Science and Public Policy, 45(5), 2018, 683–691
doi: 10.1093/scipol/scy001
Advance Access Publication Date: 2 February 2018
Article

Technology transfer into Russia's agricultural sector—Can public funding replace ailing business engagement?

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Abstract

The Russian government plans to lift the country's agriculture and food productions and aims to become the biggest global supplier of healthy, high-quality, and ecologically 'clean' foods. Although innovative activities in the field have been rising over the last decade, the intensity still remains far below both other Russian economic activities as well as other competitor nations. Policymakers focus on Russia's Research and Technology Organizations (RTOs) as a channel to transfer new technologies to agricultural and food producers. As demand for new technologies is low, public funds are invested into RTOs to increase the quality of their basic research activities. Instead of converting these additional funds into better technology transfer, agricultural RTOs specialize in government-funded basic research and reduce further their role as applied research organizations. Thereby, RTOs do not seek to increase their competitive position but instead maximize their benefits from public support. This article questions the leverage effect that public support measures have for technology transfer activities in the present case, and suggests that a more holistic approach including both supply and demand is needed.

Key words: technology transfer; agriculture; food production; sectoral innovation system; Research and Technology Organizations; Russian Federation

1. Introduction

Russia historically stood out as an exporter of raw agricultural products, like wheat. The sector now aims to increase both quantity and quality of the exports of agricultural and food products. In a first step, the plan is to replace imports by Russian products, which is further supported by the current economic sanctions against Russia. Subsequently, the aim is set to become the biggest global supplier of healthy, high-quality, and ecologically 'clean' foods.[1] The production volume of innovative products as a share of the total production has increased over time, but remains well below the industrial average for Russia (Gokhberg et al. 2017). Most innovative products are new to the firm, but not new to the market, mainly to replace imported goods. To be able to meet the quality demand of large consumer markets like the European Union and to hold a place in international value chains, Russia's agricultural production system requires technological upscaling. To achieve these ambitious objectives, Russia's socio-technological regime of agriculture production and its social and institutional processes need to radically change.

Farming yields depend greatly on applied farming technologies like machinery, genetically modified organisms, fertilizers, etc. (e.g. Pardey et al. 2004; Bender 2006; Suprem et al. 2013). The technologies that have shaped agriculture and its productivity in recent years all came from neighbouring fields of science. For example, precision agriculture (PA) uses information technology applications for soil and crop surveillance, whereas mapping technologies based on satellite data together with unmanned aerial vehicles (drones) for crops scouting has massively increased productivity (Seyfang and Smith 2007; Aarts et al. 2007; Brunori et al. 2013a; Salmon 2013). Hence, agricultural producers are likely to rely on a translation function to apply these new technologies—like consulting firms or technology providers. Empirical studies have documented the ever-increasing reliance of producers on external knowledge sources (Hagedoorn 2002; Amara and Landry 2005), with Russia's agricultural producers no different (Thurner and Zaichenko 2015a, 2015b).

The timely adaption of these efficiency enhancing technologies also plays a key role in rising agricultural production (World Bank 2007; FAO 2009; Royal Society 2009; Godfray et al. 2010; National Research Council 2010). The arrival of new technologies though is often met with resistance by agricultural producers as the Agricultural Knowledge System is built on long-standing cognitive, social, and institutional processes which are not easy to change

(Seyfang and Smith 2007) and often require third parties to ensure compatibility with external constraints, actors, rules, and artefacts of the mainstream regime (Knickel et al. 2009). Especially small farmers will rather do what they have always done instead of adapting to new technological opportunities. Hence, technological developments on the fields are likely to be incremental and build on coalition networks involving a multitude of actors in the production regime (e.g. Brunori et al. 2013b).

Although the promising commercial opportunities for Russian agricultural and food products have been noted, collaboration activities between firms and public actors are low for all phases of the innovation process. Russian policymakers have targeted these systemic difficulties together with the limited demand for technologies and provided support for technological upscaling (e.g. Thurner and Gershman 2014; Gershman and Thurner 2016).

