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Research and Technology Organizations (RTOs) in the primary sector: Providing innovation to Russia's mines and corn fields

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Abstract

Purpose – Given the immense gains in productivity in agriculture and mining over the last decades, the purpose of this paper is to study knowledge transfer from Research and Technology Organizations (RTOs) into primary sector producers. The authors inquire which of these RTOs are successfully competing for public funding, and how these funds are used. Also, the authors study what makes an RTO more (financially) successful in technology transfer than their peers and which RTOs transferred technology that was new to the Russian market.

Design/methodology/approach – This research is based on 62 RTOs which reported technology transfer to enterprises with main economic activities classified by NACE rev 1 as "A – agriculture, hunting and forestry" and "B – fishing" and "C – mining and quarrying," including oil and gas extraction.

Findings – The authors found remarkable differences between the Russian RTOs and their OECD peers, but also differences between agriculture and mining. Interestingly, competitive funding plays a different role in both industries. In agriculture, a more conservative funding paradigm prevails, and competitive funding is less important and more reliance on classical annually revolving funds is given. Competitive funding here is more used to strengthen basic R&D and to generate patentable knowledge, while in mining, these funds support technology transfer.

Originality/value – This is, to the knowledge, the first detailed study on Russian RTOs servicing her primary sector. The authors believe that studying these RTOs is of great value as RTOs are broadly under-researched and various scholars have called for more fine-grained analyses to better understand their role in the innovation system.

Keywords Russia, Research and development, Primary sector, Research and development organization

Paper type Research paper

Introduction

Scientific discoveries often stand at the beginning of production increases and the introduction of new and better products or services. A well-established stream of empirical work has provided evidence for the importance of scientific knowledge and industry-science relations for innovation activities (e.g. Rothwell, 1992; Rosenberg and

The paper is based on a pilot statistical survey of Russian Research and Technology Organizations (RTOs) initiated by the Institute for Statistical Studies and Economics of Knowledge (ISSEK) and the National Research University Higher School of Economics (NRU HSE) with assistance of the Research Laboratory for Economics of Innovation of NRU HSE, the Research Laboratory for Science and Technology Studies of NRU HSE and the Centre for Fundamental Studies of NRU HSE in 2010. The study was implemented in the framework of the Programme of Fundamental Studies of the Higher School of Economics in 2012.

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Nelson, 1994; Dodgson, 1994; Mansfield and Lee, 1996; Mansfield, 1991; Branscomb *et al.*, 1999; OECD, 2000). Good innovative performance, however, relies on the effective diffusion and assimilation of the knowledge by relevant actors (e.g. Malerba, 2002; Lazaric *et al.*, 2004). For firms, the utilization of external knowledge allows them to benefit from increasingly difficult technologies in an ever faster changing technological environment. As empirical studies show, since the 1980s the number of firms seeking external knowledge sources has increased strongly (Arora *et al.*, 2001; Hagedoorn *et al.*, 2000; Amara and Landry, 2005).

Knowledge and technology transfer might take a prominent role in those industries in which a country holds competitive advantages and is generating real economic growth. Competition in these industries will be fierce and incorporating the latest technologies at an early stage might distance competing peers and secure market share. As most free cash-flows will be accumulated by these industries, and the willingness to pay for such new and promising technologies, might well allow for a premium. For Russia, such an area of dominant economic importance is the primary sector. Commodity exports (including food and live animals, crude materials, inedible, mineral fuels, lubricants and related materials, except for electrical power) accounted for 68.6 percent of the total exports from Russia in 2009. In this year Russia produced 61,740 thousand tons (tt) of wheat, which equals 9 percent of the world production – 18,000 tt of which went into export. Also, 4,912 million tons of crude oil was extracted from Russia's soil in 2009, amounting to 12.6 percent of the world's production.

Given the immense gains in productivity in agriculture and mining over the last decades (e.g. Pardey *et al.*, 2004; Bender, 2006), we are interested in studying the sources of this new knowledge and the channels through which they reach producing firms. Supporting these processes is an essential function of Research and Technology Organizations (RTOs)[1] which specialize on the vital role of creation and distribution of new knowledge and technologies (Oxford Economics, 2008). In contrast to universities, their mission is to generate knowledge aimed at enhancing firms' competitive advantages as their unique set-up and industry links allow overcoming many of the institutional barriers to technology transfer (Autio *et al.*, 2004). Of particular interest – and the focus of this paper – are RTOs that transfer knowledge to the primary sector. The demand for such research and development services in Russia's primary sector is huge. Business expenditure on research and development in 2008 for agriculture reached 1,724 million RUR (120,240 million USD PPP) compared to 4,525 million RUR (315 million USD PPP) in mining and quarrying. These investments outperform other sectors of the Russian economy. From 2003 to 2009, Russian companies increased their expenditure on technological innovations more than threefold in absolute terms, while companies in the mining sector increased these expenditures nearly tenfold.

We believe that studying these RTOs is of great value as RTOs are broadly under-researched and various scholars have called for more fine-grained analyses to better understand their role in the innovation system (e.g. Arnold *et al.*, 2010). Much discussion of R&D and innovation focusses on so-called high-tech manufacturing sectors like electronics and pharmaceuticals, and the primary sector receives relatively little attention. Studying innovation systems for the primary sector also has an important social dimension. The twenty-first century poses challenges of energy and food security, and further productivity increases (with attention to environmental issues) are critical.

