remote patient monitoring, store and forward modes using web for data transfer |
| 2000s onwards | Mobile phones and Satellite communication | Web-enabled mobile devices are used to transmit patient information from moving ambulances to hospitals |

*Source*: [*Makena, Hayes*, 2011].

As the practice of medicine has become more complex, it is increasingly difficult for physicians to provide the right care to patients every time without the support of modern health information technology. Like any modern endeavour, healthcare demands that the right information about the right person to be delivered to the right place and time. Evidence suggests that the use of information technology (IT) offers the industry tremendous potential for resolving some of its most important issues, specifically the rising number of medical errors, escalating costs, and care fragmentation [*Kuperman, Gibson*, 2003].

To improve the quality of medicine and minimize the possibility of adverse outcomes, healthcare places great hope in the potential of Health Information Technology (HIT). HIT in general and electronic health records (EHRs) in particular are viewed as tools to reduce medical errors, improve healthcare quality, and streamline operational efficiencies [*Frist*, 2005]. Moreover, it is considered foundational to the transformation of the US health system.

Such systems will support clinical decisions, grant patients and clinicians access to health records, improve the accuracy of those records, seamlessly integrate clinical and payment functions, and facilitate the collection, reporting, and analysis of quality data. In healthcare, the ultimate goal is to employ IT so that providers can ensure patients receive the highest quality of care and best outcomes [*DePhillips*, 2007]. IT can also enable the healthcare system to improve operational efficiencies and reduce costs.

A study done by the Agency for Healthcare Research and Quality (AHRQ) indicates that telemedicine is a small but growing movement and concluded that 'active programs demonstrate that the technology can work, and their growing number indicates that telemedicine can be used beneficially from clinical and economic standpoints' [*Trembly*, 2001].

After reviewing the literature the same study identified 455 telemedicine programmes, and about 80% of which are in the US. The top three common telemedicine activities for these programmes were consultations or second opinions (290 programs), diagnostic test interpretation (169 programs), and chronic disease management (130 programs) [*Casalino et al.*, 2003].

The doption of health information technology and systems for sharing information across providers has been slow, varying across practices and countries [*Ibid.*]. Traditionally, health IT (HIT) adoption has been slow because the industry itself is vastly different from most others. Further, it spends about 50% less on IT than most other sectors [*Bates*, 2002].

More than 40% of information technology (IT) developments in various sectors including the health sector have failed or been abandoned. One of the major factors leading to failure is inadequate understanding of the socio-technical aspects of IT, particularly the understanding of how people and organizations adopt information technology [*Kijsanayotin et al.*, 2009]. A recent literature review suggests that EHR adoption rates in the US are still quite low [*Jha et al.*, 2006]. Moreover, a survey by the Commonwealth Fund (CMWF) about how EHR is used by primary care physicians found that the US lags far behind many other industrialized nations in HIT use in ambulatory care [*Schoen et al.,* 2006].

The government has made this issue a priority. The Obama Administration's national coordinator for health information technology (HIT) David Blumenthal, MD, MPP has said: 'Nothing could be more important than how we manage health information', and '"Information is the lifeblood of medical practice. It truly sustains and supports practice, and makes it possible for practice to occur in a science-based way' [NQF, 2010].

## Definitions and Categories of Telemedicine

The definition of telemedicine is different from organization to organization and varies between industry and academic perspectives. Thus there are many definitions and categories of Telemedicine depending on the background and the perspective. According to the American Medical Association (AMA) the definitions of 'telemedicine' have developed over time starting from a wide definition to a narrower one [*Tan et al.,* 2002].

The World Health Organization (WHO) defines telemedicine as 'The delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities'. [WHO, 2010] According to The European Commission (EC), 'Telemedicine is the rapid access to shared and remote medical expertise by means of telecommunications and information technologies, no matter where the patient or the relevant information is located.'[EHTEL, 2008]

The American Telemedicine Association (ATA) defines telemedicine as 'The use of medical information exchanged from one site to another via electronic communications to improve patients' health status' [ATA, 2015]. From the three different definitions of Telemedicine, we may conclude that there are three defining factors of Telemedicine: improvement of quality of healthcare, use of information technology, and distance.

Just as its definition differs between organizations and sectors, the categories of telemedicine also vary depending on the background and perspectives of any given theoretical or empirical study.

According to the World Health Organization (WHO), based on the time of the information transmitted and the interaction between patient and health professional, telemedicine can be classified into two basic types: store-and-forward (asynchronous) and real time (synchronous) [*Craig, Patterson,* 2005; WHO, 2010]. Another classification by the American Telemedicine Association (ATA) classified telemedicine services into five main categories: specialist referral services, patient consultations, remote patient monitoring, medical education, and consumer medical and health information [ATA, 2015].

After reviewing many pieces of literature on the categorization and classification of telemedicine, we decided to group all these categories and classifications into three main categories: Real Time (Synchronous), Store-And-Forward (Asynchronous), and Remote Monitoring.

### Real Time (Synchronous)

When the patient and physician are located in two different locations at the same time and by using interactive videoconference equipment, they can interact as they do in traditional face-to-face practice [*Rao, Lombardi,* 2009] it falls under the category 'Real Time telemedicine.' This may include phone conversations, online communication, and home visits.

Some devices connected to the computer enable physicians to get more information about their patients such as hearing the patient's heartbeat with the use of a stethoscope. Specialized fields such as psychiatry, internal medicine, rehabilitation, cardiology, pediatrics, obstetrics, gynaecology, and neurology have benefited enormously from this practice.

### Store-And-Forward (Asynchronous)

In this category, both the patient and the health specialist are located in two different times and locations. Store-and-forward telemedicine involves acquiring medical data (text, data, images, audio, biosignals, etc.) from the patient and then transmitting this data to a doctor or medical specialist at an appropriate time to be evaluated by a specialist at another time and location.

This category requires a good medical record system with a flexible and secure method of receiving and transferring medical information such as x-ray and digital photography. The top three specialized fields that widely use this type of store-and-forward consultation are dermatology, radiology, and pathology.

A good example of store-and-forward consultation is x-rays where a provider at a remote site typically takes x-rays of the patient and then uploads those images to a secure server along with other clinical information. Afterwards, a specialist at another time and location logs in, reviews both the x-rays and the clinical information, and writes his/her treatment recommendations [*Makena, Hayes*, 2011].

### Remote Monitoring

Remote patient monitoring enables medical professionals to monitor a patient by remotely using various technological devices. Remote patient monitoring uses devices to remotely collect and send data to a health agency or a remote diagnostic testing facility (RDTF) for interpretation. Such applications might include a specific vital sign, such as heart disease, diabetes mellitus, asthma, or a variety of indicators for homebound patients [ATA, 2015]. According to Field and Grigsby, 'the continuing improvements in technology have made home monitoring applications more clinically useful and easier for patients to use without onsite help from healthcare personnel' [*Field, Grigsby*, 2002].

## Advantages of Telemedicine

Telemedicine has many advantages for patients and providers, as well as the economy. Demand for telemedicine has continued to increase among patients and providers. Patients like telemedicine for two main reasons — it saves time and is convenient. Providers, on their part, prefer telemedicine as it facilitates better monitoring and early treatment. In general, this will improve the healthcare system and reduce the cost of the treatment. We will talk in some detail about each of these three aspects of the telemedicine system: patients, providers and economics.

### Patients

The benefits of using telemedicine among patients relate to time, money, and quality. The traditional healthcare system requires patients to travel physically from, say, their rural home to metropolitan areas in order to consult a medical specialist. By using telemedicine, patients can consult a city doctor or the rural primary care provider from their home. As we know the United States has large rural and suburban areas, and telemedicine works to save millions in travel expenses.

Moreover, quality is one of the biggest advantages of telemedicine, as patients in rural areas can access high quality healthcare services. Telemedicine aims to improve healthcare quality by increasing collaboration between providers and patients.

### Providers

With the help of telemedicine, providers can gain benefits such as access to information, decreased medical errors, and increased work efficiency. In business, time is money, but in the Emergency Room, time is life. Telemedicine provides immediate access to information for patients and on medical topics that is fast and accurate at the same time.

In addition, telemedicine will improve the accuracy of diagnosis, which would reduce medical errors, an important consideration for the medical community. One of the advantages of this system is 'tele-assistance', where a physician can get either a second or specialist opinion on their patients' diagnosis. Correct diagnosis the very first time has many benefits for both patients and hospitals, as it reduces the average recovery time and the use of unnecessary medicines. This ultimately reduces the costs borne by both patients and hospitals.

Continual education is very important in any field, and is essential in healthcare. Telemedicine can enhance the providers' learning and keep them up to date about any medical topic. Physicians can improve their education with the latest knowledge without leaving their office, thus saving providers time and money.

**Economy**

The economy will benefit from telemedicine as it will enhance the local economy and increase business retention and recruitment. Telemedicine can also improve the healthcare services' delivery system. New telemedicine technologies increase home health providers' efficiency by reducing travel time to patients' homes. In addition, patients have a greater chance of consultation with specialists by dint of new telemedicine technologies.

Furthermore, some people in rural areas cannot travel outside the community for training or studying. Telemedicine can provide high quality healthcare education and training partnership with educational institutions with the use of videoconferencing tools in rural communities. This will help cover the shortage of medical staff in rural hospitals by hiring more local people. To sum up, telemedicine provides quality healthcare services for people in rural areas, as well as improves the quality of healthcare services in both metropolitan and rural areas.

## Telemedicine in Rural Areas

According to a recent study by Dr. Alexander Vo of the University of Texas Medical Branch, one of the biggest challenges facing the US healthcare system is the provision of quality care to large segments of the population who do not have access to specialized physicians. These areas are often isolated due to geographical limitations or socio-economic conditions. Dr. Vo supports the various benefits that telemedicine brings to rural areas. One of the positive benefits of building high-speed networks is that they allow for real-time monitoring and interactions with patients without requiring their physical presence at a care center.

He argues, 'The use of technology to deliver healthcare from a distance, or telemedicine, has been demonstrated as an effective way of overcoming certain barriers to care, particularly for communities located in rural and remote areas.' He also asserts, 'telemedicine can ease the gaps in providing crucial care for those who are underserved, principally because of a shortage of sub-specialty providers.' [*Vo et al.*, 2011]

According to the 2010 US Census, about three out of ten Americans live in a rural area or a very small city; and 28.8% of Americans reside in a rural area or city of between 2,500 and 50,000 residents. The population living in rural or unincorporated areas totalled 59.5 million in 2010, or 9.5% of the population.

In 15 US states, more than half of the population lives in rural areas or in towns with less than 50,000 inhabitants. The most rural state is Vermont, with 82.6% of its population in either rural areas or small cities. 55.5% of Alaska's population lives in rural areas or small towns, whereas Hawaii has the national average (28.5% of its population in rural areas or small towns).

The objective of this paper is to forecast the adoption rate of telemedicine in a country's rural areas by using the Bass Model, using data from the US as an illustration. An advantage of the Bass model is that it can be employed even when there are no data about the phenomenon being studied. The data used in this model are based on data of other products, which have already been introduced in the market. Then, the data about existing products or technologies are related to this new product.

## Bass model

Before introducing the Bass model equation, let us define some important terms:

- $N(t)$ is the total or cumulative number of consumers who have already adopted the new product through period $t$
- $N(t-1)$ is the cumulative number of adopters for the new product through the previous time period (i.e., $t-1$)
- $S(t)$ is the number of new adopters for the product *during* the time period $t$ and can be expressed as $N(t) - N(t-1)$

where $N$ is the total number of consumers who have already adopted the new product through period t. There are three key parameters in the Bass model *m, p, and q*, where $m$ is the market size, $p$ the coefficient of innovation, and $q$ the coefficient of imitation.

The basic equation for the Bass model:

$p + (q/m)\, N\,(t-1)$

The likelihood of purchase by a new adopter in time period *t.*

$m - N\,(t-1)$

Is the number of consumers who have *not* previously adopted the new product by the start of time period *t*; this is the pool from which new adoptions in the current period can occur.

In its simplest form, the Bass model looks as follows:

$S\,(t) = [p + (q/m)\, N(t-1)]\,[m - N(t-1)]$

Where $S\,(t)$ — the number of new adopters during time *t.*

However, the estimated data cause errors of forecasting in this model. Hence, the Bass model is developed into a generalized Bass model by adding the price of the new product into the model in order to identify the likely adoption of new products when promotions and prices influence the market.

The number of new adopters during time *t:*

$S(t) = [p + (q/m)\, N(t-1)]\,[m - N(t-1)]\, Z(t)$

Where $Z(t) = 1 + \mathrm{a}\,[P(t) - P(t-1)]\, P(t-1)$

The Bass model can represent distinctly different patterns of adoption — from slow growth to instant hits. Different products include state-of-the-art consumer electronics to such common tools as the toaster and the hair dryer. Distinctly different fields include those medical breakthroughs such as artificial insemination and rural innovation [*Bass et al.,* 1994]. Bass model is a predictive model that allows us to forecast future adoptions, even when no data exist for our innovation.

We can use the parameters from the database of products that had similar characteristics when they were adopted. The model was developed for predicting sales of durable goods such as stoves, refrigerators, dishwashers, and air conditioners. These are products that, after initial adoption, are not repurchased for many years. This enabled a simple representation of the adoption process that has proven to be very robust. It works well because the assumptions in the Bass model are based on the results of diffusion research [*Bass et al.,* 1994; *Bass,* 2004]. The model has been used across a wide range of product and service categories.

However, the Bass model can still make errors and project uncertainties due to its method of estimating and assuming unknown data. Thus, before selecting the forecasting method, forecasters should choose the method most appropriate for their data [*Ofek,* 2006].

## Estimating the Parameters *m*, *p*, and *q*

### Estimating *m* (Market Potential)

It is best to estimate *M* independent of the model. In most cases, the management has a judgment and a strong intuitive feel about the size of the market, although it may be optimistic. If not, this estimate can often be obtained from analyst forecasts, marketing research, or can be calibrated by testing the logic and assumption behind the estimate (e.g. using the Delphi Method). Pharmaceutical firms, for example, often have rather precise estimates of the incidence of a disease or ailment. It is often worthwhile to obtain an independent third party estimate to calibrate and minimize the risk of bias and group think [*Bass,* 2004; *Norton, Bass,* 1992].

Some research finds it useful to treat *M* as a variable. Assuming a constant growth rate *g* over the modelling period, has often produced a more accurate and believable forecast. This is an indirect way to reflect the growth that occurs in a market when the average price drops and the demand for the product/service expands. It is also probably best to treat *M* as fixed because numerous studies have shown the simple model to be very flexible and robust [*Bass,* 2004].

### Estimating *p* и *q*

Most applications of the model make plans and decisions before the product/service is introduced in the market. No sales data thus exist with which to estimate *p* or *q*. Managers do not have an intuitive estimate of *p* and *q*. The practical approach is to use the coefficients estimated from the diffusion patterns of analogous products. The average values across a wide range of products is *p* =

Table 2. **Bass Model Parameter Estimated based on similar products**

| Product | Period of Analysis | $p$ | $q$ |
|---|---|---|---|
| Ultrasound imaging | 1965–1978 | 0 | 0.534 |
| Mammography | 1965–1978 | 0 | 0.729 |
| CT scanners (50–99 beds) | 1980–1993 | 0.44 | 0.35 |
| CT scanners (>100 beds) | 1974–1993 | 0.036 | 0.268 |
| Weighted Average for Telemedicine | | **0.119** | **0.47025** |

*Source: calculated by the authors.*

0.03 and $q$ = 0.38. Industry-specific data are available for consumer electronics, appliances, medical equipment, pharmaceutical drugs, semiconductors, agricultural equipment, etc. [*Bass et al.,* 1994].

The best process is to use analogues based on similarities in expected market reactions rather than the product category. For example, the adoption of satellite radio is more likely to be similar to cable TV than the adoption of radio. The first generation of radio had no direct competition and was free. Satellite radio has adopted a subscription-pricing model and faces a direct competitor; these are similar dynamics that cable TV faced in converting consumers from free TV to cable service. If necessary, we can consider a weighted average of $p$ and $q$ values across several categories or apply a Bayesian weighting that can be updated as new information is collected [*Bass,* 2004; *Ofek,* 2005].

In order to forecast the adoption rate of telemedicine in American rural areas, we have to estimate the three parameters $m$, $p$ and $q$.

### Determination of Total Market Size ($m$), Selection of Coefficients of Innovation ($p$) and Imitation ($q$)

First, we need to estimate $m$ — the total potential market size. According to the Economics Research Service at the United States Department of Agriculture, there are about 51 million ($m$ = 51 million) Americans living in rural areas as of July 2011.

The Coefficients of Innovation ($p$) and Imitation ($q$) should be developed by the coefficients ($p$ & $q$) of existing products at the time, according to which the products are selected to estimate telemedicine coefficients. The products that are used for the estimations should have similar data to telemedicine. There are four kinds of medical equipment products that we can use to estimate these two parameters: ultrasound imaging, mammography, CT scanners (50–99 beds), and CT scanners (>100 beds). Table 2 below sets out the weighted average values as: $p$ = 0.119 and $q$ = 0.47025.

By using the weighted average $p$ = 0.119, $q$ = 0.47025 and $m$ = 51 million, we can then forecast the adoption as shown below.

### Estimation of Demand Forecast

We used own estimates of $m$, $p$, and $q$ to illustrate how fast or slow the adoption of e-books will occur. The product life is expected to be 22 years.

$m$ = 51 million
$p$ = 0.119
$q$ = 0.47025

At $t$ = year 1, $N$ (t–1) = 0

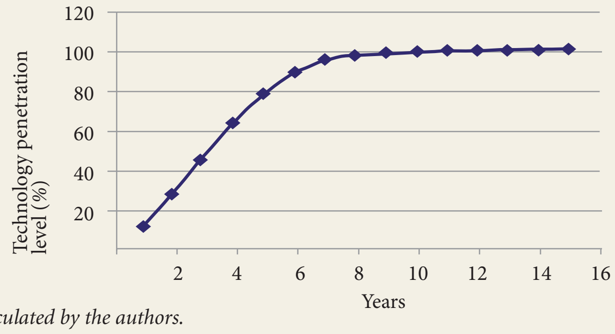
Then, $S(t) = [p + (q/m)\,N(t-1)][m - N(t-1)]$
$= [0.119 + (0.428{*}0)]{*}(51-0)$
$= 6.0690$

And $N(t) = S(t) - N(t-1)$
$= 6.0690 - 0$
$= 6.0690$

From Figure 2 and Table 3, we can estimate the adoption rate of telemedicine. In rural US, the adoption rate will rapidly increase from year 1 to 7, followed by a decline. By year 15, the adoption rate will be 100%.