Most institutional links between science, education, and agricultural production have broken since the demise of the Soviet Union, and the agricultural research and development system struggles to meet the needs of producing firms. Russia's innovation system relies greatly on its research and technology organisations (RTOs) who specialize in the creation and distribution of new knowledge and technologies. These organizations perform a bridge function between science and production lines and act as multipliers to promote awareness of potential innovation and market opportunities. More than 40 per cent are functionally connected with industries, employ half of all employees in the R&D sector and consume 64.2 per cent of the national expenditure on R&D. Though often producers and users of knowledge are part of different communities, often separated by a 'valley of death' (Landry and Amara 2012; Sutherland et al. 2004, 2010). Previous studies showed that a third of Russia's RTOs in agriculture struggle with a low awareness of the customer organization about new technologies. For 13 per cent of these RTOs, this unawareness translates into very weak ties with their customers. The customers often do not know what they want; technology transfer often fails due to a general lack of skills in agricultural firms (Thurner and Zaichenko 2016). These systemic difficulties—or market failures—require policy measures to support technological upscaling (Knickel et al. 2009).

This article asks whether these efforts really increased the technology transfer activities into agriculture and studies industry-related technology transfer activities over the time period of 2010–4. To this day, such a critical appraisal of these initiatives to raise technology transfer activities has been missing. To ensure far-reaching insights, the study looks into influencing factors on reported technology transfer activities and analyses the competitive situation that these RTOs face. Thereby, this article provides insights into the process of technology upscaling in agriculture and questions the possibilities of policy measures to stimulate technology transfer. Especially, the latter extends the debate about policy support and its possible influence on innovation activities.

2. The importance of agriculture for Russia's economy

Russia's agriculture produced more than 100 million tons of grain in 2015, more than 30 million tons of sugar beet, 30 million tons of potatoes, 15 million tons of vegetables, 8 million tons of sunflower seeds, more than 8 million tons of cattle and poultry meat, and 30 million tons of milk. The sector's output is valued at 5 trillion roubles (82 billion USD)[2] or 6 per cent of the country's gross domestic product and in 2015 covered 99 per cent of the country's demand for grain, 84 per cent of the demand for vegetable oils, 84 per cent of the sugar demand, 97 per cent of consumed potatoes, 81 per cent of milk and dairy products, and 85 per cent of the total meat and meat product consumption. Russia's agriculture employed 9.5 per cent of the national workforce in 2015,[3] and exports of agricultural products (except textiles) in the same year reached 16.2 billion USD or 4.7 per cent of total customs revenues. Most importantly, though, the sector has shown remarkable resilience to economic turbulences. While the country's economy was mired in an economic recession between 2014 and 2017, the agricultural sector showed steady growth. In fact, Russian agricultural production grew by 40 per cent between 2005 and 2015, which is comparable with Brazil (OECD-FAO 2015) and India (Government of India 2016). Even in the very difficult year of 2016, the sector still grew by 2–3 per cent (Kuzminov et al. 2017). Furthermore, the sector generates foreign currency holdings and creates a significant multiplication effect in Russia's economy, as every rouble invested returns up to 4–5 roubles in related industries.

During the Soviet Union, the country's agriculture was a main focus point for state support and one of the means to realize social utopia. The best example is Khrushchev's Virgin Lands Campaign, in which Russia's land under agricultural use extended greatly to the south and the east (McCauley 2016). When Brezhnev took the role of party secretary and head of state in 1964, he launched a major investment program in 1965 to support the meanwhile helplessly outdated and unproductive agriculture. The bad harvests in the years 1969 and 1970 triggered the highest investment activity in agriculture in all Soviet history, but the subsequent bad harvests in the years in 1972–5 could not be prevented. With a continuously deteriorating agricultural productivity, the Soviet Union became a major grain importer (Liefert and Liefert 2015). The difficulties to provide food to the cities—especially Moscow—led to the emergence of one of the most 'Russian' traditions: the dacha with the private land plot.

Still, Russia's agriculture suffers from outdated tilling techniques, inefficient irrigation practices, inadequate crop rotation practices, and unbalanced application of fertilizers which damaged the soil and left it partly unsuitable for further agricultural production (more than 11 per cent of their total area). Also, Russia struggles to increase its cropland due to the bioclimatic conditions. When grain production areas were reduced during the 1990s and less productive lands in the north were given up, the total factor productivity rose greatly (Swinnen et al. 2012). Still, grain and leguminous crop yields in Russia are as low as 1,800–2,400 kg per harvested hectare (average grain yield was 2,370 kg in 2015). Yields in the USA and Germany are as high as 7,250 kg per hectare. According to Rosstat, yields of potato also sit as low as 15,000 kg per hectare (compared with Brazil with 27,800 kg and Germany with 39,800 kg per hectare).