This paper unfolds as follows: first, we provide a literature review on RTOs, followed by a detailed description about RTOs in Russia. Subsequently, we describe how RTOs are financed, in which projects they engage, their patenting behavior and present the results of our empirical analysis. Here, we focus on specificities of RTOs servicing agriculture or mining through analyzing differences in successful competitions for public funding, the usages of such funds, revenues generated from technology transfer and the novelty of transferred technology.

In our conclusion and discussion session we will resume our findings and link them to the wider academic debate.

Literature review

In most international studies, RTOs are defined as public sector organizations which provide technology transfer and perform own scientific activities. Hales (2001) defines RTOs as organizations with significant core government funding (25 percent or a greater share) which supply services to firms in support of scientific and technological innovation. The RISE project sees the core functions of contemporary RTOs in the provision of S&T and of expertise and innovation for public agencies. Also, RTOs often are seen as an obsolete form of research institution in some post-transitional countries (Hales, 2001).

RTOs provide bridging functions for the dissemination and uptake of new technologies between science and their client firms as they effectively distribute the costs associated with the acquisition of technology and technology-related knowledge through transfer activities to different users and thereby realize economies of scale (Autio *et al.*, 2004). Their projects have a strong applied character and are oriented toward specific industrial sectors or technologies. RTOs have various outputs starting from basic research (blue sky) and applied research to product development or technical services and engineering (Mas-Verdu, 2007). Often, RTO pursue a mission-oriented research program in emerging technologies, such as biotechnology or telecommunications.

In contrast to universities, RTOs not only possess the necessary applied research, they are also better at understanding of and relating to specific firm needs (Arnold *et al.*, 1998; Bessant and Rush, 1995; Tether, 2002). In fact, previous contributions like that of Brockhoff (2003) or Leitner (2005) showed that RTOs fine-tune their transfer approach to specific target audiences, including the research design and methods they use. RTOs also play a vital support role in the "search process" in which companies identify technological opportunities (Nelson and Winter, 1982; Eisenhardt and Martin, 2000; Teece, 1986; Laursen and Salter, 2004).

For policy makers, RTOs have been seen as tools and channels for innovation policy through addressing market failures like barriers to access innovation. RTOs also play a vital role in fixing system failures (Metcalfe, 2005) to reorganize the working relationship between RTOs, universities and firms and to promote awareness of potential innovation and market opportunities. Of particular interest here is the service provision of RTOs to SMEs (Tann *et al.*, 2002; Barge-Gil and Modrego-Rico, 2008; Martínez-Gómez *et al.*, 2009) and their abilities to benefit from the public outputs generated by RTOs.

Strong increases in public competitive funding are visible through all OECD countries. Also private contract income (e.g. from firms for R&D, including foreign firms) is gaining in importance (OECD, 2011). In general, there has been increasing attempts to reduce government funding on a large scale and instead incentivize RTOs to find own sources of income. If an RTO has access to sufficient funds, RTOs can engage in more basic research or in search activities for new technologies

(Arnold *et al.*, 2010). Empirical observations from Europe support this relationship: While the German Fraunhofer institute receives a 30-40 percent core funding, they engage in substantial amounts of basic and applied research. In Sweden, on the other side, where core funding is in the 10-15 percent range, RTOs are more engaged with experimental development and services (Sörlin *et al.*, 2009). Basic research was also offered by public organizations in the UK (government labs, universities) yet only by half of private non-profit or commercialized ex-RTOs and KIBS firms (Preissl, 2000).

The reduction of government intervention in R&D has also left its mark on the ownership of RTOs. Many of them are organized in hybrid forms as public-private collaborations, private non-profit or chartered organizations. Still, the full privatization of RTOs happened rarely. Despite the central role basic and applied R&D takes in the viewpoint of policy makers and in the generation of new knowledge, non-R&D activities are of vital importance for the implementation and success of the innovation (e.g. Barge-Gil and Modrego-Rico, 2008). Also, firms are not only interested in new information but will seek comprehensive service packages with non-R&D services adding to classical R&D. However, not all such services offered by RTOs are connected with innovation, like expert opinion in legislation processes or "due diligence" studies to support the decision process in venture capital operations. In fact, this enhanced service character of RTOs makes them difficult to distinguish from other KIBS (services for supporting product development, testing or certification services or prototyping services). RTOs are also strongly engaged in education and training activities (e.g. supervision of PhD candidates and hosting post-doctorate researchers, skills development and on-the-job learning).

Russia's research institutions are classified as follows: The Russian Academy of Sciences comprises 483 research institutions which provide basic research and partly applied research using public funds (13 percent of all research organizations in Russia). Four other academies (the Russian Academy of Agricultural Sciences, the Russian Academy of Medical Sciences, the Russian Academy of Architecture and Construction Sciences, the Russian Academy of Education), in total 388 institutions (11 percent of all research organizations), provide sector-specific competences, but function independent from private business.

A large part of them, more than 40 percent, are functionally connected with industries in the business enterprise sector. These organizations employ half of all employees in the R&D sector and consume 64.2 percent of the national expenditure on R&D. Russia introduced certain changes to the organization of its research in the 1990s. Most industry-related research is still concentrated in some large state-run research centres, which were founded in the high times of the Soviet Union. Many of these organizations found it increasingly difficult to interact with industry partners, which now face a market-orientated environment.