Moreover, the coefficient of innovators is smaller than the coefficient of imitators. It causes the slope of the curve to be shallow, meaning that in the case of adoption of telemedicine in rural US, imitators are able to gauge gaps or opportunities while launching their products to compete in the market.

Fig. 2. **Bass Model Market Penetration Curve**




*Source: calculated by the authors.*

Table 3. **The Bass model forecasting with $m$= 51 (in million) $p$=0.119, and $q$=0.47025**

| *t (years)* | *N(t)* | *S(t)* | *N(t)/m (%)* | *S(t)/m (%)* |
|---|---|---|---|---|
| 1 | 6.0690 | 6.0690 | 11.90 | 11.90 |
| 2 | 13.9301 | 7.8611 | 15.41 | 27.31 |
| 3 | 23.1028 | 9.1727 | 17.99 | 45.30 |
| 4 | 32.3653 | 9.2625 | 18.16 | 63.46 |
| 5 | 40.1439 | 7.7786 | 15.25 | 78.71 |
| 6 | 45.4542 | 5.3103 | 10.41 | 89.13 |
| 7 | 48.4385 | 2.9843 | 5.85 | 94.98 |
| 8 | 49.8873 | 1.4489 | 2.84 | 97.82 |
| 9 | 50.5316 | 0.6442 | 1.26 | 99.08 |
| 10 | 50.8056 | 0.2740 | 0.54 | 99.62 |
| 11 | 50.9198 | 0.1142 | 0.22 | 99.84 |
| 12 | 50.9670 | 0.0472 | 0.09 | 99.94 |
| 13 | 50.9864 | 0.0194 | 0.04 | 99.97 |
| 14 | 50.9944 | 0.0080 | 0.02 | 99.99 |
| 15 | 50.9977 | 0.0033 | 0.01 | 100.00 |

*Source: calculated by the authors.*

## Conclusion

The Bass model is one of the best forecasting tools for predicting the adoption of a new product. However, there will still be room for error in this model. On another note, several barriers to adoption will affect the implementation rate of telemedicine. We group these barriers into four main categories: financial, technical, logistical, and cultural.

The top three factors under the financial barriers are start-up costs, ongoing costs, and reimbursement or incentives. Telemedicine consists of high technology systems that entail complex hardware and software that demand a specific level of computer skills from providers, physicians, and patients. Factors leading to technical barriers include a lack of computer skills, training and technical support, and infrastructure.

The logistical barriers of telemedicine represent a significant barrier to its widespread implementation. Regulatory issues have been identified as a barrier to implementing telemedicine programs. According to a recent survey, putting in place licensed out-of-state physicians, credentials of medical staff privileges at individual facilities, and malpractice liability are the three significant impediments to a telemedicine solution.

Cultural barriers are some of the most important barriers to the widespread adoption of telemedicine. They can be categorized into two main kinds: acceptance by physicians and patients' satisfaction. Physician acceptance includes everything related to their discomfort in using novel technological equipment in their daily practices and treating patients from a distance. Physician acceptance of telemedicine also includes quality, personal preference and previous experience, control of patient care, convenience, and reimbursement potential. Patient satisfaction includes anything that could decrease their satisfaction while using telemedicine. Patients in general are worried about the quality of remote healthcare services. F

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# The Epistemological Foundations of Music Piracy in the Digital Marketplace

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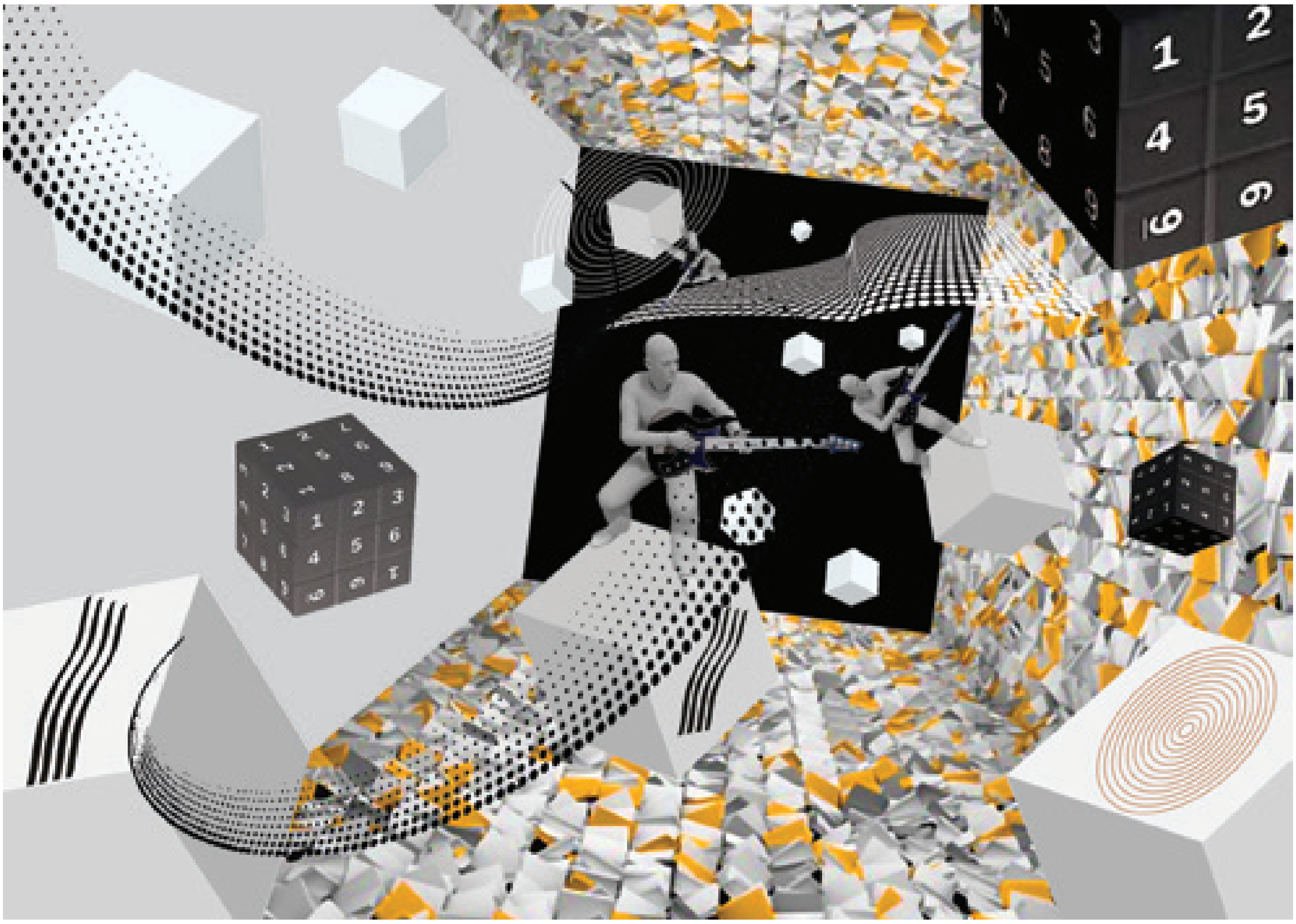

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## Abstract

**This paper examines the fundamental epistemological gap between the consumers and producers of digitally based products. Using the music industry and the significance of digital products in this arena as a case study of evolving relationships between buyers and sellers, we evaluate the nature of 'piracy' from multiple perspectives: creators, intermediaries, distributors, and end consumers.**

**Our study centres on the epistemological boundaries of these agents and actors, using existing evidence and qualitative research to examine the nature and limits of the epistemological reach of agents and actors in this digital marketplace. Our theoretical model is an adapted and applied version of Domain-Generality and Domain-Specificity in Personal Epistemology.**

**We find a series of epistemological dissonances, driven by differing levels of understanding about (and access to) the underlying technological, legal, and social structures of an evolving marketplace. As a result of instability, these structures inevitably create various epistemological boundaries. Using the developed analytical framework, the case study of music piracy illustrates how identifying epistemological dissonance helps sellers develop strategies that could minimize the impact of piracy on their revenue streams.**

**Keywords:** misic piracy; digital marketplace; personal epistemology; domain-generality; domain-specifity; epistemological gap; congruous beliefs; incongruous beliefs

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This paper argues that those interested in marketplace changes should direct their attention to evidence of where participants in a marketplace begin to display specific behaviours, which are incongruous, or at odds with their overall beliefs. The example chosen to illustrate this is the phenomenon of 'piracy' in the music industry, an activity that has been greatly facilitated by the advent of technological innovation and accidents in infrastructure development. This has been examined from number of perspectives — moral [*Al-Rafee, Cronan*, 2006], ethical [*Yoon*, 2011], legal [*Houle,* 1991] and economic [*Ku,* 2002]. These perspectives are of value to actors and agents in the digital music marketplace as illustrated by the chief executive of the International Federation of the Phonographic Industry (IFPI) Frances Moore in 2011: 'As we enter 2011, digital piracy, and the lack of adequate legal tools to fight it, remains the biggest threat to the future of creative industries.' [IFPI, 2011].

Using the specific analytical tools of law, psychology, sociology, economics and business, we can generate insights on the causes and consequences of piracy [*Wolfe, Higgins*, 2009]. However, in order to determine the root cause of piratical behaviour in the digital medium it is necessary to consider the belief systems that determine the behaviour of individuals. Accordingly, this examination uses the perspective of epistemology by using a theoretical model to deconstruct testimony and identify epistemological boundaries. It concludes that attempting to understand incongruous behaviour through an epistemological lens may be more productive than more subject discipline-specific approaches.

## Context

The music industry has evolved almost alongside changes wrought by the introduction of new computer-mediated technologies [*Alexander*, 1994]. From the development of digital recording technologies to the transmission and sharing of digital files the music industry has colonized the digital space. Often commercial organizations within this marketplace have embraced innovation without seeming to consider the ultimate consequence of their actions. The advent of cheap tape recording technology created a major crisis of copyright control; vinyl records and pre-recorded tapes could now be duplicated easily and quickly with no credible prospect of statutory censure for the copyright thief. Some hardware manufacturers, such as Amstrad [*Hayhurst,* 1985], recognized that this activity was prevalent in the music market and deliberately produced equipment to facilitate this process. With the advent of Compact Discs (CDs), the response from hardware manufacturers was further supplemented by innovative software engineering that enabled even more rapid reproduction of material on CDs using Personal Computers (PCs). Music consumers became more conscious of the fact that a discrete material object whether it be a vinyl disc, a magnetic tape, or plastic CD was no longer necessary. What made this latter stage of evolution even more critical to the revenue streams of incumbent music industry businesses was the development of a new infrastructure technology — the Internet. The Internet was independent of, yet critical to, the dissemination of digital material. Whilst incumbent purveyors of pre-recorded music could not have anticipated the scale of illegal copying and distribution by their customer base, the behaviour of consumers was fundamentally the same. As mentioned above, the scale of the illegal copying of recorded music accelerated when recording technology that did not require either specialist skills or expensive equipment became widely available to the consuming public. The notable dip in record sales in the late 1970s was attributed to such taping, and inspired the (in)famous 'Home Taping is Killing' music campaign by the British Phonographic Industry, representing the collective interests of UK recording companies [*Yar*, 2007, p. 96].

Even by the late 1970s, producers and distributors were fully aware through prior experience that new accessible technologies facilitated piratical behaviour; they developed Digital Rights Management in an attempt to protect copyrighted material [*Subramanya, Yi*, 2006]. However, this approach could not have anticipated that the boundaries of technological innovation and creativity were going to outrun and out-innovate a value chain predicated on historical structures [*Sudler*, 2013].

## Analysis

A historical deconstruction of the relationship between purveyors and consumers of music shows that customers will copy and disseminate music if they realize they can do so with ease and without censure. 'Although special coding, fingerprinting, and other methods and techniques can protect software programs, no technological protection system yet devised is completely effective. In addition, despite the clear specification of property rights, piracy still can exist due to the high cost of policing consumer behaviour and enforcing the law. As such, it is likely that software piracy will remain a prevalent and a serious problem into the foreseeable future' [*Shin et al.*, 2004, p. 103].

Yet there are limitations, and this simple transactional view cannot fully account for the changing technological, social, and economic contexts in which the music industry and its value chain exist [*Rayport, Sviokla*, 1995]. In any marketplace, whose processes of value creation and exchange have radically altered [*Parry et al.*, 2011] there may be no meaningful way in which the behaviours and actions pertinent to one context may be equated with those of another. Consider the act of copying music. In the digital environment, it can be a simple process of acquiring and engaging the correct software, which can automatically copy the music and save it to a desired destination ready for use within seconds. In contrast, the act of copying taped material required the acquisition of suitable media, another tape, a physical copy of the source material, and hardware capable of transferring material from one source to another. In addition, source material had to be purchased at some point or otherwise acquired from a willing donor. If borrowed, both parties became complicit in an act of theft and this involved a social consensus, which in turn brought risk to the participating parties: because a physical transfer of property was at the core of the transaction, it remained clear to both parties that this was an identifiable transgression. With this older technology, there were arguably far more barriers creating opportunity for a physical pause and for considering the financial, moral, and ethical choices being made at each phase of the act. Digital copying, in contrast, has removed much of this social vector by re-socialising the process at the point at which the copy is made. Sean Ebare succinctly summarises this significant difference: 'While building trust between online communicators may take longer online than in F2F [Face to Face] environments [due to reduced cues], online communication environments are in many ways a safe refuge for the expression of identity and self–concept, even when that identity is viewed as taboo in the offline world' [*Ebare*, 2005].

The illegal acquisition of copyrighted music has a radically different social and interpersonal context in the digital age. Conversely, the process of illegally sharing music digitally has lost the immediate and physical communality of purpose that added legitimacy to the act of copyright theft.

## Conceptual Framework

Individuals who are self-confessed music pirates often hold contradictory views on the nature, motivation, and assumed consequences of their actions [*Bernstein*, 1999; *Hill*, 2000; *Janssens et al.*, 2009]. What is less clear is the conceptual process by which behaviours that contradict a wider ethical and moral consideration of societal responsibility are manifest and consistently executed. Why do normally law-abiding members of society who would find theft in the physical domain repugnant, find it acceptable in the digital domain to commit theft illegally downloading copyrighted music? A detailed analysis of intent led to the construction of a decision-making matrix that details and gives weight to such factors as economic considerations and legal and ethical frameworks [*Coyle et al.*, 2009]. Their discussion concluded that only one attitudinal factor was significant in predicting whether someone had pirated in the past *and* whether someone intended to do so in the future. The basic and general consideration of whether pirating is ethical and/or criminal, captured in the legal/ethical factor, predicted past behaviour and future intentions. Clearly, the young people in the sample judged the ethical and legal aspects of music piracy to be essential considerations when pondering this issue [*Coyle et al.*, 2009, p. 12].

Whilst this is useful, it does not explain why the root cause of this consideration of legal and ethical factors should frame this decision-making process. One approach for further analysing the basis of this behaviour is the psychological approach which has as many perspectives as there are sub-disciplines within the field, such as social cognitive and motivational theories [*Denegri-Knott*, 2004; *Gopal et al.*, 2004; *d'Astous et al.*, 2005; *LaRose, Kim*, 2006; *Wingrove et al.*, 2011]. Whilst these are insights that provide potential models for examining and, perhaps influencing behaviour, these too have limitations in that they do not fully examine the foundations of the belief systems that underpin the psychological superstructure [*Goldman*, 1985]. The manner in which belief and knowledge is structured fundamentally determines behaviours in more specific societal contexts such as the legal and ethical [*Feldman, Lynch*, 1988]. In order to further examine this, a theoretical approach that attempts to describe how epistemic beliefs are layered and subject to contextual factors could have the potential to explain how such contradictory behaviours give rise to the observed discontinuity. There are several similar approaches, in particular those of *Chiou et al.* [2005] and *Shang et al.* [2008], which seek to apply theoretical frameworks to explain this behaviour, contributing significantly to the development of the debate. Accordingly, the core conceptual approach of this paper draws from and adapts Theory of Integrated Domains in Epistemology (TIDE) framework, developed by Krista Muis and her colleagues [*Muis et al*, 2006]. The TIDE framework examining differences and communalities across academic disciplines is also used to understand how dominant epistemic modes influence the nature of pedagogy. It addresses how individuals' epistemic beliefs operate in various contexts: the larger socio-cultural, academic, and instructional contexts [*Ibid.*, p. 2].

In adapting this model, beliefs in the academic domain are substituted for beliefs derived from the digital domain. In the original model, we make it clear that it is important to determine clearly, 'what is meant by academic domain knowledge?' [*Ibid.*, p. 10]. We use Patricia Alexander's work on domain knowledge (1992) and further adapt this by specifically defining the application of domain knowledge in an academic context. Academic domain knowledge is defined as '…a body of knowledge that individuals possess about a specific field of study. This body of knowledge is comprised of conditional knowledge (knowing where and when), procedural knowledge (knowing how) and declarative (knowing that) knowledge' [*Alexander*, 1992, p. 10].

This notion of a 'body of knowledge' Muis et al. apply to that which is derived from and is constructed by the wider instructional/societal context of an individual. The normative strictures and guidance determined by the educational, social, and cultural socialization process in itself form a domain of knowledge. This is useful as it provides a basic framework within which further domains of knowledge can be subdivided in order to meet the analytical demands. So for the purposes of this study, the original model can be redrawn to examine how an individual conceives the 'music industry'. This will help determine the boundaries between this specific knowledge and its relationship to wider epistemic fields. For example, if an individual, in their wider socio-cultural epistemic understanding, believes that theft of property is wrong, this could be at variance with their epistemic grasp of what constitutes theft in the digital domain. A belief in the existence of theft may not cross the boundary from the socio-cultural epistemic domain to the epistemic domain that governs belief about and action in the digital domain.