The inefficient agricultural production triggered a wave of consolidation which formed large agribusinesses during the 2000s in Russia's southern regions (Rylko et al. 2008). These businesses generated more than half of the total agricultural output in 2014 (2.1 billion roubles). Today, they drive investments, new technologies and introduce superior management practices into the sector (Gataulina et al. 2005; Serova 2007). Currently, these agricultural firms produce more than 70 per cent of the total output of grain, sugar beet, sunflower seeds, eggs, meat (cattle and poultry). Individuals' land plots primarily specialize in the production of potatoes (80 per cent of the total output), vegetables (70 per cent), fruits and berries (77 per cent), and certain niche market foods, such as honey (94 per cent) (Kuzminov et al. 2017).

The future of Russia's agricultural and food producers now lies in a more value-added production (Liefert et al. 2010). And indeed, between 2012 and 2015, the production volume of innovative products has significantly increased (+ 53 per cent), mainly due to import substitution. Still, the share of innovative agricultural and food-related products shipped in 2015 sits at 4.8 per cent—well below the industrial average for Russia (7.9 per cent). Also, the innovative product range is characterized by a low degree of novelty as products new to the market account for only 8.2 per cent of total production volume. Instead, 69 per cent classify as products new to the firm (but not new to the market) and 23 per cent are improved products based on previously existing ones (Kuzminov et al. 2017). To really meet the quality demand of large consumer markets like the European Union and to hold a place in international value chains, Russia's agricultural production system requires technological upscaling through partnerships with technology producers. With the demise of the Soviet Union though, the institutional links between science, education, and agricultural production were broken. The crisis of the agricultural research and development system continues to this day, which has weakened Russia's ability to participate in the development and application of new technologies.

While economy-wide internal R&D expenditures grew by 2.65 times between 1995 and 2014, the expenditures on agricultural R&D rose only 1.35 times (in constant prices). The share of business expenditure in the structure of funding sources for agricultural R&D reaches only 17 per cent. The low willingness of firms to invest in R&D is a common feature of the Russian economy, but the situation is particularly worrying in agriculture. Consequently, federal budgets cover 59.6 per cent of all expenditures on agriculture-related R&D (2015), which is higher than the Russian average (56.5 per cent) to make up for ailing business spending. Business expenditure for R&D, on the other hand, steadily declined from 14.8 per cent in 2002 to 9.4 per cent in 2015. Consequently, the structure of agriculture-related R&D radically changed. Between 1994 and 2015, expenditures on relevant basic research grew 2.6 times (in constant prices), while funding allocated for applied research and development halved. Accordingly, the share of basic research in the total current internal expenditures on R&D grew from 22 to 58.9 per cent while applied research dropped from 48.0 to 27.1 per cent. Agriculture-related basic research showed a positive trend (from 24.6 to 57.3 per cent between 1995 and 2014). Still, figures adjusted for purchasing power parity (631.9 million USD in 2015) not only reveal a rather low support for agricultural sciences compared with Russia's competitors like the United States (10 billion USD) but also compared with countries like India (3.9 million USD), China (3.1 million USD), the Republic of Korea (1.6 million USD), the Netherlands (1.4 million USD), Australia (911.8 million USD), Taiwan (716.8 million USD), Turkey (668.2 million USD), and Argentina (626.9 million USD).

The average annual growth rate over the last 15 years of agriculture-related R&D in Russia reaches 3.4 per cent of total R&D expenditures, compared with 5.0 per cent in Argentina and 6.4 per cent in Turkey. Also, agricultural sciences lag behind other major R&D fields in Russia. While the total Russian internal R&D expenditures grew almost 2.2 times since 1994, the share of funding allocated to agriculture-related R&D steadily decreased and reached a low in 2014–5 (1.6 per cent, compared with 3.6 per cent in 1994).

The World Trade Organization (WTO), the watchdog over unjustified trade advantages, classifies measures to support prices or subsidies directly related to production quantities suitable to distort the production and trade as part of the amber box. These measures have to be reduced over time. Government investments in research and science, on the other hand, all fall into the green box, and are allowed under the WTO regime. Thereby, they can increase significantly (WTO 2017).