Research question, design and methodology

The primary aim of our paper is to study the specificities of RTOs that transferred knowledge between 2007 and 2009 into Russia's primary sector. RTOs have been the cornerstone of technological development in the USSR and consequently Russia has a very strong sector of RTOs. Yet, very little is known about these RTOs. We want to close this gap with this exploratory study about their institutional set-up and their behavior.

To put our finding into context, we compare RTOs which provide services to agriculture to those which provide services to mining. There are remarkable structural differences between the two industries. Agriculture and its connections to state authorities remained largely intact after the collapse of the Soviet Union. The mining industry, however, became a prime target for privatization and commercial interests, resulting in the break-up of the connection of mining firms with many of their RTOs. While agricultural production happens in the vast arable lands of Russia, mining is concentrated in certain areas with economically interesting deposits. Also, operating a mine, be it open pits or not, requires much larger capital investments. Due to the sheer size of mining companies, innovation is largely user-driven, while in agriculture the dispersed farmland leaves providers of innovation in a more dominant position over the innovation process (excluding big multinational agricultural producers). Other differences are more subtle and more rooted in politics. Russian companies in the extractive industries are among the biggest corporations in the world, and the industry is characterized by a small number of large companies with significant shares under direct or indirect control by the state. These differences should also influence RTOs active in the different industries, as RTOs adjust their services to the demands of their clients and should be even greater in comparison with other industries like high-technology manufacturing. However, there is rather little research done on understanding differences on the industry or meso-level, so there is little prior evidence on which to elaborate these speculations: this makes the present study rather exceptional.

To analyze these differences servicing agriculture and mining, we ask which of these RTOs are successfully competing for public funding, and how these funds are used. Also, we study which RTOs generate how much revenues from technology transfer and which RTOs transferred technology that was new to the Russian market.

This research is based on questionnaires sent out to Russian RTOs in the framework of a survey carried out by the Institute for Statistical Studies and Economics of Knowledge and National Research University Higher School of Economics (NRU HSE) with the assistance of the Research Laboratory for Economics of Innovation of NRU HSE and the Centre for Fundamental Studies of NRU HSE in 2010. The initial data set was composed of 350 RTOs on the basis of randomized sample represented by geographic regions. Some RTOs could not provide information connected to commercial secrets or due to national security reasons (R&D in military technology areas). Also, some RTOs were reorganizing their activities or closing down and hence rejected our request. The overall response rate was over 60 percent. For this paper, we filtered the data set for RTOs which:

- reported technology transfer to enterprises with main economic activities classified by NACE rev 1 as “A – agriculture, hunting and forestry” and “B – fishing” (we shall refer to this group as agriculture); and

- reported technology transfer to enterprises with the main economic activities classified by NACE as “C – mining and quarrying,” including oil and gas extraction (we shall refer to this group as mining).

This left us with 61 observations, of which 29 cases referred to the agriculture sector and 32 to mining and quarrying. These two groups compose 31 percent of all RTOs reporting technology transfer activities. As our list of variables is extensive (most variables are combined in reducible blocks, some variables are duplicated), we excluded variables with missing values.

The tick-box questions include several groups: ownership type of RTO (public, private), level of novelty of goods and services created using RTO’s technologies (totally new or not), quality control side in the TT transactions (RTO, customer, third party), tools used for quality control (local, national and international standards, specific requirements), participation of RTO in groups and networks (institutionalized or not), etc. In terms of the survey agreement we could not request precise quantitative reports from responding RTOs, so all variables of this type represent respondents' rough estimations only.

Agriculture and mining in Russia – a historical sketch

Agricultural land in Russia is in relative abundance, despite poor soils and adverse weather conditions. Exports of grain accounted for half of imperial Russia's total exports at the end of the nineteenth century. The funds generated thereby were used to finance Russia's imports. In the same time, the rural population went hungry. The reliance on exports of natural resources did not change after the revolutionary years but led to daring experiments to ease the most pressing food shortage. The forced collectivization in the 1920s is still vivid in the country's collective memory. Grain production continued to be seen as a barometer for the effectiveness of the agricultural policies and the political leadership of the Soviet Union as a whole. Krushchev received strong support for the improvements in the lives of ordinary Russians by his policies, with meat consumption rising by 55 percent between 1958 and 1965 (Nove, 1982). With the demise of the Soviet Union came the privatization of farms. After gradual recovery of the production drop during large parts of the 1990s, Russia's agricultural ventures turned into a hotspot for agricultural entrepreneurship (especially on SMEs level). During the decade of 1999-2008, agricultural production grew by 55 percent. In 2008 agriculture output amounted for 87 percent of the level of 1990. The crop sector output reached 130 percent, livestock increased by 60 percent. Today (2009), agriculture contributes 4.7 percent to Russia's GDP and employs 10 percent of its workforce.