The following overview of the TIDE framework will help to contextualize its use and adaptation. Muis et al. begin by defining the outer boundaries of individual epistemic knowledge in the socio-cultural domain, a product of 'enculturation' in which 'individual's beliefs may be shaped by their surrounding culture and are by-products of given social contexts' [*Ibid.*, p. 32]. There are several social and cultural influences that contribute to this enculturation, such as the influence of parents, peer groups and educational environments. These 'general epistemic beliefs form an all-encompassing background, within which more context-specific epistemic beliefs are situated. In the chronological development of an individual's epistemological awareness this is the first domain to emerge within which "children begin to develop naïve theories of knowledge"' [*Ibid.*, p. 34].

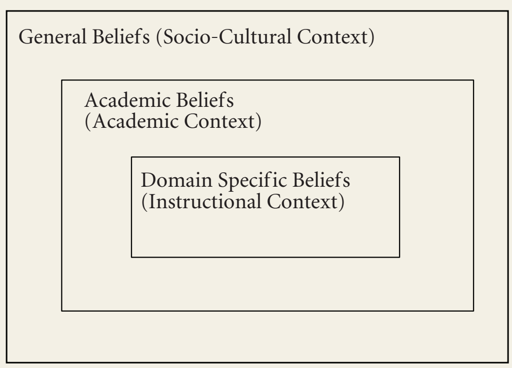
In the model 'Academic epistemic beliefs', there are those that emerge when 'individuals enter an educational system' [*Ibid.*, p. 35]. Whilst these beliefs are derived from the general socio-cultural context over time through the individual's acquisition of experience specific to the educational environment, education creates a distinct domain of knowledge, and is derived from and located within this class of experience. As an epistemic domain, academic beliefs become more pronounced and distinct as the individual progresses through higher levels within the educational system until, at the level of specialization, 'more developed individuals are primarily influenced by the predominant epistemic patterns of their domain of study' [*Ibid.*, p. 36]. However, Muis et al. recognise that in the context of academic knowledge, 'student's domain of specific epistemic beliefs are not entirely reflective of the dominant epistemologies of those domains' [*Ibid.*, p. 36]. Situated within this academic context is an instructional context, which derives from the individuals' personal and unique experience of the classroom and other elements of the educational process. In the context of education, Muis et al. note improved congruence between instructional beliefs and the wider academic structure of belief as students progress though successively higher educational stages, until the point at which graduates in a specific discipline hold personal domain specific beliefs that are almost fully congruent and aligned with the academic discipline or context within which they study or work. Furthermore, the more congruent these views are, the more likely that the epistemic beliefs derived from the instructional and academic domains will inform and influence epistemic beliefs in the wider socio-cultural domains.

The TIDE framework recognizes that these beliefs evolve and mutate over time, and that in particular the individual's instructional context is subject to developmental progression and moreover, in this multi-dimensional model, there is an endless interaction between these domains. Nevertheless, the theoretical conception of distinct elements of epistemological belief does provide a structure and process that can be used to explain how and why individuals hold seemingly contradictory epistemic beliefs. Congruence and incongruence co-exist [*Bendixen, Rule*, 2004]; within the instructional domain, the individual's knowledge is not fully in accordance with the wider academic context of the field or discipline within which they have been en-cultured. It is this particular feature of the TIDE framework which is of particular use in explaining dissonances between epistemic beliefs and action.

Figure 1 presents a representation of TIDE framework. The temporal dimension has been omitted in order to clearly illustrate the relationship between the nested epistemic domains.

For the purposes of this analysis of epistemic beliefs in the digital domain, the original TIDE model is transposed into a depiction of the relationship between the wider socio-cultural context and new core 'domain-specific' beliefs appli-

Fig. 1. **The TIDE Framework**




*Source*: [*Muis et al.*, 2006].

cable to the digital environment. Accordingly, 'Instructional context' is replaced with the 'Interface context' in order to specifically identify actions that take place at the point at which the user interfaces with the hardware and software required to access digital artefacts. Moving outwards into more general domains, the academic domain is redefined as the 'digital domain', or the entire class of hardware and software products and processes constituting the wider ecology of the digital industry. The latter comprises the multiplicity of delivery systems (hardware, networks), the processes used to construct digital product (software), and the promulgation of this class of product (marketing, advertising, promotion). The socio-cultural context remains essentially the same. This is the critical advantage of adopting the TIDE framework; it provides a conceptual map, which can be adapted to examine a wide range of specific belief systems within the context of wider societal beliefs. Here we are specifically examining the epistemic beliefs that derive from engagement with digital technology through the lens of actions and attitudes toward digital music piracy. The base structure could however also be used to examine video piracy and other forms of misappropriation of digital artefacts. This adaptation and development of the TIDE framework schematically identifies where the boundaries between domains reveal either congruous or incongruous beliefs (Figure 2, Table 1).

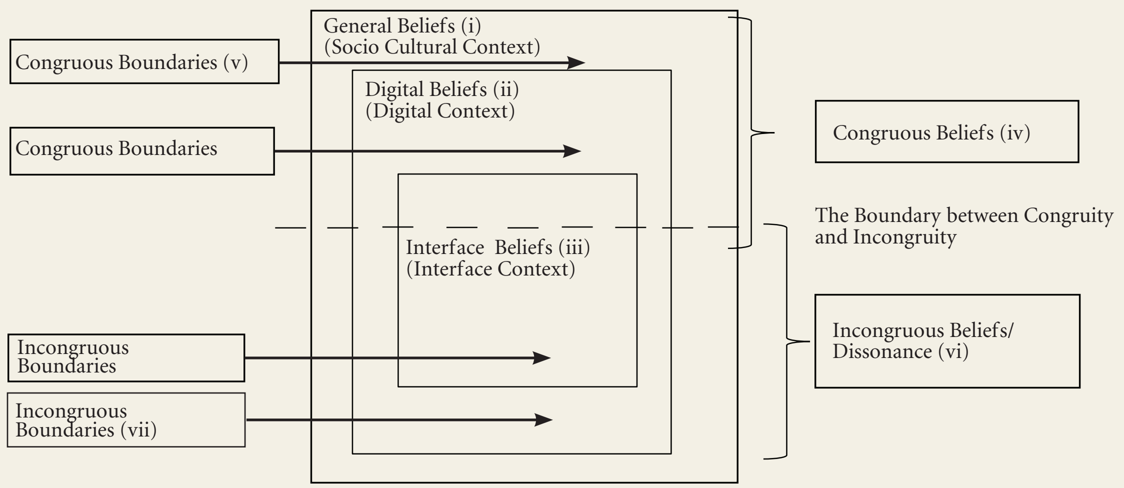
To test this model, three statements from individuals, who are self-confessed music pirates and whose confessions are available in the public domain, have been deconstructed. The sources are: *The Confessions of a Teenage Music Pirate* [YPulse, 2011], *Confessions of a Music Pirate* [*Hurewitz*, 2002], and *Confessions of a Convicted RIAA Victim Joel Tenenbaum* [*van der Sar*, 2010]. To apply this model, it is advantageous analytically to focus on one political jurisdiction in order to establish some epistemic boundaries with a degree of cultural homogeneity. This will mean that we can assume that the language used in textual evidence has a fundamentally similar meaning, in particular to limit cross-contamination of underlying societal general beliefs. However, as this is a speculative application and adaptation of an analytical model, this is best left for a more developed iteration of the technique.

## Application of the Model

The model can be illustrated as a single axis, which enables text to be deconstructed and classified along this axis, detailed in Table 2.

A table is created under which statements, either congruous or incongruous at these epistemic boundaries, are listed. The first analysis takes the form of a simple count of congruous and incongruous beliefs, located at the boundaries of these overlapping epistemological domains, generated from a reading of the

Fig. 2. **The adapted TIDE Framework**




*Source*: compiled by the authors.

Table 1. **Key terms of the adapted TIDE Framework**

| Term | Description |
|---|---|
| (i) General Beliefs | These are beliefs that are derived from the wider socio-cultural context, which includes general beliefs about the digital context, 'such as the home environment, in interaction with peers, in work related environments' [*Muis et al.*, 2006, p. 33]. |
| (ii) Digital Beliefs | These are the beliefs that an individual acquires through interaction with, and immersion in the digital environment. This domain includes modes of passive consumption of digital media such as the viewing of television programmes and listening to radio programmes. Added to this are more interactive modes of consumption, activities that are now integral to accessing digital media such as web browsing, the use of smartphone technology, and the use of public access facilities. From these passive and interactive modes, the user acquires knowledge of the skills and techniques required to access the utility of digital media. |
| (iii) Interface Beliefs | This refers to the beliefs derived from the specific set of skills and knowledge required to access a particular class of products. This is distinguished from Digital Beliefs by the peculiar understanding required to actively engage with an interface designed to enable access to and/or acquisition of a particular class of digital products, such as sound or video files. |
| (iv) Congruous Beliefs | These are the beliefs from each of the domains that are in congruity with one another. For example, a belief that theft is morally reprehensible is reflected in the actions (or inactions) an individual takes in both the digital and interface domains. |
| (v) Congruous Boundaries | These are the specific points at which the epistemic domains are congruous. Here any recognition that content must be paid for from the General Domain meets the point at which the individual pays for music consumption in the Digital Domain and also in the Interface Domain where the individual recognizes that content available for download without payment from a web resource may be illegal. |
| (vi) Incongruous Beliefs/ Dissonance | These are beliefs derived from a domain which are incongruent with other domains. Counter to the example of congruity above, a belief that theft is morally reprehensible in the General Domain may not be reflected in actions within the other domains. |
| (vii) Incongruous Boundaries | These are the specific points at which the epistemic domains are incongruous. Recognition that music must be paid for when physical copies are taken from a store, in the General Domain, is incongruous at the point at which the individual illegally downloads content for consumption in the Digital Domain without making the appropriate payment. In the Interface Domain, an individual, through a lack of technical understanding or ignorance of the relevant legal strictures may not have the appropriate epistemic reach which allows them to discern whether or not the interface they are using enables the illegal download of content. This also creates an incongruous boundary. |

*Source*: compiled by the authors.

narrative accounts. The three narrative accounts of self-confessed digital music pirates were read and statements that were congruous at the identified boundaries were given a score of one and added to the appropriate column; statements that were incongruous were similarly scored and are tallied. Neutral or general statements, which are indicative of beliefs derived from the wider socio-cultural context and which are not directly relevant to the crossover between the epistemic boundaries did not attract a score.

To more fully illustrate this process, we quote below three statements from Narrative A, *The Confessions of a Teenage Music Pirate*, and the resulting analytical interpretation.

> Many of my friends who download music from YouTube think it's perfectly acceptable since it was already online, and listening from your iPod isn't much different from listening online [YPulse, 2011] (*Incongruous between the digital and interface domain — Score 1*).

This statement expresses an epistemic belief that sits on the boundary of the 'knowing what' which constitutes part of the individual's understanding of the

Table 2. **An Analytical Axis**

| Congruent Socio-Cultural Beliefs | Congruent Digital Beliefs | Domain Specific Beliefs | Incongruent Digital Beliefs | Incongruent Socio-Cultural Beliefs |
|---|---|---|---|---|

*Source*: compiled by the authors.

digital domain. Yet it also refers to the manifestation of behaviours that are specifically generated from (mistaken) beliefs of the true nature about how the interface with digitally delivered music works. This knowledge is erroneous, and within its own frame of reference, incongruous with the individuals' wider epistemic knowledge of the digital domain, as they can clearly discern the difference between the use of 'YouTube' as a facilitator of digital consumption and an 'iPod' as an alternate mode of digital delivery. Indeed, if they could not do so, then it would be unlikely that they could access digital products as they would not have the skills or knowledge to use either. This then becomes a count of one in the table under the incongruous beliefs that sit between the music interface domain and the wider digital domain.

The following statement gives a quite different result:

> It's almost impossible for record companies to keep music off YouTube (*Congruous between the socio cultural and digital domain — Score 1*), even with new protections that recognize licensed tracks, because a small pitch change makes a song unrecognizable to the computer. I've listened to many leaked albums on YouTube, and when they're taken down, someone else usually uploads them again [YPulse, 2011] (*Congruous between the digital and interface domain — Score 1*).

This is both congruous within its own frame of epistemic reference and within the wider socio-cultural context because this is simply a statement that can be readily verified empirically by repeated observation. This then becomes a score of one in the congruous boundary (v) between the narrators' understanding of the wider socio-cultural context domain (i) and the digital domain (ii).

The classification of the third example is a little more problematic as it includes statements of speculative opinion that are difficult to validate objectively. It may very well be that this is a statement expressing an accurate set of observations. However, without knowledge of the discrete nature of the discussed population, and without a triangulation using qualitative methods, the statement must be discarded due to its unverifiable and anecdotal nature, no matter how credible it may seem. This is an example of neutral or general statements, which are indicative of beliefs derived from the wider socio-cultural context and not scored for the purposes of the analysis.

> Contrary to what many adults may think, most young people who don't pirate music, movies, or games don't do it because they think they'll be caught or because they think it's wrong. They stay away because they think they'll get viruses. This is a valid fear. I've gotten plenty of viruses from downloading P2P files, but they're usually poorly placed and very easy to get rid of. Still many people I know are *very* scared that their computers will break down, so they don't download anything illegally [YPulse, 2011].

By systematically deconstructing the three sample narratives — varying in length from 1000-3000 words — a pattern of scores is built, which yields an overall pattern of epistemic congruity and incongruity (Table 3). By collating the analysis in this manner, patterns in common epistemic congruities and incongruities can be discerned, which could indicate remedial strategies.

Table 3. **Deconstruction of Narratives by Congruous and Incongruous Beliefs**

| | Narratives | | |
|---|---|---|---|
| | A | B | C |
| Congruous Digital Beliefs | 4 | 6 | 3 |
| Incongruous Digital Beliefs | 1 | 2 | 1 |
| Congruous Interface Beliefs | 3 | 3 | 5 |
| Incongruous Interface Beliefs | 2 | 2 | 3 |

*Source* calculated by the authors.

From this demonstration of the analytical tool, we derived a high degree of epistemic congruity amongst the narratives, and most of the incongruous statements in all the narratives, from misunderstandings of the technical nature of how processes actually worked, for example, the assumption that iPod and YouTube were using identical or similar technology. These and the other incongruous epistemic beliefs are described as dissonances, beliefs that are contradictory within the individuals' own epistemic domains. Dissonance describes a statement which encompasses two contradictory views. Returning to the examples above as illustrations, when narrator A describes how friends think that '*listening from your iPod isn't much different from listening online*', this phrase is both an acknowledgement that iPods are a different medium for recorded music and an assertion that they are not 'much' different at the point of use. This form of justification, separating function from form, is inherently dissonant and is unsupportable when subject to even the simplest narrative deconstruction. The identification of such dissonant epistemic beliefs is important, but it does not necessarily mean that these epistemic foundations manifest or give rise to illegal or 'piratical' behaviour. It may be that in some individuals more verifiable epistemic domains that have less dissonance may give rise to a confidence to perform illegal activities; dissonance may arise from a secure knowledge of their own technical skill or an outright refusal to recognize the normative moral and ethical strictures of the wider socio-economic context. It is perhaps appropriate that individuals who have such congruent epistemic beliefs remain subject to the formal censure of legal and political jurisdictions. Returning to those whose behaviour may be founded on incomplete or dissonant knowledge, it may be that a correction of these dissonances may lead to a reduction of behaviour founded on incongruent beliefs and the dissonances that arise in the overlap between epistemic domains. This may indicate that organizations involved in the value chains, which extract income from the sale and distribution of digital music, may be able to reduce their exposure to revenue loss through piracy by reducing instances of epistemic dissonance.

## Discussion

Access to knowledge and comprehension of the key foundations that constitute true knowledge in the specialized epistemic domain of the interface with digital music is a key factor related to piracy. We have adapted and applied an epistemic model in order to analyse the root cause of a phenomenon that has major commercial consequences [*Peitz, Waelbroeck*, 2004]. The new model will not, and perhaps cannot, conform to the detailed constructs of pure theoretical epistemological thought. The application of this adapted model and the use of epistemic domains per se are open to detailed theoretical deconstruction and criticism [*Hofer*, 2006]. Encouragingly, this form of discourse will lead to the development of a more accurate evaluation of the root cause of piracy in the digital domain. The insights from this initial research are that music piracy is not caused by the wilful and knowing resistance to the dominant mores of the wider socio-cultural context, but by the persistence of epistemic dissonances lying at the foundations of behaviours manifested by individuals, even though they are contradictory to their wider epistemic domain.

Here exists a clear link to the recent work of de Bruin (2013) on epistemic virtues in business, which applies the concept of epistemic virtues in business to the development of business ethics. Whilst this paper is written from the perspective of the practice of business, if digital music pirates are considered as actors in the music business, then the 'belief perseverance', as de Bruin states, has a particular relevance if considered as an explanatory factor of incongruent epistemic beliefs in the digital domain. Belief perseverance means that individuals cling to beliefs too closely in the face of counterevidence [*de Bruin*, 2013, p. 591].

Describing 'belief perseverance' as a 'deeply rooted' aspect of individual psychology, de Bruin goes on to confirm that 'an explicit discussion of this bias decreases its effect by making individuals aware of this phenomenon' [*Ibid.*, p. 591]. This analysis has an important consequence for policy and legislation seeking to curb digital piracy. This view indicates that the most effective curb on digital piracy may not be the threat of punitive legal action, but rather the identification of the incongruous epistemic belief and a re-educational process that highlights these incongruities. A fuller exposition of their technical processes and the attendant costs borne by the distributors and creators of digital music and related products may do far more to adjust epistemic beliefs than the threat of a legal sanction. By adjusting epistemic beliefs, behaviour can be modified. Furthermore, this form of intervention may prove far more cost effective for those involved in the digital music value chain, as the epistemic relationship becomes one of direct education rather than indirect sanction through a political and legal jurisdiction. Businesses can avoid paying legal fees by promulgating the transparency of their business processes. In this context, the application of an epistemic analysis based on an adapted TIDE framework contributes to the management of the epistemic ecology of the digital music value chain.