Despite the increasing funds for basic research, the productivity of Russia's research remains low. Russian publication numbers in 2015 accounted for just 1.78 per cent of the total global agriculture-related publications indexed by Web of Science and Scopus and its researchers are engaged in only 0.6 per cent of global research fronts. However, publication dynamics indicate that Russia's position in the agricultural science's international ranking is somewhat improving. The overall number of Russian-authored publications has slightly increased, but their share in the total global number of publications between 2001 and 2015 has dropped from 3.16 to 2.31 per cent and from 2.98 to 2.59 per cent. In agricultural sciences, microbiology, molecular biology, and genetics the shares of Russian publications are lower than the average for all academic publications, but the numbers show growth (between 2010 and 2015 the number of publications indexed by Web of Science grew from 0.16 to 0.26 per cent, in Scopus—from 1.09 to 1.78 per cent). The topics that Russian scientists cover also differ from the focus of their international peers. Russian publications centre on food production technologies, agronomy, plant growing, and fishing. Featuring less are areas like veterinary science, interdisciplinary studies, agricultural machinery and equipment, and agricultural economics. Similar divergence of topics between Russian scientists and their counterparts has also been noted, for example, in the field of energy research (Thurner and Proskuryakova 2013). Russian scientists do show a competitive edge in fields like biotechnology. Also, Russia's overall share in research fronts for molecular biology and genetics is 3.0 per cent, and for microbiology 3.2 per cent. According to Web of Science, Russian publications account for about 0.5 per cent of the global flow of international agricultural sciences-related publications (365 in 2015). By 2015, Russia had lost nine positions in the ranking compared with 2000 and had lost in terms of the total number of academic publications against the world's leading economies. Among the 481 areas identified in global agricultural studies with the highest growth potential, Russian authors are present only in five of them (1.1 per cent) (Kuzminov et al. 2017).

Patent activity in the agricultural sector displayed an uneven but growing trend. In 1994–2015, the number of relevant patent applications filed at Rospatent had tripled, reaching almost 4,900 by the end of this period, while their share in the total number of patent applications is close to 11 per cent. While in the mid-1990s half of all patents originated from basic agricultural industries, the focus shifted in 2013–5 towards food products.

3. RTOs in Russia

Russia's Research and Technology Organizations (RTOs[4]) (ranging between 1,700 and 2,000) perform a vital bridging function for successful technology transfer by specializing in the creation and distribution of new knowledge and technologies. More than 40 per cent are functionally connected with industries, employ half of all employees in the R&D sector and consume 64.2 per cent of the national expenditure on R&D (HSE 2015).

By the end of 2015, 436 RTOs were active in agriculture-related R&D (10.4 per cent of all RTOs in the country). Around one-third of specialized R&D organizations belong to the Ministry of Agriculture (31.7 per cent), while the majority belong to the former Russian Academy of Agricultural Sciences (RAAS)[5] (62.4 per cent). Most of the resources are accumulated by organizations of the Russian Ministry of Agriculture and the Federal Agency for Scientific Organisations (FASO), institutes which account for 87.5 per cent of all internal expenditures on agriculture-related R&D, employ 91.1 per cent of the researchers, own 11.2 per cent of all land which belongs to the Russian R&D organizations (1.9 million hectares), 99 per cent of pilot farm land (139.3 thousand hectares), and 53.6 per cent of stocked ponds and other water reservoirs (118.8 hectares).

RTOs monitor technological developments closely and meet their customers' demands for technologies (Brockhoff 2003; Leitner 2005; Arnold et al. 1998). Their R&D projects are strictly applied to target-specific industrial sectors or technologies and translate basic research into product development (Mas-Verdú 2007). Thereby, RTOs disseminate new technologies and translate science into solutions for client firms. The associated costs are distributed to different users, which generate economies of scale (Autio 2004).

RTOs are not exclusively relying on revenues generated, but are funded through a variety of possible income streams, including membership subscriptions, fees-for-services obtained through competitive contracts, government core funding, and competitive contracts for public grant-funded R&D projects (Hales 2001). Government support ranges widely, from 30 to 40 per cent core funding by the German Fraunhofer institutes to 10–15 per cent by their Swedish peers (Sverker et al. 2009). RTOs also play a major role as places for skill development as they perform a bridge function for industry, universities, and other institutions (Intarakumnerd and Virasa 2002; Mrinalini and Nath 2008).