The mining industry was of even greater importance for exports and the influx of funds. After Second World War mining boomed and at the end of the eighth five-year plan of 1966-1970 the output of mines was up by 138 percent compared to 1960 (Nove, 1982). Already during the 1960s, though, the depletion of oil fields and mining districts led to a redirection of investments from Europe to the development of deposits in Siberia. These exploitation sites proved costly, and resource development swallowed up a large fraction of the investment budget for little increase in output. The output of coal, oil and ferrous metals fell by 10 percent during 1975 and 1985. Toward the end of the 1970s, iron was mined in increasingly deep pits, making the rock removal more costly, while the iron ore content was decreasing (Rumer, 1989). Coal production peaked in 1976, but from the 1960s onwards moved gradually from the Donbass in the Ukraine to the deposits of Krasnoiarsk Province in Siberia. Despite investment growth of 62 and 25 percent more employment, output grew by a meager 4 percent (Gustafson, 1989). Oil production failed to meet its targets after 1975, and Brezhnev increased the share of investments directed toward the oil industry from 28 to 39 percent of the industrial investment budget. Still, output dropped despite more capital and higher employment.

During the 1990s yields in agriculture increased dramatically – most other sectors would wish for such growth rates in output (Pardey *et al.*, 2004; Bender, 2006). Similarly to agriculture, mining showed remarkable productivity gains over the last decades and incorporated a number of groundbreaking technologies, like sensing for exploration, bio-leeching of low-grade sulfide material and automated haul trucks

(Tilton, 2003; Bartos, 2007). Productivity increases of mines in the USA reached 20 percent per annum, more than doubling in only six years (1980-1986), largely due to the introduction of innovative technologies. By 2001, labor productivity reached three times the level of 1980[2] (Bartos, 2006). The primary sector has first and foremost benefited a lot from the introduction of better and larger machinery. In the mining industry productivity increases depended largely on economies of scale associated with larger haul trucks and excavators (Doggett, 2006). Simultaneously, research expenditure in mining companies are shrinking, depending stronger on other companies like machine producers to deliver the equipment for further productivity increases (Hitzman, 2002).

Results

To address our research questions, we first study the activities of Russian RTOs servicing the primary sector. We test which of our independent variables explain the share of competitive funding of RTOs' total R&D budget, novel goods or services RTOs introduce based on their own R&D results, the number of patent applications they file for and generated revenues out of technology transfer activities per researcher. Due to the absence of normal distributions in most of our variables, we applied Kendall correlation coefficients. We also apply a Harman single factor test, but found no proof for common method bias.

Table I shows the quantitative description of our sample. Remarkably, Russia has a large portion of privately owned RTOs (over 40 percent in mining, much less in

Table I.
Means for variables

	Means by group		
	Total	Agriculture	Mining and quarrying
Innovation technology projects carried out as % of total turnover in 2009	60.29	56.15	63.90
Technology projects "new to market" carried out as % of total turnover in 2009	12.54	13.88	11.42
Number of articles published in refereed national S&T journals in 2009	27.87	39.69	17.16
Number of articles published in international S&T journals in 2009	3.95	5.97	2.13
Number of patent applications in 2009	6.38	8.72	4.25
Number of patent applications abroad in 2009	0.08	0.03	0.13
R&D staff headcount in 2009	127.39	94.76	156.97
Own R&D expenditure (thou RUR) in 2009	48,500.38	26,196.79	68,713.00
Turnover total (thou RUR) in 2009	88,230.07	43,358.14	128,895.25
S&T services turnover (thou RUR) in 2009	37,102.62	19,796.17	52,786.59
Competitive funding as % of total R&D expenditure in 2009	47.55	39.09	55.22
Number of patent applications in 2009	6.38	8.72	4.25
Revenue from TT activities per researcher in 2007-2009	933.74	665.42	1,184.16
Share of basic research in total R&D expenditure	13.54	19.07	8.36
PhD researchers headcount	73.72	54.83	90.84
Competitive funding per head	161.11	83.87	230.88
Patents per 100 researchers	24.77	22.68	26.73
Patents per 1,000 RUR of R&D expenditure	1.92	2.89	0.92
Share of public sources in R&D expenditure	39.20	48.96	30.09
Share of enterprise sources in R&D expenditure	45.84	34.30	56.60

agriculture). The overall share of competitive funding in the R&D expenditure reaches 47 percent, but is much higher in the mining sector. The share of basic research, on the other hand, is much higher in those RTOs servicing agriculture. These differences are even more prominent when normalized per head. We will analyze this point further at a later stage. Although basic research is important to all RTOs, an exclusive orientation of such organizations is absent for both agriculture and mining alike.

In mining, however, over 50 percent of the research expenditure is covered by enterprises (Table II). Particularly in mining, the necessary investments are massive and therefore require the presence of large firms. These large firms will also have a high demand for research and development activities, and instead of performing these activities in-house, they might well outsource them to an RTO in which they hold a controlling interest. This also explains the remarkably high percentage of privately held RTOs in mining.

The services RTOs offer to their clients are similar in both industries (Table II). Most RTOs offer S&T information services, comprising intelligence on existing patents, technical information and experimental production facilities. When asked about the main source of information on new technology and trends in S&T, our respondents ranked their databases of white and grey Russian literature and their own R&D units as most prominent. For both industries, they indicate that big government clients also act as providers of new information. This is rather unique, as OECD wide studies show that RTOs hold close relations with universities as a channel to new knowledge (OECD, 2011), which only hold a minor importance for these Russian RTOs.