The major methodological issue is consistency of interpretation: whether a statement should be classified as either congruous or incongruous, or simply ignored as being unclassifiable. The prime challenge here lies in selecting the criteria used to make this judgment, if, however, the epistemic domains are reasonably well-defined and specific, this means that in most cases triangulation of stated opinion against settled expert knowledge is possible. In the case of the epistemic domain covering access to digital music, there are some technical specifications (file formats, enabling Internet protocols) that determine the physical reality of engagement in this domain. Narrated opinion can be measured against more certain knowledge, whilst this analytical approach does not in itself guarantee that all such interpretations will be valid; accuracy and validity will improve by following a simple rule — the higher the number of observations and interpretations made, the lower the error rate will be [*Kotrlik et al.*, 2001]. Moreover, to further reduce bias and individual subjectivity, the same data set of narrated witness could be analysed by more than one individual. Again, the greater the number of individuals who deconstruct the narrative, the lower the aggregate difference of subjective interpretation [*Miles, Huberman*, 1984]. Another way to improve the accuracy of interpretation would be to situate the assembled narratives in a homogenous socio-cultural epistemic domain, as this will provide common frames of cultural and linguistic references against which the epistemic domains nested within can be analysed. In brief, there are three strands of development that are needed to fully test this analytical approach: a more detailed critique of the theoretical foundation, a large-scale study with a multiplicity of interpreters, and applications of the technique within a homogenous socio-cultural context.

## Conclusion

This paper set out to argue that those interested in marketplace dynamics in the digital environment should direct their attention to evidence of where participants in this marketplace begin to display specific behaviours, which are incongruous or at odds with their overall beliefs. Furthermore, it has been demonstrated how an epistemic approach could yield valuable indicators for remedial action that lies beyond the remit of political and legal jurisdiction. This demonstration of an analytical tool has implications for the control of music piracy. The analysis enables those organizations involved in combatting the loss of revenue to music piracy to develop a new class of preventative techniques that would not be dependent on legal instruments or overtly coercive measures to deter music piracy. The approach is independent of this solution, and participants in the value chain could seek to reduce music piracy without the overt cooperation of the statutory authorities. Where political jurisdictions are openly hostile to commercial influence on the framing of statutory instruments, this may be a valuable adjunct to framing a commercial strategy. The micro study, intended only to demonstrate the application of the model, also revealed that epistemic dissonances are centred on technical misunderstandings of the mode of digital music delivery. These incongruities may be the foundation of some piratical behaviour in this domain. In turn, this indicates that some form of educational process to make existing and new users of digital music more fully informed of the technical architecture underpinning this activity would help to reduce piracy. If further studies were to show that this approach had an empirically measurable effect, then the cost effectiveness of this technique should be judged against alternative approaches such as the use of legal enforcement and redress. F

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Science

# Identifying Directions for Russia's Science and Technology Cooperation

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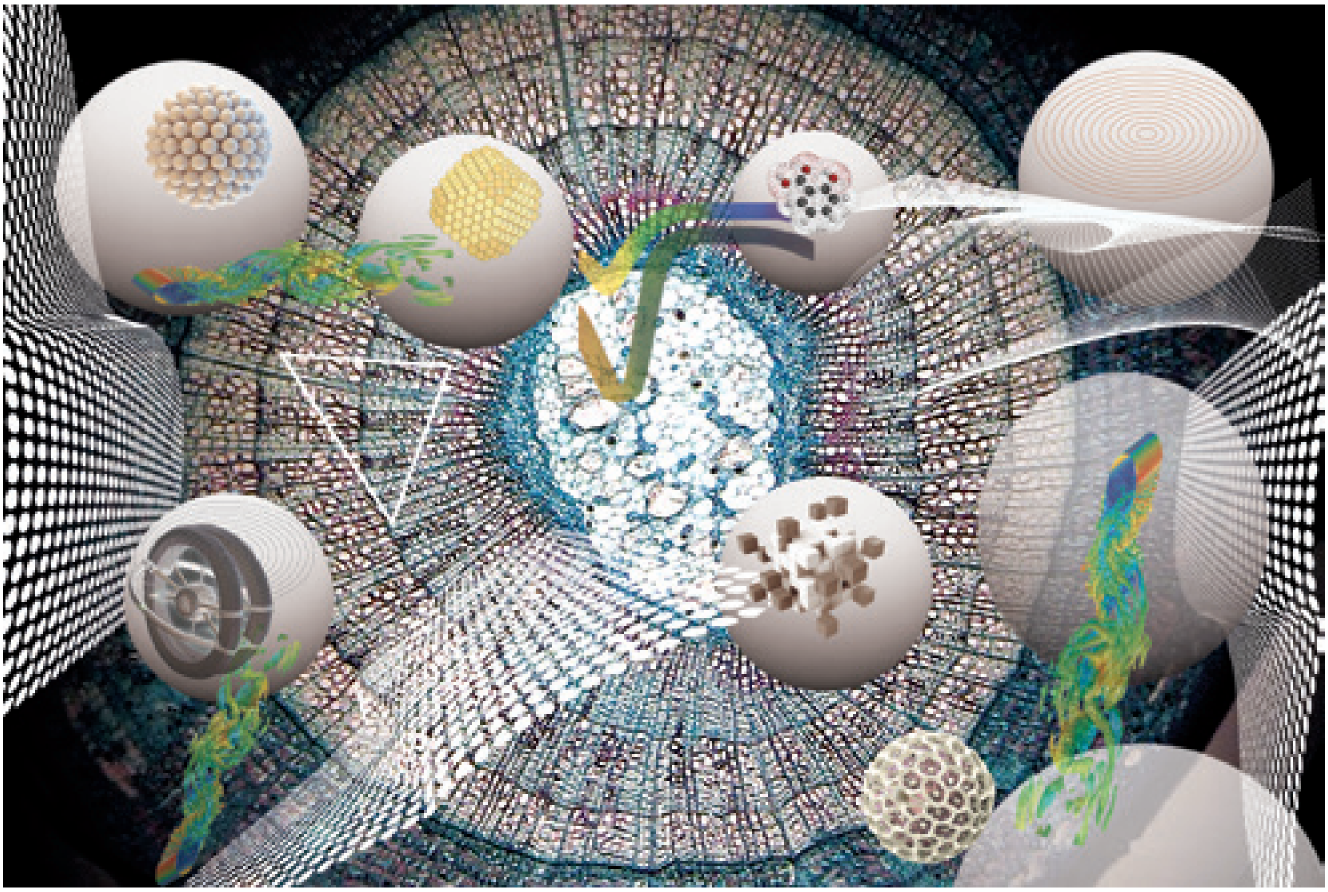

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## Abstract

**Strong international partnerships are a key vehicle for building an efficient national innovation system. Successful global cooperation needs comprehensive knowledge of the features of the science and technology (S&T) sphere in a changing environment of global division of labour, competition, and political climates. New realities and trends emerge, changing the established 'rules of the game' and calling for immediate actions from politicians, experts, and various economic actors.**

**The authors propose an analytical approach to build and examine an empirical database. Drawing on bibliometric analysis and expert survey tools, such an approach helps allows identifying the most promising areas for Russia's international S&T cooperation. The authors assess the scope for applying the proposed methodology. Based on the latest available data in Web of Science, the international scientific citation indexing service (2014 and early 2015), they compare the structure and variation over time of scientific specializations in Russia, leading S&T countries, and several rapidly growing global economies.**

**The cooperation priorities that were identified via matrix analysis were complemented with data from expert surveys. The surveys highlighted the partner organizations, thematic areas, and instruments of S&T cooperation, which indicate some of the future possibilities for Russia's international S&T cooperation.**

**Keywords:** science and technology cooperation; international partnerships; priorities for STI cooperation; bibliometric analysis; expert interviews

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One of the most important factors underpinning the effective development of the national science, technology, and innovation system is its global integration, based on balanced partnerships with other countries. Strengthening international science and technology cooperation (ISTC) helps to stabilize the national economy and promote growth in its scientific potential. Up-to-date notions of the nature of S&T development against the backdrop of large-scale changes in the international division of labour and intensifying global competition determine the outlined cooperation strategies. The most successful of these strategies are summarized, improved, and circulated on international and national levels. Both traditional, well-established approaches and entirely new, pilot initiatives are introduced. Although the actual forms of partnership and corresponding policy measures are disseminated relatively intensively, certain problems that are not always easy to overcome still persist. The continuing emergence of new challenges and trends is forcing a change in the established rules and has prompted a need for a swift response by policy makers, politicians, experts, and economic players [OECD, 1988, 1988, 2015; European Commission, 2011, 2012].

In the context of developing Russia's ISTC, the following issues demand particular attention:

- The global economy and society are facing a growing number of global problems and solutions, which can only be resolved on an international level. Climate change, shortage of water resources, epidemics, and other global challenges all require a united effort to retain multilateral S&T collaboration independent of national agendas or the political environment. Searching for responses to these challenges shapes government policy around large-scale, complex, and long-term issues on a global and national level.
- Growing budgetary restrictions in many countries, including Russia, are increasing the demands on scientific facilities and the structure and effectiveness of funding for the sciences, and are broadening the range of problems encountered in government-supported scientific research. Against this backdrop, long-term guidelines (priorities) defined using forecasts, Foresight studies, and other analytical methods have become key when drafting S&T policy and policy instruments.
- The increasing complexity of the foreign political situation (in particular, the introduction of political and economic sanctions against Russia, and response measures by the Russian government) poses real threats to the national economy and scientific sphere. The negative effects are evident, and will continue to intensify if Russia does not succeed in embarking upon an innovative developmental model, raising the efficiency of all spheres and sectors of the economy, achieving high growth rates and quality, and making active use of scientific results and new technologies.

ISTC has been examined in many countries around the world and many studies have been devoted to the subject, focusing, in particular, on questions such as science, technology and innovation policy in Russia [*Gokhberg et al.*, 2009; *Gokhberg, Kuznetsova,* 2011; *Gokhberg, Zaichenko et al.*, 2011] and selected foreign countries [*Xiwei, Xiangdong*, 2007]. These also study priority areas and mechanisms for cooperation, including regulatory and legal frameworks, joint collaboration bodies, and financial instruments that support cooperation [*Gutnikova et al.*, 2014]. In several works, specific recommendations have been drafted to strengthen ties in science, technology and innovation between certain countries and regions, together with ways to achieve these aims through working with stakeholders [*Arzumanyan et al.*, 2012; *Balashova et al.*, 2013; European Commission, 2013; *Sokolov et al.*, 2014]. In works devoted to Russia's collaboration with leading countries abroad, special attention has been paid to expanding Russia's involvement (including in the geographical sense) in international S&T collaboration and analysing the restrictions impeding these efforts. Some studies devoted to collaboration prospects in the framework of BRICS offer a comparative analysis of the national innovation systems of the countries in this group [*Cassiolato, Vitorino*, 2009; *Gokhberg et al.*, 2012; *Arroio, Scerri*, 2013; *Cassiolato et al.*, 2013; *Kahn et al.*, 2013; *Scerri, Lastres*, 2013].

The Organization for Economic Cooperation and Development (OECD) actively engages in studying international cooperation by developing effective management decisions taking into account the specifics of innovation processes using an open innovation model. The interdisciplinarity and hyper-connectedness of certain segments of scientific systems are an important factor, and at the same time a condition, of the emergence of network collaboration on various levels, the consolidation of the ramified international research infrastructure and other elements of the system to support science, technology and innovation. Analytical and practice-oriented efforts are focused on deepening the internationalization of research in the public and private sectors, intensifying academic mobility and professional contacts, supporting project-specific and institutional cooperation between national research institutes and companies, and increasing the effectiveness of collaboration and broadening collaboration horizons [OECD, 2012a, 2012b, 2014].

From an objective standpoint, it is beneficial for Russia to look for joint collaboration objectives and priorities with other countries and set up a dialogue for ISTC. Some of these are not difficult to identify and are simply a continuation of policy from previous periods, while others still need to be found and added to the agenda of possible future partnerships. In the current economic and foreign political situation, streamlining bilateral collaboration[1] is a top priority for taking advantage of Russia's competitive advantages. The particular importance of this form of ISTC stems from its ability to directly influence the effectiveness of involvement in the international division of labour and output of domestic scientific achievements and high-tech products in traditional and emerging markets. In this regard, there needs to be some differentiation between approaches to developing ISTC with a focus on the specifics of different groups of states (Table 1). The implementation of a complex array of measures to develop ISTC needs to take account of the state of Russian research and development (R&D), and if Russian R&D fits into both national S&T priorities and the global standard. However, the data presented in Table 1, although incomplete, show that in every case there needs to be a detailed analysis of areas of mutually beneficial relations and the scientific, technological and economic profiles and needs of current and potential partners.

This paper proposes an approach to form a database to justify prospective areas of international S&T collaboration for Russia using bibliometric and expert analysis.

## Methodology

In order to research ISTC priority areas, we tested a complex approach combining a bibliometric analysis of S&T specialisations in Russia and other countries and areas of joint publication activity with an expert assessment of collaboration priorities broken down thematically and by country.

Studies of publication activity are often used to compare the effectiveness of the scientific systems in developed countries [*Wagner,* 1995; *Tijsen et al.,* 2002; *Klitkou et al.,* 2005; *Gokhberg, Sagieva,* 2007; *Jarneving,* 2009; *Arencibia-Jorge, de Moya-Anegón,* 2010; *Peclin, Juznic,* 2012; *Gokhberg, Kuznetsova,* 2012] and the power dynamics in the research environment [*Barré,* 1987; *Grupp,* 1995; *Schneider,* 2010; *Kotsemir,* 2012; *Confraria, Godinho,* 2014; *Zacca-Gonzalez et al.,* 2014]. Aside from serving particularly scientific objectives, this makes it possible to establish an information resource, which may be used to increase the adaptiveness and effectiveness of state policy and to identify the most promising areas for international collaboration. The largest international database of publication activity and scientific citations is the Web of Science (WoS), which, as of the start of 2015, had indexed roughly 58.3 million records, classified under 151 research areas or 263 research areas for scientific journals.[2]

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[1] Russia has signed bilateral S&T collaboration agreements with more than 70 countries.

[2] For more on international scientific citation databases see [*Brusoni et al.,* 2005; *Brusoni, Genua,* 2005; *Yang, Meho,* 2006; *Fingerman,* 2006; *Falagas et al.,* 2008; *Archambault et al.,* 2009].

Table 1. **Trajectories of bilateral S&T collaboration between Russia and foreign countries**

| Groups of countries | Positive and negative factors when selecting ISTC areas | Possible ISTC areas for Russia |
|---|---|---|
| Developed countries | Strong economic and technological potential<br>Potential interest in exporting technology from the previous technological wave to Russia, contacts in specific R&D fields, importing ideas and 'minds'<br>Traditional restrictions on exporting advanced technologies (especially dual purpose)<br>Involvement in economic sanctions | Maintaining (searching for) mutually beneficial, sustainable areas for cooperation<br>Carrying out joint projects and programmes, including megascience<br>Involvement in the activities of international organizations, global initiatives<br>Growth in academic mobility |
| BRICS countries | Maintaining positive growth dynamics in a number of countries<br>Production of 'cheap' and 'reverse' innovations<br>Ambitions in science and technology, high interest in developing collaboration with Russia<br>Pressure of explicit and implicit restrictions in technological exchanges with the West | Updating the general framework for ISTC priority areas<br>Commercialization of R&D results<br>Signing additional agreements with clear and well thought-out benefits for Russia<br>Serving as platforms to expand Russia's communication with other states and international organizations<br>Signing in 2015 of a memorandum of cooperation in science, technology and innovation (medicine, biotechnology, food safety, nanotechnology, high-power computing, support for technology and innovation infrastructure transfers)<br>Creation of the BRICS Development Bank |
| Other countries with fast-growing economies | High economic growth in the long-term<br>Own ambitions in science and technology, high interest in developing ISTC<br>Opportunities for mutually beneficial technology exchange | Joint development of advanced technologies<br>Localization of Russian high-tech manufacturing, S&T centres<br>Exchange of best practices<br>Expanding Russian high-tech exports |
| Other developing countries | Demand for 'simple' and cheap technological solutions, products, etc. | Implementation of more general programmes through assistance in international development |

*Source*: compiled by the authors.

The scientific specialisation of countries is determined by comparing the thematic structure of its publications, while the scientific specialisation index (SSI) of country *j* in scientific field *i*, calculated as the relationship between the share of its publications in scientific field *i* in the total number of publications of country *j* and the equivalent global figure [*Gokhberg*, 2003; *Gokhberg, Sagieva*, 2007]. Those fields where the SSI value is higher than 1 are classified as areas of scientific specialisation. It is important to bear in mind the following characteristics of the SSI for analytical purposes and to justify administrative decisions. First, the index value is highly dependent on the thematic structure of journals in a particular country. The largest scientific citation databases traditionally are geared towards the natural and medical sciences to the detriment of a wide range of humanities and social disciplines. Second, it is important to bear in mind national specifics, which can manifest themselves in surges of joint publications by academics from developed and developing countries in extremely narrow disciplines (for example, parasitology and tropical medicine in some of the poorest countries in Africa). Third, the scale of publication activity is important. The structure of publications among the traditional leaders is, as a rule, more thematically balanced and growth is not sporadic or uneven in nature. Where publication figures are low overall, there are strong imbalances in certain scientific fields. Thus, this figure is effective when comparing the structure of scientific publications in different regions or groups of countries, evaluating the publication activity of a particular country, or identifying potential scientific partners in a specific research field [*Pianta, Archibugi*, 1991; *Barré*, 1991; *Nagpaul*, 1993;

*Guena*, 2001; *Tuzi*, 2005; *Laursen, Salter*, 2005; *Murmann*, 2012; *Bongioanni et al.*, 2013, 2014; *Abramo et al.*, 2014; *Acosta et al.*, 2014; *Askens et al.*, 2014].