Funding and ownership of RTOs depend greatly on the industry in which they are active. In agriculture, state ownership has historically been high, while in mining, many RTOs belong to the large mining companies. A previous study compared RTOs engaged in technology transfer with agriculture, mining and quarrying, high-tech, medium high-tech, medium-low-tech, and low-tech industries. Certain factors, like the role of the client, have in fact opposite effects in different sectors. Agricultural RTOs struggle with their clients' limited awareness of technologies and with intense competition from highly innovative firms (Thurner and Zaichenko 2015a). Another study showed the tendency of RTOs in agriculture to publish relatively more than their peers in mining and register more patents. Still, they battle to translate their success into transfer activities. Demand for services was very low as most client organizations struggle to pass on the costs for new technologies to their consumers (Thurner and Zaichenko 2015b).

Russian agricultural RTOs received on average 4.4 million roubles in 2014, compared with an average of 219.0 million roubles for Russia's total number of RTOs. These funds stem mainly from the federal budget. The practice of public funds has been criticized for inadequate priority setting and a generally low culture of design and technical documentation. Furthermore, this strong orientation towards public funds further delineates R&D producers from their clients, who find the developed solutions impractical or unsuitable for agricultural producers. To increase efficiency in the knowledge production in the Russian economy, public funds are now allocated in a more competitive way to ensure the quality of the funded projects. Furthermore, the total number of organizations was reduced. Since 1995 their number has dropped by 17.6 per cent, mainly in line with the country-wide shrinking numbers of RTOs. Also, RTOs are now slightly better equipped. In institutions supervised by the RF Ministry of Agriculture, the value of machinery and equipment grew in 2005–14 (in constant 2005 prices) from 309.100 to 478.400 roubles/employee. RTOs in agriculture also generate additional income, which meanwhile amounts to almost one-fifth (18.4 per cent) of all work they perform. A total of 7.9 per cent of their income involves the production of commercial products. Many of these organizations have hence been criticized as 'isolated', as they lost contact with both the academic community and agricultural production; and have diversified into other activities to generate additional income (some of which has nothing to do with their specialization).

R&D-related services are equally important for the successful implementation of innovative technologies (e.g. Barge-Gil and Modrego-Rico 2008). Most client firms seek comprehensive service packages with non-R&D services added to classical R&D and many RTOs also offer engineering services (Preissl 2006; Barge-Gil and Modrego-Rico 2008), expert opinion in legislation processes or 'due diligence' studies. Internationally, the prevailing engineering services cover support for product development, testing or certification services, or prototyping services. Here, Russian RTOs are no different. A recent study on services provided by RTOs showed that, while engineering services are mostly sold as a package together with technology transfer activities, another group focuses on education and training services as stand-alone offerings mainly covered through federal budgets. RTOs under private or mixed ownership offer a much greater variety of services than those under entire public ownership.

The skill set of R&D personnel in the agricultural sector improved in recent years. The share of support staff decreased while the share of researchers, including doctorate holders, rose. The number of researchers engaged in relevant areas steadily dropped from 18.2 thousand in 1994 to 11.3 thousand in 2015. Russia still has the fourth largest cohort of researchers, after Japan (39 thousand), China (23 thousand), and India (14 thousand).[6] Comparable with Russia, countries like Korea (with 10.1 thousand), Iran (9.9 thousand), and Argentina (8 thousand), experienced an increase in the number of agricultural researchers during the previous 10–15 years (on average by 3.5–5 per cent a year). Russian research personnel is ageing fast though, which leads to discontinuities as skills are lost and young researchers have not been trained adequately. In 2015, the share of researchers under the age of 39 years in agricultural sciences was 42.9 per cent, those aged between 40 and 59 years was 31.5 per cent, and older than 60 years was 25.6 per cent. Between 1994 and 2015, the number of researchers older than 70 years grew ninefold. The increase of funding allocated to agriculture-related basic research could not be translated into adequate productivity growth including international academic publications.