These results suggest that Russian RTOs are not cooperating much directly with other knowledge generators but rather consult published materials. The focus on Russian material suggests that RTOs are not concerned with the technology transfer from outside of Russia into the country but are more engaged in making innovation suitable to a Russian environment, making use of country-specific knowledge. Innovation could come in through import substitution. In agriculture, for example, this could happen through the purchase of machinery or genetically modified seeds. In mining, technology could be imported through alliances with other, more advanced companies like it happens in the case of the exploration of arctic shell gas. These findings are in line with Acharya and Keller (2009), who suggest that the productivity impact of international technology transfer often exceeds that of domestic technological change.

	Total	Agriculture	Mining and quarrying
Scientific and experimental services	21.3	13.8	28.1
Engineering services	29.5	13.8	43.8
S&T information services	63.9	69.0	59.4
Technical testing services, certification services, standardization and metrology services, etc.	47.5	48.3	46.9
Project consulting (excluding R&D and engineering services)	52.5	58.6	46.9
Training services	44.3	48.3	40.6
Production services	60.7	58.6	62.5
Other services	24.6	27.6	21.9
No services offered	3.3	3.4	3.1

Table II. Services offered to customer in 2009 (percent)

The majority of the own income is generated by innovation technology projects in both of the industries. The share of new to market technological innovations (radical innovations) is slightly above 10 percent of the turnover. On average, the RTOs in agriculture generated 43,358 thousand RUR total turnover, with 19,796 thousand RUR stemming from S&T services. This compares to 128,895 thousand RUR turnover for mining with a 52,786 thousand RUR from S&T service turnover. Interestingly, RTOs in agriculture published more in international scientific journals and applied for more patents in the year 2009, which shows a greater focus on the generation of research outcomes as public goods (Table III).

When asked what hampered the creation of new knowledge in RTOs, 45 percent identified the lack of specialists within their own organization, together with up-to date research equipment. Around one-third of our respondents mentioned low demand on the side of potential customers. This lack of specialists could very well result in the limited direct communication with other knowledge producers as indicated above. The biggest factor hampering the transfer of knowledge was the lack of financial resources in customer organizations, followed by high economic risk of implementation of S&T results (Table IV). OECD-wide RTOs identified "increasing scientific impact," "increasing the degree of internationalisation," "recruitment and retention of highly qualified personnel" and "increasing contract research" as their main challenges in the next five years (OECD, 2011). Interestingly, however, RTOs in mining are by far more successful in attracting customers from outside Russia. As many Russian companies in this industry are global actors and have rich industry experience, the RTOs owned by or servicing these large corporations gain competitive advantages which also make them sought after providers of knowledge to international customers. We could not identify if these customers were situated in former soviet republics.

Having outlined some major features of the survey data, and describing how Russian RTOs for the primary sector operate, we will now analyze in greater detail the share of competitive funding in the R&D expenditure, the patents applied and revenues out of technology transfer.

Table III. Frequencies for factors hampering creation of new knowledge (percent)

	Total	Agriculture	Mining and quarrying
Lack of specialists in your RTO	45.9	51.7	40.6
Poor competence of specialists in your RTO	16.4	10.3	21.9
Lack of up-to-date research equipment in your RTO	47.5	51.7	43.8
Underdeveloped experimental base in your RTO	24.6	34.5	15.6
Management shortcomings in your RTO	8.2	3.4	12.5
Low demand for S&T results from the side of potential customers	36.1	41.4	31.3
High competition with other Russian RTOs	11.5	10.3	12.5
High competition with foreign RTOs	16.4	6.9	25.0
Lack of information on new technologies	3.3	3.4	3.1
Lack of information on the cutting-edge directions of S&T in the world	9.8	6.9	12.5
Weak cooperation with partner RTOs	14.8	10.3	18.8
Underdeveloped R&D infrastructure	11.5	3.4	18.8
Poorly worded tasks from customers	9.8	13.8	6.3
Other	14.8	20.7	9.4

	Total	Agriculture	Mining and quarrying
D2 Level of novelty of goods and services based on S&T results of your RTO in 2007-2009: totally new	−0.092	−0.232	0.03
D3 Patent applications in 2009	0.11	0.347*	−0.057
D4 Revenue from TT activities per researcher in 2007-2009	0.048	0.11	0.016
I01 Share of basic research in total R&D expenditure	0.112	0.128	0.126
I02 Share of innovation projects with enterprises in the total turnover in 2009	0.141	0.234	0.049
I03 Value of complete innovation technology projects related with new to market technological innovation in 2009	0.167	0.29	0.117
I04_1 Quality control: by responding RTO	−0.009	−0.052	−0.054
I04_2 Quality control: by the customer	0.233*	0.394*	0.099
I04_3 Quality control: by third-party organization	−0.014	−0.11	0.089
I05_1 Quality control tool: technical regulations	−0.02	0.179	−0.152
I05_2 Quality control tool: common national standard	0.243*	0.251	0.24
I05_3 Quality control tool: national sectoral standards	−0.031	0.166	−0.097
I05_4 Quality control tool: international quality standards	0.115	0.412*	−0.099
I05_5 Quality control tool: requirements specified by contract agreement	0.142	0.247	0.065
I06_1 Groups and networks membership: formally associated institutions	−0.092	0.052	−0.229
I06_2 Groups and networks membership: formally independent institutions	0.143	0.26	0.116
I07 PhD researchers headcount	0.203*	0.322*	0.12
I08_1 Source for researchers inflow in 2007-2009: university graduates	0.075	0.077	0.097
I08_2 Source for researchers inflow in 2007-2009: university staff	0.107	0.357*	−0.081
I08_3 Source for researchers inflow in 2007-2009: enterprise staff	0.179	−0.082	0.384*
I08_4 Source for researchers inflow in 2007-2009: other RTOs staff	−0.156	−0.149	−0.205
I09 Competitive funding per head	0.473**	0.477**	0.455**
Pats_per_resea	0.041	0.295*	−0.155
Pats_per_1,000RUR_RD	0.05	0.277	−0.14