The analysis of joint publications offers valuable research information, which may be useful in political decision making [*Luukkonen et al.*, 1993; *Katz, Martin*, 1997; *Dumont, Meeusen*, 2000; *Grupp et al.*, 2001]. It allows us to study key partners, promising areas for collaboration, broken down by country, and the characteristics of forming co-authorship networks, on both organizational and personal levels [*Gomez et al.*, 1995; *Glänzel*, 2001; *Wang et al.*, 2005; *Zhou, He*, 2009; *Hoekman et al.*, 2010]. Supplementing a bibliometric analysis with a network analysis allows the density of the observed ties to be evaluated [*El Alami et al.*, 1992; *Basu, Kumar*, 2000; *Chinchilla-Rodríguez et al.*, 2010; *Ding*, 2011; *Perc*, 2010]. Joint publication figures, however, only give a general overview of the level of cooperation. It is important to bear other aspects in mind too, for example, the existence of common research interests, modern equipment for joint experiments, international laboratories, strong skill sets in a particular area, personal contacts, youth exchange and academic cooperation programmes, new scientific journals, joint monographs and reports, and regular communication events such as conferences.

When identifying ISTC prospects, the global challenges facing humanity should not be ignored — joint efforts are needed on both a regional and international level. Global challenges in many ways format the multipolar scientific world and determine S&T development priorities as reflected in part in national industry development strategies. To identify and analyze these priorities, a range of expert surveys are widely used alongside other methods [European Commission, 2011; ICSU, 2011; *Silberglitt et al.*, 2006; UNIDO, TUBITAK, 2003]. Currently, distance personalized questionnaires and working face-to-face and online conferences are the most widespread tools [NISTEP, 2010, p. 28; *Sokolov et al.*, 2014; *Syrjänen et al.*, 2009].

In line with the methodical approaches outlined above, our study involved:

- identifying the scientific specialisation of Russia and 25 other countries according to five major and 39 detailed scientific areas (Table 2). The search used all current Web of Science databases. For each country, we looked at figures such as publication numbers; position in the overall publications ranking; proportion of specific industries as a percentage of all publications in the country; and countries' specialisation index in specific scientific fields;
- evaluating the scale and structure of joint publications by Russian researchers with colleagues from 25 countries (the number of joint publications, their proportion as a percentage of total internationally co-authored publications by Russian academics (broken down by country), and joint publication activity dynamics in 2003–2014);
- expert surveys and interviews with the scientific advisors of 15 foreign embassies in Russia, representatives of 38 leading Russian universities and research institutions involved in international programmes, and 530 foreign experts (online). Individual expert assessments were summarized and analyzed to obtain additional information on the current state and development prospects of Russian ISTC, partner countries, and the forms and thematic fields of collaboration with these countries. Respondents were given a list of prospective technologies and thematic R&D areas (in line with the Russian S&T Development Forecast for the period up to 2030, as approved by the Chairman of the Government of the Russian Federation on January 3, 2014) [*Gokhberg*, 2014].

## Bibliometric analysis results

### Scientific specialisation

The analysis allowed the following conclusions to be drawn. The scientific profile of virtually all of the countries included in the study shifts immediately after new technology trends emerge (Table 2). New industrial and rapidly developing countries are shown to be most efficient in this regard.[3] Over the last ten

[3] The attribution is conditional and serves only for ease of interpretation.

years, industrial biotechnology has been the specialist scientific field of countries such as Singapore (SSI 2.98), Malaysia (1.34), China (1.44), Brazil (1.14), and India (1.11), and nanotechnology in Singapore (3.22) and Taiwan (2.12). At the same time, these countries maintain their specialisation in traditional fields such as agriculture, forestry and fisheries (Brazil — 3.59, Argentina — 2.16), chemical engineering (Iran — 2.55) and materials engineering (China — 2.24). The majority of 'old' leaders of the global economy as a general rule support a broad profile of areas of specialisation and close SSI values between traditional (physics, chemistry, medicine) and relatively new scientific fields (biotechnology, ICT, and others).

The absolute leader in the majority of scientific fields is still the US, losing its position only in a few areas. China overtook the US in the number of publications in materials engineering in 2006, computer technology, ICT and chemistry in 2007, and new chemical technologies, civil engineering in 2008. Some growing economies are now likely going through the stage that the leading global economies went through 30–40 years ago, when areas of scientific specialisation were less clearly classified, and attention was paid to many scientific fields at once.

Table 2. **Scientific specialisation index of countries in 2003–2013**

| Scientific field | Austria | UK | Germany | Spain | Italy | Netherlands | Finland | France | Argentina | Mexico | Brazil | India | China | South Africa | Israel | Iran | Canada | USA | Turkey | Switzerland | South Korea | Malaysia | Singapore | Taiwan | Japan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Industrial biotechnology | | | | | | | 1.2 | | | | 1.1 | 1.1 | 1.4 | | | | | | 1.1 | 1.2 | **1.9** | 1.3 | **3.0** | 1.4 | **1.7** |
| Physical sciences | 1.1 | | 1.4 | 1.0 | 1.2 | | | 1.4 | 1.1 | 1.4 | | 1.2 | 1.2 | | 1.2 | | | | | 1.2 | 1.4 | | 1.4 | 1.3 | **1.5** |
| Materials engineering | | | | | | | | | | | | 1.4 | **2.2** | | | 1.2 | | | | 0.6 | **1.9** | 1.5 | **1.6** | 1.4 | 1.3 |
| Chemical sciences | | | 1.0 | 1.2 | | | | 1.0 | 1.1 | | | **2.0** | 1.6 | | | **1.7** | | | | 0.9 | 1.4 | 1.4 | 1.2 | 1.0 | 1.3 |
| Environmental biotechnology | | | | 1.1 | | | 1.1 | | 1.3 | 1.3 | 1.1 | **1.7** | 1.0 | 1.3 | | | | | 1.0 | 0.9 | **1.6** | **1.6** | 1.1 | | 1.3 |
| Nanotechnology | | | 1.0 | | | | | | | | | 1.4 | **1.6** | | | 1.3 | | | | 1.0 | **2.4** | 1.8 | **3.2** | **2.1** | 1.2 |
| Basic medicine | 1.0 | 1.1 | 1.1 | | 1.3 | 1.3 | 1.0 | | 1.1 | | 1.2 | | | | 1.1 | | 1.2 | 1.3 | | 1.2 | | | | | 1.2 |
| Other agricultural sciences | | | | **2.1** | 1.2 | | 1.2 | | **2.3** | **1.6** | **1.9** | 1.5 | | 1.2 | | 1.3 | | | **1.9** | 0.6 | 1.5 | **2.3** | | 1.1 | 1.2 |
| Biological sciences | 1.2 | 1.1 | 1.1 | 1.2 | 1.0 | 1.1 | 1.2 | 1.1 | **2.0** | 1.5 | 1.4 | | | 1.6 | 1.1 | | 1.2 | 1.2 | | 1.2 | | | | | 1.1 |
| Mechanical engineering | | | | | 1.0 | | | 1.1 | | | | 1.0 | 1.5 | | | **1.8** | | | | 0.8 | 1.3 | 1.2 | 1.0 | 1.1 | 1.1 |
| Clinical medicine | 1.4 | 1.2 | 1.2 | | 1.4 | **1.6** | 1.2 | 1.0 | | | | | | | 1.3 | | 1.2 | 1.3 | 1.8 | 1.3 | | | | | 1.1 |
| Electrical engineering, electronic engineering, information engineering | | | | | | | | | | | | | **1.5** | | | 1.3 | | | | 0.6 | 1.5 | 1.8 | **2.2** | **2.1** | 1.0 |
| Other engineering and technologies | | | | | | | | | | | | 1.1 | **1.9** | | | 1.3 | | | | 0.7 | 1.3 | 1.4 | 1.2 | 1.5 | 1.0 |
| Medical engineering | 1.1 | | | | 1.1 | 1.1 | | | | | | | | | | | 1.1 | 1.2 | | 1.1 | 1.2 | 1.2 | **1.9** | 1.3 | 1.0 |
| Agricultural sciences | | | | **1.6** | 1.0 | | 1.2 | | **2.1** | **2.0** | **3.1** | **1.6** | | **1.6** | | **1.5** | 1.1 | | **1.8** | 0.8 | | 1.3 | | | 0.9 |
| Agriculture, forestry and fisheries | | | | **1.6** | 1.0 | | **1.6** | | **2.2** | **2.3** | **3.6** | **1.6** | | **1.6** | | **1.5** | 1.3 | | 1.3 | 0.7 | | 1.2 | | | 0.9 |
| Environmental engineering | | | | | | | | | | | | 1.1 | **1.7** | 1.1 | | 1.4 | 1.0 | | 1.3 | 0.7 | 1.0 | **1.7** | | 1.1 | 0.8 |
| Other natural sciences (multidisciplinary) | 1.2 | 1.4 | 1.1 | | 1.1 | 1.3 | 1.1 | 1.1 | 1.1 | | | 1.5 | 1.1 | **1.9** | 1.3 | | 1.1 | 1.4 | | **1.5** | | **1.8** | | | 0.8 |
| Chemical engineering | | | | 1.3 | | | | | **1.7** | 1.5 | 1.1 | **1.7** | 1.4 | 1.2 | | **2.6** | | | 1.8 | 0.5 | 1.4 | **2.2** | 1.4 | 1.1 | 0.8 |
| Computer and information sciences | 1.0 | | | 1.0 | | | | | | | | | **1.6** | | | 1.1 | | | | 0.7 | 1.2 | **1.7** | **1.7** | **1.7** | 0.8 |
| Earth and related environmental sciences | 1.2 | 1.2 | 1.0 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | **1.7** | 1.4 | | 1.1 | 1.0 | **1.8** | | | **1.4** | 1.0 | 1.1 | **1.3** | | | | | 0.7 |
| Veterinary science | **1.4** | 1.1 | | | 1.2 | 1.0 | | | 1.7 | 1.4 | **3.6** | | | **1.9** | | 1.4 | | | **2.8** | **1.4** | | | | | 0.7 |
| Mathematics | 1.2 | | 1.0 | 1.3 | **1.3** | | | **1.5** | 1.0 | 1.3 | | | 1.3 | | **1.9** | **1.5** | | | 1.0 | 0.7 | | | | | 0.7 |
| Animal Science | | | | 1.3 | **1.4** | 1.2 | | | 1.6 | 2.2 | **3.4** | **2.6** | | **2.0** | | **1.7** | 1.3 | | 1.3 | 0.7 | | | | | 0.7 |
| Civil engineering | | | | | | | | | | | | | **2.0** | | | **1.7** | 1.0 | | 1.3 | 0.6 | 1.3 | 1.2 | 1.4 | 1.3 | 0.6 |
| Health sciences | | **1.5** | | | | **1.6** | **1.4** | | | | 1.9 | | | **1.8** | | | **1.5** | **1.5** | | 1.2 | | | | | 0.5 |
| Media and communications | | 1.2 | | 1.3 | | 1.1 | **1.6** | | | | | | | **1.9** | | | | 1.2 | | 0.5 | | **2.1** | **1.6** | 1.3 | 0.2 |
| Social sciences | | **1.7** | | | | 1.3 | | | | | | | | **1.8** | **1.6** | | 1.3 | **1.5** | | 0.6 | | 1.2 | | | 0.2 |

*Notes*. This table takes into account the following types of documents in all languages and all scientific fields indexed on Web of Science: articles, reviews, and conference proceedings papers. The search was carried out on all current Web of Science databases. This data is current as of the first half of September 2014.

*Source*: authors' calculations.

Table 3. **Key characteristics of publication activity among Russian academics (according to Web of Science data for 2003–2013)***

| Years | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Key Russian publication activity figures** | | | | | | | | | | | |
| Total publications | 28 707 | 28 876 | 28 422 | 27 508 | 28 997 | 30 825 | 31 201 | 29 627 | 31 135 | 31 044 | 31 911 |
| Position in global publications ranking | 11 | 12 | 13 | 15 | 15 | 16 | 16 | 16 | 17 | 17 | 17 |
| Share of global flow of publications (%) | 2.74 | 2.64 | 2.45 | 2.24 | 2.16 | 2.16 | 2.08 | 2.01 | 2.01 | 1.88 | 1.93 |
| **Fields where Russian science occupies a leading position**** | | | | | | | | | | | |
| Physical sciences | 6 | 7 | 7 | 8 | 7 | 7 | 7 | 8 | 7 | 8 | 8 |
| Mathematics | 10 | 9 | 9 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| History and archaeology | 11 | 11 | 10 | 10 | 10 | 12 | 10 | 9 | 9 | 9 | 11 |
| Chemical sciences | 7 | 8 | 8 | 10 | 10 | 9 | 11 | 11 | 11 | 12 | 12 |
| Mechanical engineering | 8 | 9 | 11 | 11 | 11 | 12 | 11 | 13 | 12 | 13 | 12 |
| Materials engineering | 9 | 9 | 10 | 10 | 11 | 10 | 10 | 13 | 11 | 12 | 12 |
| **Fields where Russian science is lagging critically behind**** | | | | | | | | | | | |
| Civil engineering | 40 | 18 | 42 | 36 | 40 | 38 | 52 | 52 | 60 | 56 | 47 |
| Health sciences | 39 | 39 | 41 | 40 | 42 | 48 | 50 | 49 | 53 | 51 | 54 |
| Other agricultural sciences | 46 | 46 | 52 | 60 | 46 | 57 | 53 | 66 | 57 | 58 | 57 |
| Media and communications | 10 | 30 | 32 | 36 | 40 | 47 | 38 | 40 | 38 | 42 | 57 |
| Animal and dairy science | 70 | 73 | 71 | 57 | 67 | 64 | 76 | 68 | 91 | 79 | 68 |
| Veterinary science | 58 | 68 | 80 | 62 | 70 | 67 | 67 | 69 | 73 | 67 | 69 |
| **Key thematic areas in Russian sciences on the Web of Science database ***** | | | | | | | | | | | |
| Physical sciences | 38.0 | 37.7 | 37.2 | 37.1 | 36.4 | 35.8 | 35.1 | 34.6 | 34.8 | 35.2 | 34.0 |
| Chemical sciences | 20.9 | 21.6 | 20.9 | 20.2 | 20.5 | 19.6 | 19.3 | 19.4 | 19.8 | 18.1 | 18.8 |
| Biological sciences | 10.7 | 11.1 | 10.4 | 10.9 | 10.9 | 10.6 | 10.4 | 11.3 | 11.0 | 11.1 | 10.9 |
| Materials engineering | 9.3 | 9.8 | 8.5 | 9.3 | 8.7 | 8.8 | 8.4 | 7.9 | 8.8 | 8.9 | 9.1 |
| Earth and related environmental sciences | 8.6 | 8.6 | 8.1 | 8.7 | 7.9 | 8.5 | 8.6 | 8.2 | 7.9 | 7.6 | 7.9 |
| Mathematics | 6.8 | 7.1 | 7.9 | 7.8 | 7.1 | 8.1 | 8.1 | 8.4 | 8.0 | 8.1 | 7.3 |

*Notes.*

* This table and subsequent tables take into account the following types of documents in all languages and all scientific fields: articles, reviews, conference proceedings papers. We used the tool to go between Web of Science categories and the scientific field classification system developed by the OECD (OECD fields of science classification: http://incites.isiknowledge.com/common/help/h_field_category_oecd_wos.html).

** Russia's position in the global ranking by the number of publications in respective fields of science.

*** Share of respective fields of science in the total number of Russia's publications (%).

*Source*: authors' calculations.

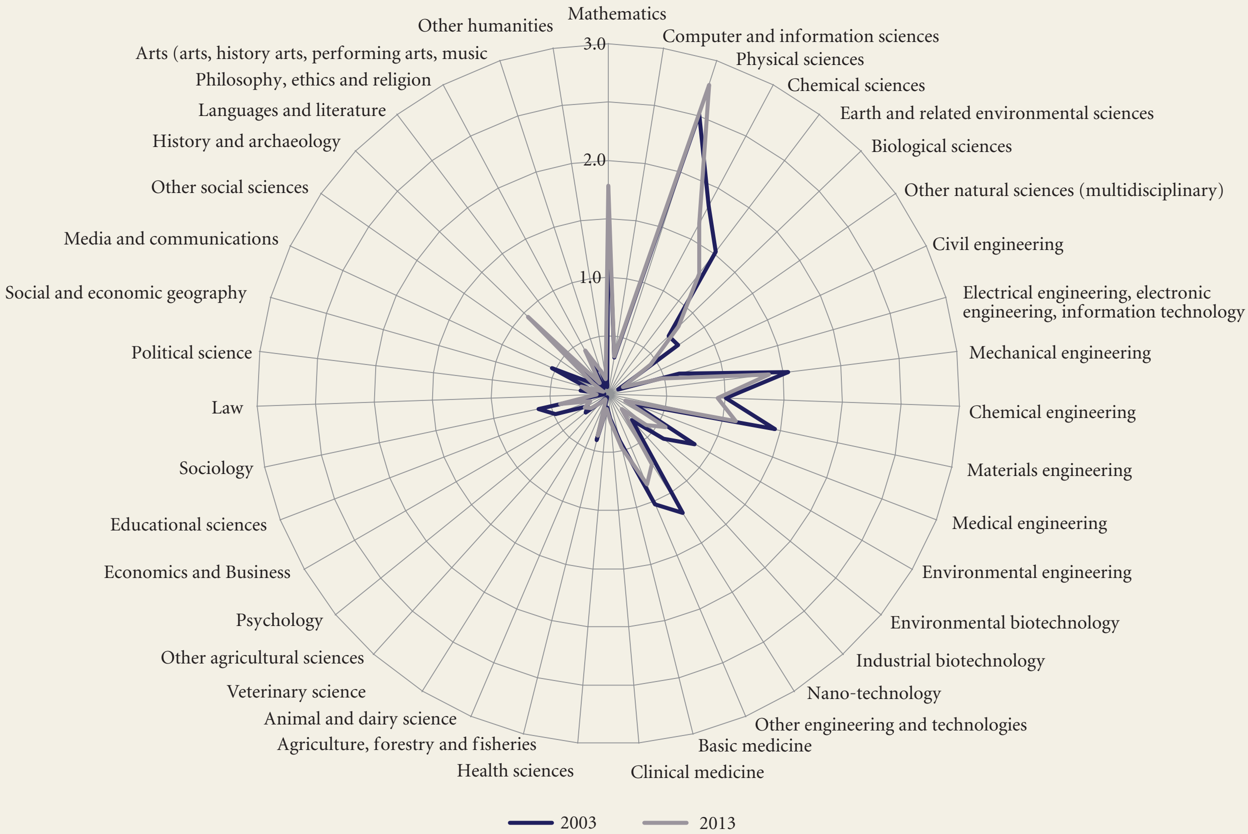
According to Web of Science data, the publication activity of Russian academics in 2003–2013 grew slowly and the country's position in the global rankings fell (Table 3). Russia only managed to secure a position among the top 20 leaders in certain natural science fields: 6th–7th place for physics and 7th–12th place for chemistry. The SSI value for physics is 2.78 and for mathematics and chemistry 1.78. The prevalence of publications in natural and exact sciences has led to them playing a decisive role in shaping Russia's scientific specialism. In the context of technological modernization, it is telling that the SSI for technical sciences is close to one, while for medical and agricultural sciences the figure is no higher than 0.4.