4. Research methodology

This research is based on a questionnaire-based large-scale study of RTOs in Russia by the Institute for Statistical Studies and Economics of Knowledge (ISSEK) and the National Research University Higher School of Economics (NRU HSE) in 2011–5 (covering 2010, 2012, and 2014 reporting years). The initial data set was composed of information garnered from 1001 RTOs based on a randomized samples representing different geographical regions. Some RTOs refrained from answering the questionnaires due to commercially sensitive information or national security interests (R&D in military technology areas). Also, some RTOs underwent reorganization of their activities or closed down and hence rejected our request. Still, the overall response rate was over 60 per cent.

For this article, we filtered the data set and earmarked as 'agricultural' only those RTOs which meet at least one of the following criteria:

- Specialize in agricultural sciences.
- Report more than one customer enterprise from the agriculture sector (regardless of total number of customers).
- Report one customer enterprise from the agriculture sector, but as a sole customer.

We calculated six logistic regressions, providing probability models for the group of agricultural RTOs as well as for the other RTOs in our sample. We used data collected in the years 2010, 2012, and 2014, respectively. This approach allows for a detailed comparison of agricultural with non-agricultural RTOs. All logistic regressions build on the same dependent binary variable (presence of technology transfer at an RTO) and the same set of predictors. Each probability equation has the following form:

$$p = \frac{1}{1 + e^{-z}},$$

where p is the probability of technology transfer activity by an RTO, and

$$z = \text{const} + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 + b_8x_8,$$

where

const: equation constant;

×1: dummy 'Provision of engineering and/or implementation services reported';

×2: dummy 'Basic research share in IERD > sample median';

×3: dummy 'Development share in IERD > sample median';

×4: dummy 'Federal budget appropriations share in IERD > sample median';

×5: dummy 'Competitive funding share in IERD > sample median';

×6: dummy 'Publications in indexed (Scopus/WoS) international journals > 0';

×7: dummy 'Patent applications > sample median';

×8: dummy 'R&D staff headcount > sample median';

b1…b8: respective coefficients.

The last two rows of the table include the Nagelkerke R-square (equivalent of R-square statistics for logistic regressions) and the ratio of correctly predicted cases (given that predictions are random at 50 per cent and perfect at 100 per cent) as an indicator for the model's quality. As we search for relationships between given predictors and the dependent variables, we pay attention to separate significance coefficients based on Wald statistics (chosen cut-off values are 0.05 and 0.01).

5. Findings

The descriptive analysis of the sample size as presented in Table 1 confirms the developments that were discussed earlier. The federal funds as percentage of Intramural expenditure on R&D (IERD) have been growing steadily and now reach 50 per cent of the funds available to RTOs. Consequently, the share of basic research (traditionally funded out of federal budgets) has increased, while the percentage of development (applied science) has decreased. Also, the statistics show the decline in headcount in R&D staff, though the numbers were still higher in 2014 than in 2010. The allocation of funds between basic research and applied research/development shows how much agriculture is following its own trajectories (Table 2). While the share of basic research is consistently above average, the share of research towards development of applicable solutions is remarkably low. This dependency on public funds should have been accompanied by a competitive distribution of these funds. The presented sample, though, shows that the share of funds that had been received on a competitive basis is well below average. This further contributes to the conservation of the former inefficient structure. One variable that shows the changes in the last years is the RTO staff headcount. One possible reason for this careful, almost cautious, development can also be found in the data. The share of agricultural RTOs under public ownership is extremely high (almost 100 per cent). The share is much lower for other R&D areas, though the trend of public ownership is increasing there at a fast pace too.

Table 1. Sample size.

	Reporting year		
	2010	2012	2014
Total sample size	1,001	879	749
RTOs active in agriculture, *n* (%)	161 (16.1)	97 (11.0)	156 (20.8)

Table 3 demonstrates the development of technology transfer activities of RTOs. While in 2010, 75 per cent of all RTOs reported at least some technology transfer activities, the share steadily declines and reaches a value of 62.8 per cent in 2014. The numbers in 2010 far exceed the average reported activities from other fields, while in 2014 the number of RTOs in agriculture that reported transfer activities is in line with the average. This declining trend is also visible in the provision of technology services. If the technology transfer activities of Russian RTOs declined, maybe their clients found technology support elsewhere? When asked about competition, foreign research institutions seem to be successful in Russia. While only 13 per cent of RTOs mention these actors as direct competitors in 2010, this share rises to 23.7 per cent in 2014. Also, foreign technology and engineering firms have increased their presence. Foreign industrial enterprises, on the other hand, have been mentioned by around a quarter of RTOs in 2010, but are only mentioned by 16 per cent in 2014 (Table 4).