Notes: *,**Significance at level of 0.05, 0.01 (two-tailed) respectively

Table IV. Share of competitive funding

Share of competitive funding in the R&D expenditure total in 2009

The funding mechanisms for research in Russia changed considerably over recent decades. In the Soviet era until 1991, the funding system was based on revolving budgets. Subsequently, a funding distribution system aimed at selecting excellent research proposals became more dominant. The research projects are suggested by firms or RTOs and submitted for funding to the relevant agency. Despite the changes, government remained the main resource of R&D funding. In 1995 this share fell to 72 percent. The rest of the funding was distributed on a results-oriented competitive basis (Gokhberg, 1994). Meanwhile, the share of public sources in their total R&D expenditure averages 67 percent (Science Indicators, 2011). This trend is similar to observations in OECD countries (OECD, 2011).

Given that research projects are submitted for funding to the relevant agency, the degree to which RTOs are making use of such funds is an indicator of how successful they are in competing against other proposals (see, e.g. Blume-Kohout *et al.*, 2009). This rationale, however, has not been equally manifested throughout the industries; there are areas where funding still is largely based on annually revolving budgets. We would expect that industries like agriculture with largely publically owned RTOs still rely on such rather conservative financing means. Mining and quarreling, on the other hand, is seen as very competitive, and highly profitable, with some of Russia's biggest companies active. We might expect to see more competition for funding here.

Throughout the primary sector, the share (percentage of total budget) of competitive funding RTOs receive shows correlation with quality control in line with national standards as indicated by national regulations and quality control of the project's outcome executed by the customer. The positive correlation shows that those projects that receive competitive funding, have such agreed measurable targets in place. Interestingly, for agriculture to have a higher share of competitive funding, quality control follows the higher set of international standards. This could very well be an outcome of different standards for food production within Russia and main consumer markets outside of Russia, e.g. the EU. Particularly if these products are designed for the international markets, production processes and quality of the final product will have to match international quality standards.

The control variable competitive funding per head shows a positive and significant correlation, indicating more members equals more competitive funding. The positive correlation with PhD holders indicates that competitive funds require a well-written proposal in line with high scientific standards. The importance of intelligence toward writing research proposals to successfully compete for funds is also visible in the total sample and in the agriculture subsample, with a positive correlation with the total number of PhDs an RTO has on its payroll. Especially in agriculture, not only the number of PhDs on an RTO's payroll, but also the intake of former university researchers shows a positive correlation with the share of competitive funding. These researchers who have previously worked at universities have gained experience in writing project proposals and are familiar with the latest research results. Interestingly, the total number of patents and the patent applications per researcher is positively correlated with the share of competitive funding, but only in agriculture. These applications are a measure of the usage of such funds and it indicates that competitive funding in agriculture is used to create new knowledge which is patentable.

As intuitive as these findings are, the more surprising is the absence of the relationship in the other subsector. The mining sector also displays the significant relation of competitively distributed funds an RTO receives only with the intake of enterprise staff. In mining though, the influx of enterprise staff shows significant influence on a high share of competitive funding in the R&D expenditure. This shows the adjustment of the workforce toward technology transfer. Such experts help the RTO to better understand the most urgent needs of mining companies and also facilitate communication.

Number of patent applications in 2009

Patenting activities is an interesting indicator for RTO technology transfer activities due to various aspects. A large number of patents signals technological leadership to potential customers and are seen as indicative for high-quality research. The benefits of such signals for science-industry collaborations have been demonstrated by previous contributions like Bruno and Orsenigo (2003).

Patent applications in the primary sector show a strong positive correlation with the share of basic research in total R&D expenditure. In this line, a higher number of PhD holders in their workforce raise the likelihood of patent applications. This correlation is even more prominent in the subgroup of agriculture. Most patent applications come from RTOs, which are formally independent. This correlation is also repeated in the subgroup of mining. For such RTOs with no ties to enterprises, patenting is the core activity to protect their knowledge in the process of technology transfer. For others, such a protection of intellectual property from their customer is of little or no importance.

In the subgroup of agriculture, the share of competitive funding in the R&D budget, the share of basic research in their R&D activities and the number of PhD researchers in an RTO show high correlations with patent applications. These findings seem intuitive, as patents are an outcome of successful R&D activities, supported by a high proportion of an RTO's resources dedicated to basic research and classically educated researchers at PhD level. Nevertheless, none of these variables show a positive correlation with the number of patent applications for the subgroup of mining. For RTOs in mining, the intake of former university staff is positively correlated with the number of patent applications, which shows the importance of well-trained scientists and patentable knowledge. Also, there are significant differences between the subgroups on the use of quality control tools. While in agriculture, those projects that base on common national standards are likely to result in patent applications in agriculture, in mining such international quality standards are positively correlated with patent applications. We interpret these finding as such: In agriculture, most patentable activities stem from the successful implementation of international knowledge after adjusting it for Russian circumstances. The major mining companies, as players of worldwide significance, search for internationally novel knowledge which is in line with international standards. In line with this argument, we found earlier on that RTOs in mining have a number of international clients, in contrast to agriculture.