The structure of Russia's scientific specialisation is visualized by scientific field in Figure 1. The disparity between the relatively high indices of traditional fields (physical sciences, materials engineering, mechanical engineering) and the lower figures for social sciences, humanities, computer sciences, chemical sciences and nanotechnologies, and in prospective fields such as industrial biotechnology, is clear to see. Even the preliminary analysis of the bibliometric data clearly shows that the problem in Russian sciences lies not so much in it falling behind technologically developed countries, but rather in the far-from-optimal concentration of research efforts, both in terms of scale and structure. The poor choice of priorities is linked to the specific nature of Russia's economic development in recent times and the legacy of the Soviet era (Box 1).

**Joint publications**

As shown in Figure 2, the dynamics of joint Russian publications with other countries fluctuate, having grown by little more than 1% over the last decade.

Fig. 1. **Russia's scientific specialisation index by publications indexed on Web of Science, in 2003 and 2013**




*Source*: authors' calculations.

Box 1. **Russia's publication activity thrust: historical circumstances**

The dynamics of Russian publications on Web of Science are to a large degree shaped by trends, which took hold in Soviet times. In 1975, there were 28,900 of all types of publications by USSR academics on this database. By 1990, this figure reached 42,600, where it stayed until this bar was raised again in 2007. In 2014, the total number of former Soviet countries' publications was 53,600. For comparison, in China the number of publications increased from 62 in 1975 to 8,152 in 1981, and by 2014 had already reached 319,600.

The prevalence of physics and chemistry in the structure of Russian publications is a long-standing, historical phenomenon. In 1975–1992, the USSR's proportion of physics in total publications increased from 19.9% to 28.2%, while chemistry reduced from 30.9% to 24%.

The fact that the USSR was closed off from the rest of the world also had an impact on the intensity of Soviet researchers' collaboration with foreign colleagues, which continued to be relatively low: the proportion of joint publications in 1973 was only 1.25% (315 publications) and reached 5.03% (2,100) in 1990. In the early 1990s, cooperation between researchers in the former Soviet Union and foreign academics started to grow rapidly. By 1992, the proportion of joint publications for all former Soviet states reached 10.6% (3,900) and in 1994 16.7% (6,300). In 1999, this figure rose to 26.4% (10,900) and by 2014 to 32.3% (17,600 publications).

Russia's key channels for scientific collaboration existed back in Soviet times and have not changed significantly since. The USSR's main scientific partners were Germany (primarily East Germany) and to a lesser degree the US. In 1973–1990, Germany accounted for 27% of the total number of joint publications by the USSR with other countries, while the US accounted for 14%. Since 1992, the share of these two countries in total publications by former Soviet academics has remained virtually unchanged, fluctuating between 23% and 27%.

Some similarity can also be seen in thematic terms. In 1973–1990, the main areas of foreign scientific collaboration for the USSR, as indexed on Web of Science, were interdisciplinary studies in physics (10.4%), condensed matter physics (9.6%), biochemistry and molecular biology (7%), interdisciplinary studies in chemistry (5.9%) and physical chemistry (5.6%).

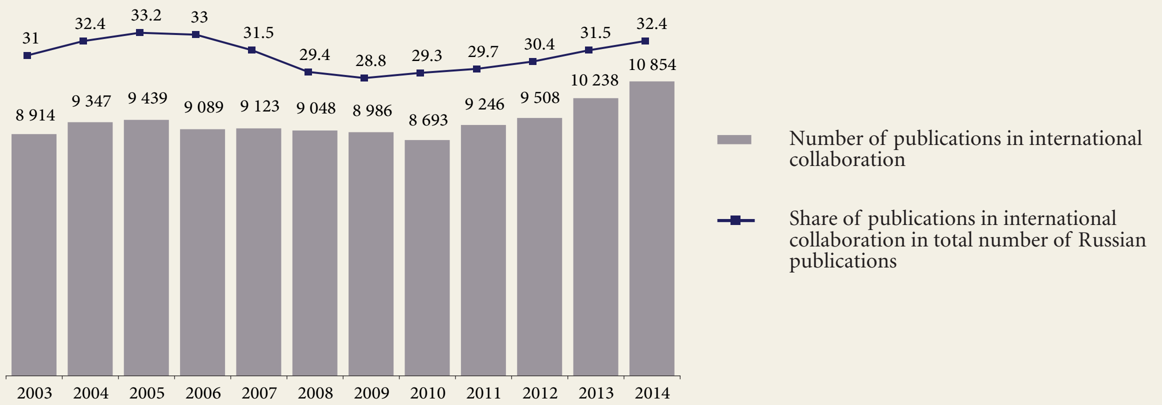
*Source*: authors' calculations.

Table 4. **Basic characteristics of joint publications by Russian academics with foreign colleagues in 2003–2014**

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of permanent partners (100 or more publications between 2003-2014) | 31 | 32 | 33 | 33 | 32 | 35 | 34 | 38 | 49 | 54 | 56 | 58 |
| Number of partner countries for Russia in terms of international co-authorship | 99 | 107 | 113 | 124 | 109 | 120 | 117 | 114 | 119 | 130 | 131 | 154 |
| Average number of partner countries in joint publications | 1.66 | 1.78 | 1.86 | 1.89 | 1.94 | 2.00 | 2.03 | 2.25 | 2.59 | 3.10 | 2.85 | 2.85 |

*Source*: authors' calculations based on the data of the Web of Science (data is current as of April 2015).

Fig. 2. **Dynamics of joint publications by Russian academics with foreign colleagues (according to Web of Science data for 2003–2014)**




*Source*: authors' calculations.

However, a stable trend of intensifying international collaboration has started to establish itself: the group of partner countries is expanding (including permanent partners) and the average number of authors in a single joint publication is growing (Table 4). Today, as in Soviet times, the key partners of Russian researchers are colleagues from Germany and the US (roughly 26% each of the total number of joint publications). France, the UK and Italy are also among this group of important partners, which can be explained both by traditional scientific ties and the emigration of Soviet academics after the collapse of the USSR.

Table 5 shows data for several countries with the best figures for international co-authorship with Russian academics in absolute terms or in growth terms over the period 2003–2014. Out of all countries with which Russian academics had joint publications, three countries stand out: China, with three-fold growth; Australia, with four-fold growth; and Turkey, with seven-fold growth. The observed trend can be explained not only by mutual interests, but also by the active involvement of Russian and foreign researchers in large-scale collaborative Megascience projects (such as the Large Hadron Collider at CERN, among others).

Table 6 shows the distribution of joint publications by Russian and foreign academics according to the thematic areas with the highest figures (total over 2003–2014) or highest rates of growth. As expected, in absolute terms traditional physical sciences and mathematics, materials engineering, and certain other engineering sciences are the leading fields. The most intensive growth in publication activity was recorded in interdisciplinary studies, nanotechnology, applied mathematics, metallurgy, and certain medical fields. However, negative dynamics were seen in Russian priority areas such as electronics, aerospace engineering, nuclear physics, nuclear science and technology, and modern areas in chemistry.

Table 5. **Russia's key partner countries in terms of joint scientific publications**

| Country | Share of publications as a percentage of total Russian co-authored publications (%) | | Number of joint publications (units) | | Growth in joint publications over 2003-2014 (%) |
|---|---|---|---|---|---|
| | 2003 | 2014 | 2003 | 2014 | |
| USA | 25.3 | 27.3 | 2 257 | 2 965 | 31.4 |
| Germany | 26.9 | 26.7 | 2 400 | 2 895 | 20.6 |
| France | 12.3 | 15.7 | 1 096 | 1 699 | 55.0 |
| UK | 9.1 | 14.5 | 815 | 1 571 | 92.8 |
| **China** | 2.9 | 9.7 | 262 | 1 049 | **300.4** |
| Switzerland | 4.4 | 7.2 | 394 | 779 | 97.7 |
| Finland | 3.1 | 5.6 | 276 | 604 | 118.8 |
| **Czech Republic** | 2.2 | 5.4 | 192 | 589 | **206.8** |
| **Brazil** | 1.7 | 5.0 | 154 | 542 | **251.9** |
| **Australia** | 1.5 | 4.9 | 133 | 535 | **302.3** |
| **India** | 1.2 | 4.8 | 110 | 522 | **374.5** |
| South Korea | 2.9 | 4.6 | 257 | 503 | 95.7 |
| **Austria** | 1.8 | 4.1 | 164 | 447 | **172.6** |
| **Turkey** | 0.6 | 3.8 | 51 | 408 | **700.0** |
| **Taiwan** | 1.3 | 3.5 | 113 | 379 | **235.4** |

*Source*: authors' calculations based on the data of the Web of Science (data is current as of April 2015).

Table 6. **Leading thematic areas of Russia's S&T collaboration with foreign countries**

| Scientific field (Web of Science categories) | Number of joint publications (units) | | | Percentage of Russia's joint publications in the period 2003-2014 (%) | Growth in joint publications over 2003–2014 (%) |
|---|---|---|---|---|---|
| | 2003 | 2014 | 2003–2014 — total | | |
| Physics Condensed Matter | 1 046 | 689 | 10 065 | 8.9 | –34.1 |
| Physics Multidisciplinary | 859 | 787 | 9 910 | 8.8 | –8.4 |
| Astronomy Astrophysics | 604 | 858 | 8 588 | 7.6 | 42.1 |
| Physics Applied | 709 | 758 | 8 317 | 7.4 | 6.9 |
| Physics Particles Fields | 558 | 739 | 7 929 | 7.0 | 32.4 |
| Materials Science Multidisciplinary | 574 | 799 | 7 485 | 6.7 | 39.2 |
| Chemistry Physical | 552 | 694 | 6 834 | 6.1 | 25.7 |
| Optics | 363 | 483 | 4 957 | 4.4 | 33.1 |
| Physics Atomic Molecular Chemical | 430 | 382 | 4 703 | 4.2 | –11.2 |
| Biochemistry Molecular Biology | 421 | 365 | 4 611 | 4.1 | –13.3 |
| Physics Nuclear | 420 | 319 | 4 418 | 3.9 | –24.0 |
| Geosciences Multidisciplinary | 247 | 329 | 3 468 | 3.1 | 33.2 |
| Chemistry Multidisciplinary | 341 | 199 | 3 244 | 2.9 | –41.6 |
| Mathematics | 266 | 244 | 2 808 | 2.5 | –8.3 |
| Nuclear Science Technology | 180 | 290 | 2 736 | 2.4 | 61.1 |
| Physics Mathematical | 229 | 179 | 2 344 | 2.1 | –21.8 |
| Physics Fluids Plasmas | 101 | 268 | 2 158 | 1.9 | 165.3 |
| Instruments Instrumentation | 127 | 202 | 1 823 | 1.6 | 59.1 |
| Mathematics Applied | 64 | 343 | 1 578 | 1.4 | 435.9 |
| Chemistry Inorganic Nuclear | 153 | 81 | 1 371 | 1.2 | –47.1 |
| Spectroscopy | 28 | 87 | 653 | 0.6 | 210.7 |
| Geochemistry Geophysics | 26 | 101 | 625 | 0.6 | 288.5 |
| Chemistry Organic | 84 | 20 | 569 | 0.5 | –76.2 |
| Engineering Electrical Electronic | 13 | 45 | 315 | 0.3 | 246.2 |

*Source*: authors' calculations based on the data of the Web of Science (data is current as of April 2015).

Table 7. **Russia's potential partner countries for collaborative projects in certain scientific fields**

| Country | Scientific field | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Clinical medicine | Industrial biotechnology | Computer and information sciences | Civil Engineering | Electronics and electrical engineering | Environmental biotechnology | Health sciences | Veterinary science | Agricultural sciences |
| Austria | X | | X | | | | | X | |
| UK | X | | | | | | X | X | |
| Germany | X | | | | | | | | |
| Spain | | | X | | | X | | | X |
| Italy | X | | | | | | | X | X |
| Netherlands | X | | | | | | X | X | |
| Finland | X | X | | | | X | X | | X |
| France | X | | | | | | | | |
| Canada | X | | | X | | | X | | X |
| USA | X | | | | | | X | | |
| Switzerland | X | X | | | | | X | X | |
| Japan | X | X | | | X | X | | | |
| Argentina | | | | | | X | | X | X |
| Mexico | | | | | | X | | X | X |
| Brazil | | X | | | | X | X | X | X |
| India | | X | | | | X | | | X |
| China | | X | X | X | X | X | | | |
| South Africa | | | | | | X | X | X | X |
| Iran | | | X | X | X | | | X | X |
| Turkey | X | X | | X | | X | | X | X |
| Israel | X | | | | | | | | |
| South Korea | | X | X | X | X | X | | | |
| Malaysia | | X | X | X | X | X | | | X |
| Singapore | | X | X | X | X | X | | | |
| Taiwan | | X | X | X | X | | | | |

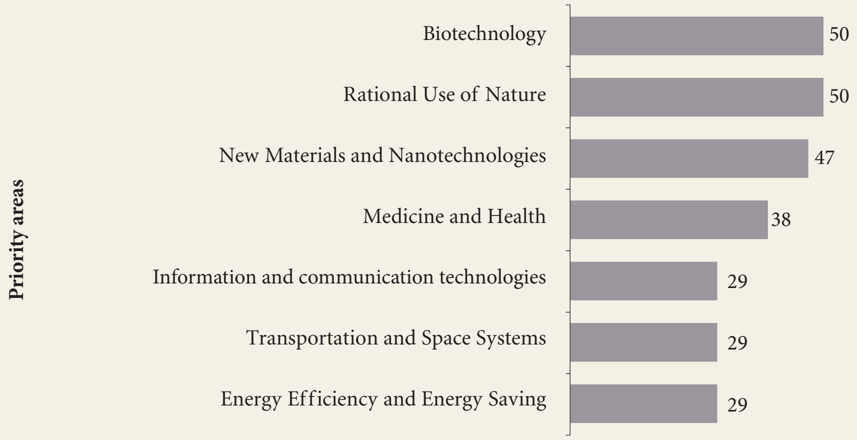
*Source*: compiled by the authors.

The results of bibliometric analyses of scientific specialisation and joint publications of Russian and foreign academics were used to compile a matrix of likely areas of long-term stable research cooperation according to scientific field and country, a fragment of which is given in Table 7. Notwithstanding the unfavorable foreign political conditions, collaboration with global leaders, BRICS nations, and some new developed economies demonstrating high growth in publication activity in certain scientific fields shows promise and is desirable for Russia. The analysis of bibliometric data reveals Russia's gaping holes in fields such as cell and tissue engineering, neuroimaging, robotics, and medical informatics. Generally, these fields are some of the most advanced, which creates some objective barriers when seeking partners for specialist projects. Evidently, special measures are needed to support Russian developments and guarantee access to foreign achievements.

## Results of the expert survey

The expert survey of those involved in international programmes with a Russian party, conducted to supplement the bibliometric analysis, allowed us to identify partner countries and organizations and collaboration fields and instruments, as well as obtain individual assessments from qualified experts regarding the prospects of developing ISTC.

Fig. 3. **Priority S&T areas in the Russian Federation** (proportion of respondents selecting the corresponding response, %)




*Note:* The total exceeds 100% as respondents could select several responses.

*Source*: results of the survey carried out by ISSEK, NRU HSE.

Biologists, physicists, mathematicians, chemists, geologists, representatives of the medical and engineering sciences, and employees from large multidisciplinary organizations took part in the survey (Skolkovo Institute of Science and Technology, National Research Nuclear University 'MEPhI', Tomsk Polytechnic University, Russian Academy of Sciences Institute of Oceanography, MISiS National University of Science and Technology, Southern Federal University, Immanuel Kant Baltic Federal University, and Voronezh State University). The activities of each of these are linked to one or more of the current priority areas for development in science and technology (Figure 3).

The geography of the respondents' international collaboration in the S&T sphere was extremely vast and covered dozens of countries (Figure 4). The global leaders — Germany, US, China, UK and Japan — are still the main partners of the surveyed organizations, which is in line with the bibliometric data.