In a next step, we applied a logistic regression model to identify factors which influenced the reported technology transfer (Table 5).

While the share of basic research in RTOs active in other fields than agriculture actually positively contributes to technology transfer, this influence is not visible for RTOs in agriculture. The same holds true for the share of IERD devoted to development. On the other hand, the share of federal budgets in IERD does not affect the probability of technology transfer into agriculture at all. In other areas of economic activities, a high share of federal budgets in IERD negatively impacts technology transfer activities. The lower the share of federal budgets, the higher the share of business funds. In turn, the competitively distributed funding increases the probability of technology transfer with RTOs other than agriculture. Also here, its impact is not present for agriculture-related RTOs.

The number of staff in agricultural RTOs was higher than average but fell below average in 2014. In 2012, when the headcount of staff in agricultural RTOs reached its highest value, the variable demonstrated a negative effect on technology transfer likelihood. After the consolidation of staff headcount, this negative effect

Table 2. All-sample medians (used as cut-off values for binary conversions).

	2010	2012	2014
Basic research as percentage of IERD	0.5	5.0	10.0
Development as percentage of IERD	40.0	50.0	35.0
Federal budget appropriations as percentage of IERD	40.0	50.0	50.0
Competitive funding as percentage of IERD	10.0	15.0	11.0
Publications in indexed (Scopus/WoS) international journals	3	1	1
Patent applications	3	2	2
R&D staff headcount	70	88	80
Share of researchers as percentage of R&D staff	50.0	50.0	50.0

Table 3. Technology transfer activities reported (%).

	Reporting years and categories of RTOs					
	2010		2012		2014	
	Agricultural	Other	Agricultural	Other	Agricultural	Other
Technology transfer reported (dependent binary variable)	75.2	60.2	68.0	63.8	62.8	62.4
Alternative dummies: Non-zero technology transfer revenues	62.7	39.8	68.0	53.1	55.1	55.5
Provision of technology services[a]	59.0	51.7	51.5	51.8	53.2	52.3
None of the listed criteria above	10.6	18.9	10.3	14.1	16.3	15.0

[a]Engineering and/or implementation services.

Table 4. RTOs facing competition (%).

	Reporting years and categories of RTOs					
	2010		2012		2014	
	Agricultural	Other	Agricultural	Other	Agricultural	Other
Foreign research institutions and universities	13.0	14.8	27.8	21.4	23.7	18.9
Foreign technology/engineering firms	13.7	15.4	27.8	25.4	21.8	25.5
Foreign industrial enterprises	24.8	24.9	20.6	16.9	16.0	15.3

Table 5. Logistic regressions for dependent binary variable ‘Technology transfer reported’: shown only significant coefficients B.

	Reporting years and categories of RTOs					
	2010		2012		2014	
	Agricultural	Other	Agricultural	Other	Agricultural	Other
Provision of engineering and/or implementation services reported	1.030**	0.837**	1.062*	0.737**	0.840*	0.911**
Basic research share in IERD > sample median		0.382*		0.658**		
Development share in IERD > sample median		0.424*		0.450*		0.456*
Federal budget appropriations share in IERD > sample median				−0.484*	1.143**	−0.407*
Competitive funding share in IERD > sample median		0.341*				0.711**
Publications in indexed (Scopus/WoS) international journals > 0				0.639*	0.795*	
Patent applications > sample median						
R&D staff headcount > sample median			−1.499*			0.662**
Constant	0.240	−0.889	0.081	−0.958	−1.370	−0.294
Nagelkerke R-square	0.099	0.114	0.262	0.152	0.183	0.199
Percentage of correctly predicted values	72.7	65.1	76.3	65.7	67.9	68.6

*Significance at 0.05 level; **Significance at 0.01 level.

disappeared. Interestingly, the share of RTOs in agriculture that reports the provision of engineering and/or implementation services is consistently higher than the average. These services are mostly offered as an add-on to technology transfer projects.