Comparing this data with findings from other countries is difficult. OECD wide studies have shown that patenting activities are concentrated in a few highly active organizations. It is not uncommon for 20-30 percent of RTOs not to obtain a single patent in a given year. In our sample, only 31 percent of RTOs did not apply for any patents. The vast majority did. Understanding the patenting activities gives vital clues for income generation. Public Research Organizations in other countries report to generate around 21.5 percent of their income through patents in Germany, 18 percent in South Korea or 13 percent in the Netherlands (OECD, 2003) (Table V).

Revenue from TT activities per researcher in 2007-2009

For the primary sector, revenues created from technology transfer activities show positive correlation only with the competitive funding per head and common national standards or international quality standards in the quality control of the technology transfer projects. The latter takes a prominent role for revenue generation from technology transfer activities in the agriculture subgroup. The quality control of the final result of those projects which generate a lot of revenues from technology transfer activities per researcher are passed on to third-party organizations in the mining subgroup.

Interestingly, the value of completed technology transfer projects with technological innovation, which is classified as new to the market, is negatively correlated. The correlation coefficient is also negative for both subgroups, but is significant only in mining. Finally, revenues were negatively correlated with a high number of patents related to RTO's R&D budget in the agriculture subgroup. We interpret this finding as a proxy for efficiency in research. The more efficient RTOs in research in agriculture are less likely to generate revenues from technology transfer activities.

	Total	Agriculture	Mining and quarrying
Share of competitive funding in the R&D expenditure total in 2009	0.11	0.347*	−0.057
Level of novelty of goods and services based on S&T results of your RTO in 2007-2009: totally new	0.158	0.026	0.297
Revenue from TT activities per researcher in 2007-2009	0.07	−0.084	0.184
Share of basic research in total R&D expenditure	0.276**	0.432**	0.033
Share of innovation projects with enterprises in the total turnover in 2009	0.04	−0.085	0.221
Value of complete innovation technology projects related with new to market technological innovation in 2009	0.197	0.329*	0.051
Quality control: by responding RTO	0.069	−0.022	0.21
Quality control: by the customer	−0.044	0.155	−0.203
Quality control tool: common national standard	0.349**	0.422*	0.278
Quality control tool: international quality standards	0.364**	0.272	0.475**
Groups and networks membership: formally associated institutions	0.04	0.105	−0.059
Groups and networks membership: formally independent institutions	0.325**	0.314	0.32*
PhD researchers headcount	0.222*	0.444**	0.044
Source for researchers inflow in 2007-2009: university graduates	0.039	0.116	−0.04
Source for researchers inflow in 2007-2009: university staff	0.148	−0.045	0.367*
Competitive funding per head	0.173	0.327*	0.096
Pats_per_resea	0.725**	0.734**	0.73**
Pats_per_1000RUR_RD	0.568**	0.578**	0.494**

Notes: *,**Significance at level of 0.05, 0.01 (two-tailed), respectively

Table V.
Patent applications

Such efficiencies are indicative for a specialization on basic R&D, and our data suggests that for agriculture, such a specialization is not coherent with a focus on technology transfer (Table VI).

Novel goods and services based on S&T results of the RTO in 2007-2009

The introduction of novel goods or services an RTO introduces, which is based on its own research activities, is probably the original activity for which RTOs were founded. Interestingly, we see only the network memberships RTOs belong to as a variable with significant correlation. While in agriculture, formally associated institutions introduce the most novel goods and services based on own R&D results, in mining it is the formally independent institutions that are most actively introducing them (Table VII).

Conclusion

This is, to our knowledge, the first detailed study on Russian RTOs servicing the primary sector. We described in great detail Russian RTOs actively transferring knowledge into the primary sector. This is a vital prerequisite for further comparative studies both on sectoral and on national levels.

Also, we showed interesting differences between RTOs servicing agriculture and mining. We explained some of these differences through industry specifics, like the strong enterprise ownership, for example or the high enterprise funding. However, not

	Total	Agriculture	Mining and quarrying
Share of competitive funding in the R&D expenditure total in 2009	0.048	0.11	0.016
Level of novelty of goods and services based on S&T results of your RTO in 2007-2009: totally new	0.037	0.023	0.04
Number of patent applications in 2009	0.07	−0.084	0.184
Share of basic research in total R&D expenditure	−0.004	0.133	−0.138
Share of innovation projects with enterprises in the total turnover in 2009	−0.066	0.016	−0.121
Value of complete innovation technology projects related with new to market technological innovation in 2009	−0.267**	−0.234	−0.308*
Quality control: by responding RTO	0.035	0.164	−0.076
Quality control: by the customer	−0.017	0.257	−0.195
Quality control: by third-party organization	0.058	−0.214	0.322*
Quality control tool: common national standard	0.225*	0.088	0.305
Quality control tool: international quality standards	0.281*	0.349*	0.234
Quality control tool: requirements specified by contract agreement	−0.058	−0.026	−0.04
Groups and networks membership: formally associated institutions	0.073	−0.054	0.176
Groups and networks membership: formally independent institutions	−0.037	0.127	−0.204
PhD researchers headcount	−0.147	−0.057	−0.218
Competitive funding per head	0.369**	0.4**	0.364**
Patents_per_researcher	0.048	−0.033	0.117
Patents_per_1,000RUR_R&D	−0.196*	−0.318*	−0.06