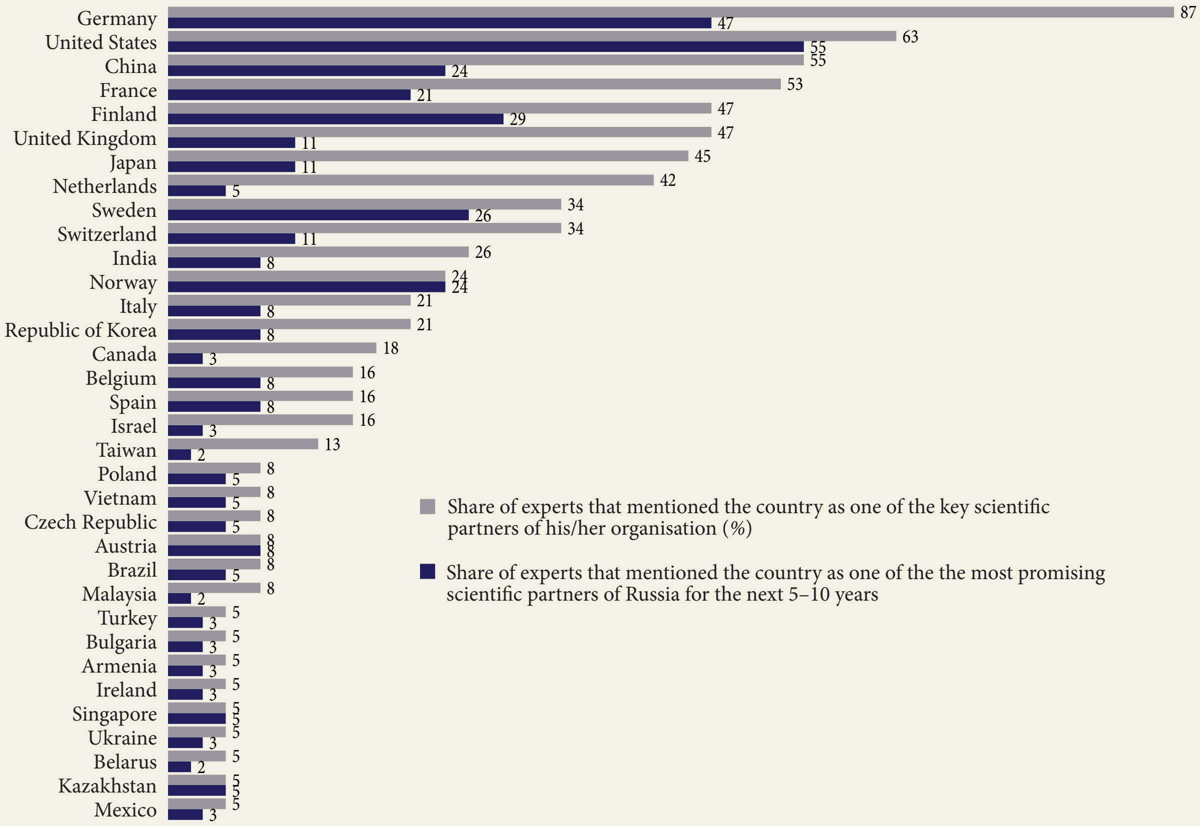
In the next 5–10 years, according to experts, the leading countries will probably continue to be Russia's main partners in the S&T sphere. These may be joined by Sweden, Netherlands, Finland, Spain, Norway, Austria, Singapore, Switzerland, Czech Republic, Brazil, Kazakhstan, and others.

As for ISTC development conditions, the respondents indicate that many of the barriers in this sphere are caused by internal circumstances linked to the complex economic situation in the country: depreciation of the rouble, budget deficit, and the inert nature of Russian bureaucracy. However, almost 45% of those surveyed reported that they had already experienced some negative impact of foreign political conditions.

Among the barriers and restrictions on developing ISTC are:

- a fall in the intensity of collaboration, including the reduction in the number of contracts signed; restrictions on access to funding through the European Union framework programmes; the suspension of a number of international projects due to a significant proportion of electronic components for R&D and modern equipment and technology falling under the sanctions; and the decrease in opportunities for Russian academics to work in international laboratories;
- general increase in the complexity of relations with partners, even as far as a reduction in business correspondence;
- costs and other problems in purchasing and supplying equipment and consumables;
- a fall in collaboration with foreign state institutions (for example, joint programmes with Russia were curtailed by the US Geological Survey, the leader in environmental monitoring);

Fig. 4. **Countries with which respondent organizations already collaborate in the S&T sphere and the most promising for collaboration in the next 5-10 years**




*Source*: results of the survey carried out by ISSEK, NRU HSE.

- refusal to publish articles by international journals which were previously happy to collaborate with Russian authors;
- limited grants handed out to Russian participants at international conferences;
- growing cost of scientific work following the depreciation of the rouble;
- difficulties in obtaining visas for scientific workers;
- difficulty in attracting foreign professors;
- the outflow of foreign specialists.

Many respondents pointed to guarded attitudes towards Russian academics among foreign colleagues, even those with experience of long-term collaboration. Foreigners fear that the involvement of an organization from Russia could have a negative impact on the fate of a project and jeopardize funding from national or international structures. In several cases, this trend has been successfully overcome through negotiations. Long-term contact partially offsets the negative impact of foreign political conditions. At the same time, experts remarked upon the comparatively high stability of ties with universities and foreign companies. There were even instances of scientific collaboration that were comparable with circumstances during the Cold War, for example in optics and laser technologies.

One of the consequences of the current foreign political climate, according to experts, is the geographical expansion of Russia's international collaboration in the S&T sphere, where partners from BRICS, ASEAN, and APEC countries are playing an ever-increasing role.[4] Table 8 lists Russia's ISTC priorities as a summary of the bibliometric analysis and expert survey results.

[4] However, the bibliometric analysis confirmed the existence of potential for cooperation only with certain countries in these groups and in certain scientific areas.

Table 8. **Priorities for Russia's S&T collaboration with foreign countries**

| No. | Area of S&T collaboration | Countries | Type of research | | |
|---|---|---|---|---|---|
| | | | Theoretical | Applied | Theoretical and applied |
| | **Information and communication technologies** | | | | |
| **1.** | Computer architecture and systems | Germany, Israel | x | x | x |
| **2.** | Telecommunication technologies | Germany, Israel | x | x | x |
| **3.** | Data processing and analysis technologies | Germany, US, India | x | x | |
| | | Germany | | | x |
| **4.** | Hardware components, electronic devices, and robotics | Germany | | | x |
| **5.** | Predictive modelling and simulation | France | x | | |
| | | EU countries | | | x |
| **6.** | Information security | | | | |
| **7.** | Algorithms and software | Israel, Germany, Italy | x | x | x |
| | **Biotechnology** | | | | |
| **8.** | Development of the scientific and methodological basis for biotechnology research | Spain, Japan, Sweden, France, Germany | x | x | x |
| | | UK, Israel, US, Belgium | x | | |
| | | UK, Israel | | x | |
| **9.** | Industrial biotechnology | China, France, Germany | x | x | x |
| **10.** | Agricultural biotechnology | US, Germany, UK, Japan, France | x | x | x |
| | | Netherlands | x | x | |
| | | Poland | | x | |
| **11.** | Environmental biotechnology | Netherlands, Brazil | x | x | |
| | | UK, Italy, France, Germany | x | x | x |
| **12.** | Food biotechnology | Netherlands | x | x | |
| | | Italy, Spain, France, Germany | x | x | x |
| **13.** | Forestry biotechnology | Finland | x | x | |
| | | France, Germany | x | x | x |
| **14.** | Aquabioculture | France, Germany, Norway | x | x | x |
| | **Medicine and health care** | | | | |
| **15.** | Discovery of drug candidates | US, Germany, India | x | x | x |
| | | UK, France | | x | |
| | | Sweden, China | x | | |
| **16.** | Molecular diagnostics | US, Singapore, Taiwan, Japan, Portugal, China, Germany, Armenia, UK, Finland | x | x | x |
| | | Italy, France | x | | x |
| | | Sweden, Norway | x | | |
| **17.** | Molecular profiling and identification of molecular and cellular pathogenesis mechanisms | US, Germany, Sweden | x | x | x |
| | | Japan, UK | | x | |
| | | France, China, Italy | x | | |
| **18.** | Biomedical cell technologies | Japan | | x | |
| | | Portugal | x | | |
| | | Sweden, US, UK | x | x | x |
| | | Germany, Italy | x | | x |
| **19.** | Biocomposite materials for medical application | Germany, Israel, Switzerland | x | x | x |
| | | France | | x | |
| **20.** | Bio-electrodynamics and radiation medicine | US, Israel | x | x | |
| | | China, Finland, Germany | x | x | x |
| | | France | | x | |
| **21.** | Genomic passportisation of humans | US, UK, Singapore, Japan, Sweden | x | x | x |
| | **New materials and nanotechnologies** | | | | |
| **22.** | Structural and functional materials | US, Germany, Japan, Italy | x | x | x |
| | | Finland | | x | |
| | | France, Israel | x | x | |
| **23.** | Hybrid materials, converging technologies, bio-mimetic materials and medical supplies | France, Czech Republic | x | x | x |
| | | USA | x | | |
| | | China, Spain | | | |
| | | Germany, Finland | | x | |
| **24.** | Computer simulation of materials and processes | US, Germany, Japan, Finland, Israel, UK | x | x | x |
| | | China | x | | |

*Table 8 (continued)*

| | | | | | |
|---|---|---|---|---|---|
| **25.** | Diagnostics of materials | US, Germany, Japan, Italy | x | x | x |
| | | Finland | | x | |
| | **Rational use of natural resources** | | | | |
| **26.** | Environmental protection and safety technologies | Germany, Sweden, US, China | x | | |
| | | EU countries, Japan, South Korea, Hungary | x | x | x |
| | | Kazakhstan, Saudi Arabia, Germany, US | | x | |
| **27.** | Monitoring of environment, assessment and forecasting of natural and technogenic emergencies | Norway, US, France, Japan, member states of the UN WMO, EU countries, South Korea, Italy, Germany | x | x | x |
| | | UK | x | x | x |
| | | Finland, Saudi Arabia | | x | |
| | | Finland, Sweden | x | | |
| **28.** | Exploration of subsoil assets, mineral prospecting and integrated development of mineral and hydrocarbon resources | Saudi Arabia, Germany, US | | x | |
| **29.** | Exploration and utilization of oceanic resources, the Arctic and Antarctic | US, Germany, Norway, France, Finland | x | x | x |
| | | | | x | |
| | **Transport and space systems** | | | | |
| **30.** | Development of an integrated transport space | Finland, Brazil | | x | |
| | | Canada, US, Germany, France, Italy | x | x | x |
| **31.** | Increasing safety and environmental neutrality of transport systems | Sweden, US | x | | |
| | | Germany, France, Brazil | x | x | x |
| | | Netherlands | x | x | |
| **32.** | Prospective transport and space systems | US, Germany | x | | |
| | | France, China | x | x | x |
| | | Netherlands | x | x | |
| | **Energy efficiency and energy saving** | | | | |
| **33.** | Efficient exploration and mining of fossil fuels | Saudi Arabia, Germany, US | x | x | x |
| **34.** | Efficient and environmentally clean heat and power engineering | Germany, US | x | | |
| | | Saudi Arabia | | x | |
| | | France | | | |
| **35.** | Safe nuclear power engineering | Saudi Arabia | | x | |
| | | Germany, US | x | | |
| **36.** | Efficient use of renewable energy sources | Czech Republic | x | | |
| | | Saudi Arabia | | x | |
| | | Germany, UK, Brazil | x | x | x |
| **37.** | Prospective bioenergy | Saudi Arabia | | x | |
| **38.** | Deep processing of organic fuels | Saudi Arabia | | x | |
| **39.** | Efficient storage of electric and thermal energy | Saudi Arabia | | x | |
| **40.** | Hydrogen power | Saudi Arabia, Germany, US | | x | |
| **41.** | Efficient transportation of fuel and energy | Saudi Arabia | | x | |
| **42.** | Smart power generation systems of the future | Germany, US, Canada | x | x | x |
| | | Saudi Arabia | | x | |
| **43.** | Efficient energy consumption | Saudi Arabia, Germany, US | | x | |
| **44.** | Modelling prospective power generation technologies and systems | USA | x | | |
| | | Saudi Arabia | | x | |
| | | EU countries, Germany, France | x | x | x |
| **45.** | Development of an advanced electronic component base for power engineering | Saudi Arabia | | x | |
| | | Germany, China, US | x | x | x |
| **46.** | New materials and catalysts for power engineering of the future | US, UK, BRICS countries, Germany, Netherlands, France | x | x | x |
| | | Saudi Arabia | | x | |
| | | Australia | x | x | |

*Note*. The list of areas in the second stage of the itemization was compiled in accordance with the Russian S&T Development Forecast for the period up to 2030 [*Gokhberg*, 2014].

*Source*: compiled by the authors.

## Conclusion

The proposed approach to selecting ISTC priorities is not without its limitations, of course, as noted in the description of the research method. However, the authors did not set out to identify specific partners for cooperation, and, as international practice shows, such an aim is not what is called for. A more pressing task is to summarize the analytical data and evaluations, which will be beneficial to those making the decisions based on the available information and negotiations with partners. Using data that are more diverse will ultimately better satisfy Russia's national interests, in terms of overcoming the after-effects of economic and political crises, implementing national modernization objectives, and guaranteeing scientific achievement on a global level. The intensifying and increasing scales of international cooperation are key factors behind the achievement of Russian S&T complex development targets.

The current model of ISTC needs to be improved radically in the interest of intensifying the country's role as an equal participant in international S&T relations. Among the real and potential advantages derived by Russia from collaboration with foreign states in science, technology, and innovation, long-term ties with leading research centres and academics are of the greatest value. This would increase and transfer knowledge as well as thematic and geographical distribution of a range of ISTC areas; improve forms and mechanisms of integration in the global context; and increase Russia's involvement in solving global problems which would also positively impact the domestic condition, among others. From a strategic perspective, we can count on the intensification of partnerships with all states in future.

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# Managerial Engagement with Scenario Planning: A Conceptual Consumption Approach

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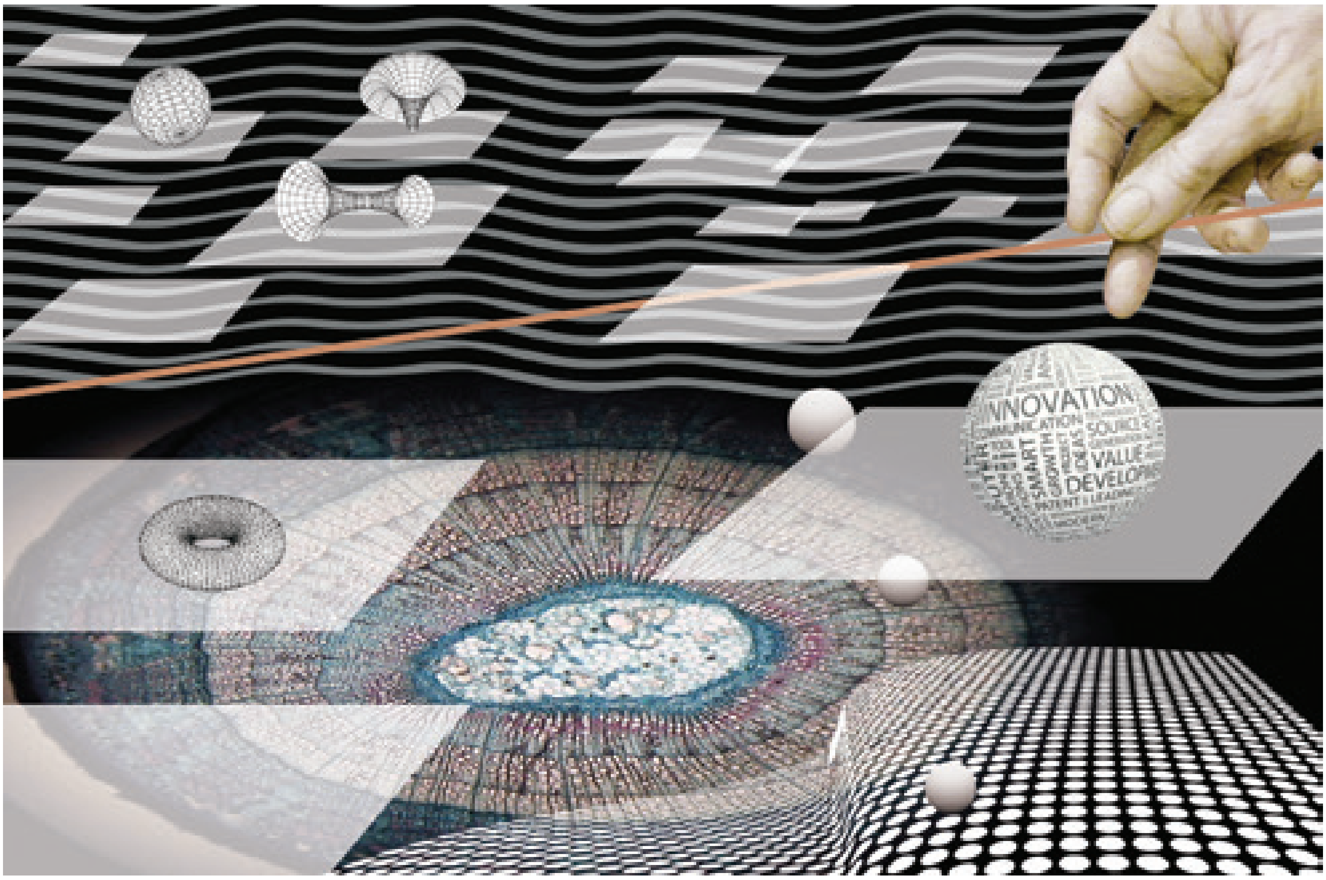


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## Abstract

**Scenario development is widely used to reduce uncertainty while making decisions in high velocity environments. Despite this fact, managerial fixation on short term performance objectives, their penchant fear of the unpredictable future and their sheer inability to face the alternative futures generated in the scenario planning exercises has led to little value capture from this activity.**

**The paper analyzes the factors that determine the willingness of decision-makers, to be actively involved in scenario planning. The authors suggest that effective incentives to promote the interest in this activity and its impact can be found, if we consider the decision-makers, as 'consumers' of certain ideas, concepts, expectations, and competencies. In particular, the paper hypothesizes and validates the assumptions that the selection of appropriate targets for scenario planning, commitment to achieving them, expectations of positive outcomes, increasing the frequency of scenario planning exercises are more likely to be expressed in the growing interest of managers and stakeholders to develop scenarios.**

**The presented results are tested on the most common — intuitive logic approach to scenario planning. The authors expect future research to go further to empirically test the proposed hypotheses, and if possible, ascertain whether similar hypotheses could be generated in the context of other tried and tested scenario planning methodologies such as the probabilistic modified trends, competitive intelligence and cross impact analysis.**

**Keywords:** strategic foresight; scenario planning; intuitive logics methodology; conceptual consumption

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The rapid pace of change in the business environment has increased the need for strategic Foresight in creating and capturing a sustainable competitive advantage. In this regard, the organization of episodic scenario planning exercises has become a dominant logic of organization in high velocity environments [*Amer et al.*, 2013; *Sarpong, O'Regan*, 2014; *Varum, Melo*, 2010]. Scenario planning is a 'disciplined way of looking outside the daily business which involves careful scanning of the contextual environment, dialectic inputs from external observers and creative re-organization of relevant information into meaningful, future-oriented knowledge' [*Schlange*, 1997, p. 877]. The practice relies on the generation and probing of heuristic narratives in the form of scenarios representing compelling visions of a future not so detached from the very world in which they are expected to play out. These scenarios are frequently modelled by drawing on internal resources and structures as well as external factors that may have a likely impact on the future of organizations [*Mackay, McKiernan*, 2006]. While a plethora of methodologies underpinning scenario planning have been developed over the years, management consultants and facilitators increasingly rely on the intuitive logic methodology as a heuristic framework in organizing these exercises [*Wright, Cairns*, 2011; *Mackay, McKiernan*, 2006]. The rise of the intuitive logic as a methodology of choice is driven by two main reasons. First, it employs eclectic techniques and activities that are often informal in nature, yet may force actors to 'think the unthinkable' within their situated practice and organizational environments. Second, it encourages managers to take individual and collective responsibility in making strategic decisions in fast-moving and complex conditions.

