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FIRM-LEVEL EVIDENCE ON THE COOPERATIVE INNOVATION STRATEGIES IN RUSSIAN MANUFACTURING

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FIRM-LEVEL EVIDENCE ON THE COOPERATIVE INNOVATION STRATEGIES IN RUSSIAN MANUFACTURING

This paper focuses on revealing the heterogeneous impact of firms' specificities and the environment on the sophistication of the cooperative innovation strategies. We use the firm-level data on innovation strategies of over 1200 manufacturing enterprises in Russia to model the networking strategy as a simultaneous choice of the range of cooperative linkages (within and beyond the value chain and knowledge production sectors). The determinants comprise the internal factors (as absorptive capacity) and the external conditions (e.g. technological opportunities, appropriability and competition regimes). Revealed effects prove the initial heterogeneity hypothesis thus challenging the wide-spread simplified perception of 'openness' of the innovation strategy as a one-dimensional characteristic.

Keywords: Innovation cooperation; open innovation; firm-level; Russia; manufacturing; innovation strategy; multivariate probit.

JEL: L2, O3.

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Introduction

For the recent decades the cooperative behavior has been considered as one of the central topics in the innovation studies. The importance of engaging external knowledge sources was formally emphasized in the central conceptual models (e.g. the chain-link model of innovation (Kline and Rosenberg, 1986)) and reflected in the statistical measurement frameworks (Oslo Manual, 2005). These theoretical considerations were fully supported by the emerging base empirical evidence that has greatly improved our understanding of different patterns of cooperative innovation strategies. However, few researchers focused on the empirical analysis of the determinants for the cooperative innovation strategies, fully taking into the account the heterogeneity of motivations for the different configurations of collaborative networks.

This study employs the firm-level data on the innovation activities of the Russian manufacturing enterprises to address the major research question: what are the key determinants (including the internal firm specificity and the characteristics of the external environment) that lead a firm to enter into innovation cooperation, either with a specific actor or with several partners simultaneously?

To address this question we use the results of the specialized survey entitled “Monitoring the innovation activity of actors of the innovative process”, which the Institute for Statistical Studies and the Economics of Knowledge (ISSEK) of the National Research University Higher School of Economics (NRU HSE) has undertaken in 2014-2015 and provides data for 1208 manufacturing enterprises.

We estimate a multivariate probit model with nine simultaneous equations, each one representing the type of innovation cooperation chosen by firms: cooperation with customers, suppliers of raw materials, competitors, providers of services, related value-chain members, consulting firms, universities, research organizations and public and local authorities. We control for six dimensions determining cooperative strategies: general firm’s characteristics, competitive environment, technological opportunity, absorptive capacity, appropriability conditions and public support as explanatory variables. The model allows us to analyze the heterogeneity of innovation cooperation strategies, by including different innovation cooperation partners, and possible correlation between them and to take into account the possibility of simultaneous cooperation agreements.

The remainder of the paper is structured as follows. Section 2 provides a brief overview of the theoretical and empirical literature on innovation cooperation, focusing on innovation cooperation strategies and factors that may either contribute or prevent cooperative behavior. Section 3 shifts the focus to the dataset description, variables construction and estimation methodology. An econometric analysis of the cooperative behavior is delivered in Section 4. Section 5 presents main results and concludes with possible directions for future research.

Background

1. An overview of innovation cooperation

There is a rich body of literature that provides theoretical insight on why firms engage in cooperation and what are the results of such relationships to the different actors of the innovation processes. The study (Hagedoorn, Link, Vonortas, 2000) identifies three board perspectives to address these issues: (1) transaction costs, (2) strategic management and (3) industrial organization theory.

Strategic management theory concentrates on the firm and its internal organization, strategic choices and decisions to sustain competitive advantages over rivals. There are several approaches, taken by strategic management scholars, toward research partnerships: competitive force, strategic network, resource-based view of the firm, dynamic capabilities view and strategic approach to research partnership. Industrial organization theorists focus on the firm as well, but try to analyze the effects of firm actions on industrial structure, economic efficiency, and social welfare, emphasizing the role of knowledge spillovers. They pay attention to the risks involved in cooperation, related to the perceived public good nature of knowledge and the difficulty in appropriating the returns from it (Hagedoorn, Link, Vonortas, 2000; Miotti, Sachwald, 2003).

Transaction cost theory can be viewed as a combination of the above two theories. The main focus of transaction costs theory is the definition of the determinants of internal coordination of the transactions through markets and hierarchies. This theory confirms transaction cost efficiency as the incentive for joint research projects, but ignores many strategic benefits of cooperation such as “learning, creation of legitimacy, and fast market entry when it involves the issue of partner choice” (Arranz, Fdez. de Arroyabe, 2008).

According to each of these theories, various reasons that lead a firm to cooperate and to form a research partnership can be distinguished. Still the primary goal of corporations is its value maximization. The firm value is a long-term approach and the decision-making process takes into consideration various sub goals: realistic strategic growth plan, recurring revenue and its multiple streams, ensuring competitiveness, cost saving, customers diversification and others. However during the last decades the business environment has changed significantly. The globalization of markets, increased competition, product-process life cycle contraction, high mobility of qualified staff, the availability of private venture capital and other factors have contributed to the business development model change-over. The idea is that companies in the process of creating new technologies and products are paying attention not only to support internal corporate research and development, but also to attract external ideas, intellectual property, competences, human resources and tangible assets. According to (Chesbrough, 2003), new open business model requires an active cooperation with various external organizations that facilitates accelerated and sustainable development, effective protection and use of intellectual property etc.