6. Discussion and conclusion

This article set out to study technology transfer activities into agriculture and to reflect on these developments in the wider context of policy setting. The findings presented in the article suggest that—despite increased policy measures—technology transfer activities have not picked up but instead fell to a low level. While increasing support for basic research through public funding has given RTOs in other parts of the economy an advantage, which they translated into increased technology transfer activities, the contrary is true for RTOs in agriculture. The policy support has incentivized RTOs to move further into the production of basic research. However, this lies outside their traditional activity. Historically, the activities of RTOs stand in stark contrast with universities, whose main mission is education, and with enterprises, which produce goods and services. In fact, RTOs have been fairly unproductive in basic research as indicated by publication output and patent application.

Contrary to the general trend, only a small share of the public funds that RTOs receive is distributed on a competitive basis. This might well be connected to the increasing public ownership over the period under consideration. This share has now reached almost 100 per cent. The linkage between RTOs, public funding, and state ownership has further increased the gap between the stages of the R&D cycles. This development leads to a further loss of applied competencies and increasingly alienates RTOs from their client firms.

Furthermore, while increasing public funds have strengthened technology transfer activities in other fields, this link is not visible in agriculture. It seems that once a certain percentage of federal funds have been allocated to the RTOs budgets, the technology transfer activities are actually given up in favour of activities that generate more federal funds. This change in self-understanding is also supported by two other findings: RTOs identified increasingly identified universities as their competitors, whereas at the same time employing more PhD holders. This trend is especially worrying as RTOs have been fairly unproductive in knowledge generation as measured by publication output or patent application.

These findings raise questions about the usefulness of policy intervention in the absence of real economic demand for technology transfer. Recipients of policy support will try to maximize their benefits from new initiatives. As such, the exclusive orientation of RTOs towards increased funds for basic research is of little surprise. A similar behaviour has been demonstrated by Thurner and Roud (2016) in manufacturing companies. Here, demand for green technologies of firms under state ownership has been triggered mainly if new public funds were offered.

Another factor that deserves attention is the presence of foreign technology providers. These firms offer technological solutions that may well be more advanced than home-made solutions from Russian providers. In a previous study, around 11 per cent of Russian RTOs active in the agricultural sector reported competition from such firms (Thurner and Zaichenko 2016). The strong devaluation of the rouble during the past few years gave Russian solutions a competitive advantage over foreign suppliers.

Supporting the technology-supply aspect side though is probably not far-reaching enough. Previous studies of RTOs in agriculture found that clients are reluctant to invest in new technologies because their home markets do not allow passing on the additional costs to the customer. Unfortunately, exact information about the status of most R&D projects is not available, but estimations suggest that a very low share of these results is used by more than one client. Thereby, the technology generation and distribution become relatively expensive as the RTO cannot benefit from economies of scale or learning curves. In the present case, policymakers intend for Russian agricultural and food producers to tap into new international markets with a much higher willingness to pay for quality products. These opportunities are not pursued due to technology path dependencies and sufficient returns on investment in the home markets. It seems that, the prevailing system of technology provision, through RTOs commissioned by a Russian client who is successful in the home market with the existing technology, is insufficient. Instead, a more radical solution may well be needed.

Acknowledgement

This research was conducted within the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) and supported within the framework of a subsidy granted to the HSE by the Government of the Russian Federation for the implementation of the Global Competitiveness Program.

Notes

1. Presidential Address to the Russian Federal Assembly of 3 December 2015.
2. The average exchange rate in 2015 was 1 dollar = 60.7 roubles.
3. This and subsequent agriculture- and food industry-related indicators for the Russian Federation are quoted from the Russian Ministry of Agriculture and Rosstat publications.
4. Besides RTOs, the literature also speaks of other institutions like publicly funded technology transfer offices at universities, public research organizations, publicly funded regional economic development agencies, knowledge-intensive business service (KIBS) firms, etc.
5. After the Federal Law of 27 September 2013 No. 253-FZ 'On the Russian Academy of Sciences, reorganisation of state academies of sciences, and amendments to certain Russian Federation legislation' had been passed, the Russian Academy of Agricultural Sciences (formerly a state academy of sciences) was affiliated with the Russian Academy of Sciences (RAS). According to the RF Government's instruction of 30 December 2013 No. 2591-r 'On approval of the list of organisations supervised by the Russian Federal Agency for Scientific Organisations (FASO)', organizations previously supervised by the RAAS now report to the FASO.
6. Many countries like the USA do not provide data.

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