Nevertheless, we know that the managerial fixation on short-term performance objectives, their penchant fear of the unpredictable future, and their sheer inability to face the alternative futures generated in these exercises has led to little value-added from scenario planning exercises [*Cunha et al.*, 2006; *Hodgkinson, Healy*, 2008]. In short, managerial engagement and proactive participation in scenario planning exercises have been problematic, especially when they are not very clear as to why they should be thinking about the unknown future, and how these scenario planning exercises as a whole could contribute to their organizations' ability to create and capture sustainable value in the future [*van der Heidjen*, 1996]. Insufficient answers to such questions often taken for granted could undermine the commitment of managers to engage adequately in scenario planning exercises. The potential negative influence of this disconnect on the formulation and implementation of ideas generated from scenario planning calls for new ways to rally managerial support and active engagement with scenario planning in practice. While this call pervades the strategic Foresight literature [*Cairns et al.*, 2009; *Forster*, 1993], it remains mostly neglected. Accordingly, we respond to this need by drawing on the psychological scholarship on consumption to examine how the basic idea of preference formation and information consumption could augment our understanding of managerial engagement with scenario planning. Departing from a narrow focus on physical consumption to consuming concepts, our theoretical lens help us to offer an alternative interpretation to understand ing the managerial desire to consume concepts and ideas about the future, and signal to themselves and others their beliefs about the unknown future and its influence on creating value and capturing competitive advantages.

The paper is structured as follows. First, we provide an overview of intuitive logic as a dominant methodology employed in scenario planning exercises. Next, we introduce the concept of conceptual consumption and its vicissitudes on peoples' desire to consume concepts. We then explore the relative strength of conceptual conception to show how managers' desire to consume concepts may encourage them to engage in intuitive logic as a methodology in scenario planning even when other methodologies offer more utility. Finally, we develop some propositions and identify potential empirical indicators to provide insights into the effectiveness of intuitive logic as a scenario planning methodology.

## The intuitive logic methodology

Among the plethora of scenario planning methodologies, the intuitive logic approach has received the most significant scholarly attention [*Bradfield et al.*, 2005]. A key characteristic of this dominant approach to organizing scenario planning is its reliance on a group or a variety of key actors in developing plausible multiple scenarios of the future in ways that inform and support decision making that embraces and integrates the full set of potential political, economic, social, technological, ecological and legal (PESTEL) factors that shapes the future. Promising strategic opportunities for the identification of novel opportunities and limitations in the fleeting business environment, variants of the methodology has been proposed each consisting of sequential discrete actions and prescriptive steps [*Foster*, 1993]. The typical generic steps underpinning the methodology (Table 1) is outlined by Wright and Cairns [*Wright, Cairns*, 2011].

The starting point of scenario work according to this methodology depends on the purpose of the scenario undertaking. It is generally related to a particular management issue or area of general concern, which in turn determines the focus in terms of the driving forces to be examined. Thus, the intuitive logic based scenario work can be either descriptive or normative and the scope may be extremely broad as in the development of global scenarios or narrowly focused on a particular issue [*Bradfield et al.*, 2005]. The final output of the intuitive logic methodology is a coherent set of logically linked scenarios in discursive narrative form; moreover, the narratives are often embellished with pictures, newspaper clippings and vivid graphics for effect, most of which are contrived.

## The concept of conceptual consumption and the intuitive logic methodology

Consumption remains an important construct in understanding human basic needs and survival. With the advent of modern technologies, the nature of consumption in everyday life has broadened to include the consumption of ideas, information, and concepts [*Ariely, Norton*, 2009]. The implication is that we do not only engage in physical consumption. Rather, we continuously engage in other virtual forms of consumption that constitutively enhance our welfare. For example, consider our daily interactions with brands, our proclivity to read blogs and stories, and how we have internalized research findings about the impact of a daily walk in the woods on our health. Such pervasive consumption or utilization of concepts, ideas or information — often based on previous experience(s) — has come to be known as conceptual consumption [*Ariely, Norton*, 2009]. The inventiveness of the range of non-physical consumption, as argued by [*Ferraro et al.*, 2009], has the potential to shape our beliefs and attitudes, to influences our decision making, and even impact on the formation and perpetuation of our individual and collective preferences. From this perspective,

Table 1. **Generic steps underpinning the intuitive logic methodology of scenario planning**

| Steps | Actions |
|---|---|
| 1 | Setting the agenda: involves defining the issue and process, and setting the scenario time scale |
| 2 | Determining the driving force: entails the process of working first individually and then collectively as a group |
| 3 | Clustering the driving forces: involves group discussion to develop, test and name the clusters |
| 4 | Defining the cluster outcomes: involves defining two extremes, yet highly plausible – and hence, possible – outcomes for each of the clusters over the scenario timescale |
| 5 | Impact/ uncertain matrix: determining the key scenario factors A and B |
| 6 | Framing the scenarios: defining the extreme outcomes of the key factors, A1/A2 and B1/B2 |
| 7 | Scoping the scenarios: building the set of broad descriptors for four scenarios |
| 8 | Developing the scenarios: working in sub-groups to develop scenario storylines, including key events, their chronological structure as well as the 'who and why' of what happens. |

*Source*: [*Wright, Cairns*, 2011].

we argue that managers' desires to consume information, ideas and concepts — about the future in this case — has a fundamental role in shaping their behaviour and subsequent engagement with scenario planning. We found four classes of conceptual consumption that we feel can be best used to explain potential managerial engagement with scenario planning. These include: 'expectancies', 'goals', 'fluency', and 'regulatory fits'. We encourage readers to probe the psychology literature further for a more comprehensive review of other seemingly paradoxical or self-abnegating behaviour that can also be grouped under the broad rubric of conceptual consumption. In the next section, we briefly review these constructs and show how they may help to extend our understanding of managerial engagement with scenario planning.

**Consuming Expectancies**

Creating expectations about the possible outcomes of different courses of action is known to be one way to cope with uncertainty when making decisions [*Zeelenberg et al.,* 2000]. Human expectation from a particular activity determines their commitment to it. Scholars have noted that stating the expectation from engaging in a certain behaviour can increase the likelihood of performing it [*Fitzsimons, Morwitz,* 1996*; Morwitz et al.,* 1993]. For instance, expecting humour influences peoples' enjoyment of comedy movies and makes them more likely to watch such films in future. Such expectations guide perceptions about what constitutes knowledge, and also shape behaviour since people tend to seek confirmations of their beliefs [*Fiske, Taylor,* 2008]. Thus, by consuming expectations, we refer to how managers' expectation of generating value from scenario planning may influence their propensity to engage with scenario planning exercises. The implication of our conjecture is that managerial expectations of the possible outcomes of scenario planning may affect their engagement with it. For example, managers might often ask themselves what would happen if they were to rely on the intuitive logic methodology or traditional forecasting techniques that rely on number crunching. Alternatively, they simply ask whether it might be better to opt for another scenario planning methodology. As argued by [*Olson et al.,* 1996, p.211], 'expectancy' forms the basis for virtually all behaviour. In this regard, the outcome expectancies of using the intuitive logic methodology might influence managerial behaviour in the following way: If expectancies are favourable, the result is a renewed effort to engage with scenario planning and discussion processes. If their expectancies are sufficiently unfavourable, the result is reduced effort, or even complete disengagement from further attempts [*Armor, Taylor,* 1998*; Zeelenberg et al.,* 1998].

Although expectancies tend to be confirmed most of the time [*Olson et al.,* 1996], it should be noted, however, that expectancies influence not just perception and internal experiences but also external events without conscious awareness [*Chen, Bargh,* 1997]. While violations of expectancies are not uncommon [*Zeelenberg et al.,* 2000] managerial expectancies are likely to be either positive or negative. If managerial expectations on probing the future via the intuitive logic methodology are positive, there is more likelihood that managers will prefer it for their scenario planning exercise. However, if their expectancies are negative, it is very likely that they opt for another methodology to complete the scenario planning exercise. In the case of a negative experience, expectancies have been violated resulting in negative emotions [*Zeelenberg et al.,* 2000]. In the context of deciding whether to use an intuitive logic methodology for scenario planning exercise, there are at least two ways in which these violated expectancies can result in the experience of negative emotions. The first way entails situations in which the chosen option ends up being worse than the rejected options. This is the case when intuitive logic methodology was the chosen option because it was expected to be the best, yet it turned out that another scenario planning methodology would have been better. Following these 'bad decisions', managers are likely to experience *regret.* The second way is if the intuitive logics as the chosen methodology results in an outcome that is worse than expected. Such 'disconfirmed expectancies' often give rise to the experience of *disappointment.* Accordingly, this may have a measurable effect on their engagement with the intuitive logic methodology.

Taken together, these suggest that preconceptions and ideas with or without experience with the intuitive logics methodology can modify their engagement with it. Consuming expectancies, from our study's perspective, imply that managers' perceived expectation in the use of the considered methodology for scenario planning may influence their behaviour, and thus their engagement with it. Thus:

*Hypothesis H1a*: Managerial perceived expectations of using intuitive logics methodology during the scenario planning exercise will positively influence their engagement with it.

*Hypothesis H1b*: Managerial perceived expectations of using intuitive logics methodology during the scenario planning exercise will negatively influence their engagement with it.

**Consuming Goals**

Most theories on goals have emphasized conscious choice and guidance of behaviour on a moment-to-moment basis resulting in an increasing probe into the nature and functions of goals in psychology and consumer behaviour [e.g. *Gollwitzer, Moskowitz,* 1996*; Oettingen, Gollwitzer,* 2001]. We refer to consuming goals as an integrated pattern of beliefs, attributions, and effects that produces behavioural intentions [*Weiner,* 1986; *Koestner et al.,* 2002]. Goals are seen as cognitive structures that can be represented in terms of movement and progress toward some abstract and desirable end state or in terms of commitment to a fixed and desirable end state [*Fishbach, Dhar,* 2005]. People's choices are therefore usually driven by multiple underlying goals, each of which — if viewed in isolation — may appear conflicting [*Jung, Pawlowski,* 2009]. For example, individuals simultaneously believe in saving for retirement as well as taking luxurious vacations, doing well academically and socializing actively with friends, and so forth.

Setting goals therefore serves as a strong motivating factor in enacting action. From this perspective, we argue that the predominant behaviour of managers in a scenario planning exercise is simply to consume goals. In other words, managers' choice of scenario planning as a tool to probe the future is usually driven by the underlying goals of understanding and creating a future business environment. This implies that the goals set for a scenario planning exercise implicitly influence the extent to which managers are likely to actively participate and engage with the process. These goals cannot be set in stone and are often difficult to quantify; believing that such goals are likely to be achieved serves to motivate and shape the consistent choice of actions. This means that the goal set for an activity shapes peoples' reaction to and involvement with it. Consequently, the agenda of the scenario planning exercise serves as a reference point that drives peoples' effort and engagement with it. We argue that this is consistent with the first step in the intuitive logic methodology which is about agenda setting. A carefully crafted agenda on the part of the facilitator is therefore imperative in getting managers to actively engage with the scenario process.

The regulation of multiple goals requires the facilitator to consider both the progress in moving towards the goal as well as the strength of commitment to the goal [*Koestner et al,,* 2002]. We propose that the level of commitment to goals set for scenario planning exercises will potentially have implications for regulating managers' behaviour during the process and subsequent actions. Consequently, if the choice of intuitive logics methodology is used to infer the general level of managers' commitment to a scenario planning exercise goal(s), and those goals are consistently met, then they are more likely to engage with it. This conclusion led us to the following hypotheses:

*Hypothesis H2a*: The goals set for a scenario planning exercise will positively influence managerial engagement with intuitive logic methodology.

*Hypothesis H2b*: The commitment to the goals set for a scenario planning exercise will positively influence managerial engagement with the intuitive logic methodology.

### Consuming Fluency

Consuming fluency refers to the ease with which stimuli are processed and experienced due to several occurrences [*Ariely, Norton,* 2009]. Zajonc showed that being exposed to a stimulus leads to more positive affective reactions [*Zajonc,* 1968]. Furthermore, Whittlesea found that exposure to stimuli — whether conscious or not — leads to more positive affective reactions due to perpetual fluency resulting from familiarity [*Whittlesea,* 1993]. This means that the more frequently stimuli occur, the more the relevant stimuli are familiar, and consequently the greater the scope for liking which impacts judgement and behaviour [*Ferraro et al,* 2009*; Fang et al.*, 2007*; Simmons, Nelson,* 2006]. However, we know that scenario planning is frequently treated as an episodic exercise. Nevertheless, the rapidly changing business environments observed today [*Sarpong, Maclean,* 2011] mean that organizations must carry out scenario planning exercises regularly in order to stay in tune with their short-lived markets and technologies. Managers who frequently organize these exercises are more likely to understand how they are relevant to their organization's competences and are more likely to be committed to such exercises, which in turn means they are more likely to be engaged in such processes. Thus:

*Hypothesis H3a*: The frequency of scenario planning exercises will positively influence managerial engagement with the intuitive logic methodology.

*Hypothesis H3b*: The sense of 'feeling right' when a manager uses the intuitive logic methodology during a scenario planning exercise which will positively influence their subsequent engagement with it.

### Consuming Fit

The idea of consuming fit originated from the concept of 'regulatory fit', which is itself closely related to consuming fluency. A consuming fit proposes that people generally experience a regulatory fit when they pursue a goal in a manner that sustains their regulatory orientation. Thus, by consuming fit we refer to the feeling of ease accompanying tasks that are easy to process [*Ariely, Norton,* 2009]. Having a right feeling during a task increases motivations which align with behaviour [*Higgins,* 2000, 2005]. Thus, human feelings or views shape behaviour and attitudes towards a particular task. From this perspective, consuming fit arguably increases managerial perceptions that scenario planning is the 'right' way to engage with the unknown future and thus increases their sense that what they are doing is important during the scenario planning process. We therefore propose that a scenario planning exercise, which involves pursuing a goal as discussed in the previous section, is itself evaluated more positively when the strategic nature of the methodology used (i.e. the intuitive logics) fits the regulatory orientation of the managers pursuing the goal.

Combining these together, consuming fit we argue influences phenomena ranging from the amount of effort managers devote to tasks [*Vaughn et al.*, 2006], their susceptibility to persuasive appeal [*Cesario et al.*, 2004], and to their ability to engage in effective self-control [*Hong, Lee,* 2008]. Consuming fit implies that managers' perceived feelings, when engaging with intuitive logics during scenario planning exercises within their regulatory orientation, may influence their behaviour. Accordingly, this may have a measurable effect on their engagement with relevant exercises. If managers feel intuitive logic will help them achieve the goals of the scenario planning exercise, then they tend to engage in the process. However, if managers think that intuitive logic is not good enough to help them achieve their scenario planning goals, then it is likely they will not engage in it. We thus hypothesize that:

*Hypothesis H4a*: Managerial regulatory fit during a scenario planning exercise will positively influence their engagement with the intuitive logic methodology.

*Hypothesis H4b*: Managerial regulatory fit during a scenario planning exercise will negatively influence their engagement with the intuitive logic methodology.

## Discussion and Conclusion

In this paper, we argued that managerial engagement with scenario planning exercises has been quite problematic, especially when managers are not very sure about the value that can be captured from such exercises. Focusing on the intuitive logic methodology, we drew on the psychological idea of conceptual consumption as a meta-theoretical lens to develop our understanding about when managers are more likely to engage and participate actively in scenario planning exercises. In doing this, we partially integrated the literature on scenario planning and conceptual consumption to provide a common predictive basis for examining managerial engagement with scenario planning in practice. In addition, we developed some propositions to advance our thesis. While these propositions are not exhaustive, they may serve as a starting point for future empirical investigations into managerial engagement and participation in scenario planning exercises. We suggest that future research delves further to empirically testing our hypotheses, and if possible, ascertaining whether similar hypotheses could be generated in the context of other tried and tested scenario planning methodologies such as the probabilistic modified trends, competitive intelligence and cross impact analysis.

While our paper provides some significant insights into managerial engagement with scenario planning, it has some limitations. Our scant review of the burgeoning literature on the conceptual consumption construct means that we might have missed opportunities to develop some of the ideas we presented more substantially. Future investigations drawing on conceptual consumption hold enormous possibilities. We hope that this study will be an important stepping-stone towards a new exploration in scenario planning research that can greatly enrich our understanding of managerial and stakeholder engagement with scenario planning.

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