Notes: *,**Significance at level of 0.05, 0.01 (two-tailed), respectively

Table VI. Revenues from TT activities per researcher in 2007-2009

only ownership, but also membership of different networks showed differences between the industries. To analyze such differences in greater detail we statistically tested input- and output-specific variables. Thereby we showed that competitive funding plays a different role in both industries. We interpret this as a sign of different dominating funding paradigms. In agriculture, a more conservative funding paradigm prevails, and competitive funding is less important and more reliance on classical annually revolving funds is given. Competitive funding here is more used to strengthen basic R&D and to generate patentable knowledge, while in mining, these funds support technology transfer. These findings point toward different intentions from funding agencies. Particularly for the mining, technology transfer should help improve its technological position.

We argue that in the case of RTOs in mining, those, which receive public funds, use them to enable technology transfer. In turn, the generated revenues out of these technologies transfer projects for companies result in patents and subsequently in a higher stream of revenues. These findings are unique, and might well be confined to the mining industry. Our results suggest how much internal and external factors influence the technology transfer strategies for each particular RTO. Unfortunately our sample size was too small for further analysis. For example, we would be interested to study different behavior of privately owned vs publically owned RTOs, and we encourage other researchers to have a closer look at the relationship of ownership

	Total	Agriculture	Mining and quarrying
D1 Share of competitive funding in the R&D expenditure total in 2009	−0.092	−0.232	0.03
D3 Number of patent applications in 2009	0.158	0.026	0.297
D4 Revenue from TT activities per researcher in 2007-2009	0.037	0.023	0.04
I01 Share of basic research in total R&D expenditure	0.09	0.208	0.033
I02 Share of innovation projects with enterprises in the total turnover in 2009	−0.104	−0.265	0.003
I03 Value of complete innovation technology projects related with new to market technological innovation in 2009	0.145	−0.029	0.279
I04_1 Quality control: by responding RTO	0.241	0.209	0.289
I04_2 Quality control: by the customer	0.073	0.08	0.067
I04_3 Quality control: by third-party organization	−0.052	−0.164	0.059
I05_1 Quality control tool: technical regulations	0.235	0.227	0.239
I05_2 Quality control tool: common national standard	0.093	0.074	0.107
I05_3 Quality control tool: national sectoral standards	−0.065	0.074	−0.216
I05_4 Quality control tool: international quality standards	−0.009	−0.012	−0.004
I05_5 Quality control tool: requirements specified by contract agreement	0.037	−0.08	0.139
I06_1 Groups and networks membership: formally associated institutions	0.207	0.414*	0
I06_2 Groups and networks membership: formally independent institutions	0.138	−0.119	0.488**
I07 PhD researchers headcount	0.086	0.018	0.117
I08_1 Source for researchers inflow in 2007-2009: university graduates	0.045	0.169	−0.059
I08_2 Source for researchers inflow in 2007-2009: university staff	−0.012	−0.005	−0.017
I08_3 Source for researchers inflow in 2007-2009: enterprise staff	0.066	0.09	0.049
I08_4 Source for researchers inflow in 2007-2009: other RTOs staff	0.12	0.244	0.016
I09 Competitive funding per head	0.121	0.011	0.198
Patents_per_researchers	0.12	−0.067	0.239
Patents_per_1,000RUR_R&D	−0.056	−0.149	0.008

Notes: *,**Significance at level of 0.05, 0.01 (two-tailed), respectively

Table VII.
Novel goods and services based on S&T results of the RTO in 2007-2009

structure and strategic behavior. It appears to be a rather rich studying field. Mapping these strategies, which RTOs in other areas and other industries have taken, and understanding how they deal with external factors like institutional insecurity in times of economic crisis is challenging. However, more of such studies would provide a rich base for comparative studies and would support policy makers, RTOs and enterprise management with sound data to improve the innovation climate in non- or less R&D intensive industries. For example, how do the strategies of RTOs differ if they deal with enterprises with a high- or low-knowledge absorption capacity?

RTOs in emerging markets and in the primary sector have up to now attracted surprisingly little attention from previous research. We hope that our study filled parts of the void and raises interest with fellow researchers to study these organizations which have such an important role to play in the development of these economies. Finally, we would like to call out for more methodologically diverse studies. More in-debt case studies about individual aspects of competitive behavior of RTOs could help to improve our understanding about their role in the innovation process.

Notes

1. The term RTOs is here used to include public, semi-public and private research institutions. In line with EARTO is approach, we see their predominant activities in providing research and development, technology and innovation services to enterprises, governments and other clients. This contrasts with universities, whose main mission is education, and from enterprises which produce goods and services.
2. During the 25-year period of the study of Tilton and Landsberg (1999) the average copper mine head grades actually decreased, so productivity gains cannot be attributed to better deposits.

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