However, the incentives for engaging in cooperative agreements are basically complex, furthering the cooperation with several partners simultaneously. Explanation of success lies in a synergy effect, when efficiency and power of the whole is more than the sum of individual elements. Instead this section simply highlights some notes from the literature concerning the benefits of collaborative relationships with different types of organizations and also the barriers that effect the company's decision to enter into cooperation agreements.

2. Cooperative strategies: incentives and obstacles

Inter-firm cooperative agreements are one of the major modes companies use to access knowledge developed in the global innovation networks. Innovation as an economic phenomenon is determined both by technology push (e.g. encompassed in the technological opportunities and the appropriability conditions) and by demand factors (e.g. market demand) (Harabi, 1992). On this basis the cooperative agreements within the supply chain hold a special role. Collaboration within the supply chain usually are associated as vertical linkages with suppliers and/or customers.

Close cooperation with **suppliers** has a wide variety of benefits. Suppliers have two significant advantages (Un, Asakawa, 2015). Firstly, they have high position in the knowledge chain. By supplying inputs and raw materials they influence the production flow. Secondly, they operate in the same industry segment, having close contextual knowledge distance to the company. Being closely linked allows firms to reduce costs and project development lead times (Clark, 1989) through the implementation of just-in-time delivery, logistical solutions etc. Also suppliers provide the firm an opportunity to involve in planning and operation in innovation projects (Fritsch, Franke, 2004) and finally to be a pilot user of supplier's innovation. In view of the foregoing, cooperation with suppliers has a great positive impact on the innovation process and favors the development of both marketing and organizational innovations (Sánchez-González, 2013).

A relationship with **customers** can also help firms to gain the competitive advantages. Customers are kind of the information source about user needs (Tether, 2002) and market trends and opportunities (Von Hippel et al. 1999). Despite consumers are downstream collaborators and have a different operation environment, thanks to including them in product creation and development processes firms can get advantages over its competitors. When a company knows its customer objectives, it might be able to meet those needs more rapidly than competitors and to reduce the risk of uncertainty associated with market introduction. Furthermore, consumers may serve as information source about the innovations of competitors (Padmore, Schuetze, Gibson, 1998). Linkages with customers will be especially valuable, if companies deal with novel and complex innovation, or when the end market is poorly understood.

In cooperation with suppliers and customers firms face typical types of partnering barriers, which include external (e.g. extensive administrative procedures and bureaucracy, government regulations) and internal (e.g. different cultures, lack of IPRs and IP management) issues. Furthermore, there are some specific factors, for instance, knowledge received from consumers and suppliers is predominantly tacit and emotional-value-related, and that can skew the results. Furthermore, clients often take a conservative approach, showing disinterest in innovations, while suppliers may infringe delivery schedule or deliver inferior goods. In this respect vertical cooperation may be costly in terms of time and efforts.

Suppliers and customers apart, firms may cooperate in innovation with other external partners, such as market actors, knowledge "producers", consulting firms and public authorities.

Cooperation with the knowledge production sector, i.e. **universities and research organizations**, holds a unique position among all cooperation types, because it is a major source of basic scientific and technological knowledge, which is essential for innovation, technology and economic growth (Cohen, Nelson, Walsh, 2002; Mansfield, 1998).

Scientific fundamental knowledge is especially important in early phases of the innovation process characterized by high uncertainty and low demand for the outcomes (Veugelers, Cassiman, 2005). Hence, companies cooperating with universities and research organizations increase their ability to realize more radical innovations and to produce newly launched entries (Kaufmann, Tödtling, 2001). Moreover, there are also economic advantages. Firstly, firms may receive various kinds of public support to R&D and innovation. Secondly, it can lead to the acceleration of return on investments through a rapid diffusion process. Due to the fact that research organizations are upstream in the knowledge chain of the industry (Un, Asakawa, 2015) business sector is concerned with intellectual property transmission. Intellectual property transfers enable companies to disseminate and utilize the patented technology in the market (OECD, 2004), providing means for shortening the innovation cycle and sharing costs.

Educational benefits and improvement of reputation and prestige are other motives why firms and scientific research organizations decide to collaborate. Their cooperative agreements increase the mobility of employees and researches across them (Hackett, 2008) and allow enterprises to trainee employees and to offer highly qualified and expert researches (Schmidt et al., 2007). Innovation collaboration attracts new commercial contracts and consumers, helping enterprises to secure its competitive position.

However the cooperation between universities, research organizations and industry sector face the variety of barriers. One of the main challenges is the divergence of respective objectives of collaboration partners, related to the lack of complementarity between scientific studies and business function (Fiaz, Naiding, 2012; Garcia et al., 2015). It leads to the communication and trust issues connected to transmission of information. A rigid control of intellectual property rights, technological copyrights, knowledge transfer and privacy of both partners are required to overcome the threats of misappropriation of the results. Furthermore, contractual relationships and the need of knowledge capitalization induce transactional barriers. Thus, science-industry cooperation is characterized by high uncertainty, spillovers to other market actors, information asymmetries between partners and transaction costs for knowledge exchange, which requires the presence of absorptive capacity (Veugelers, Cassiman, 2005).

Furthermore, there is an opportunity to be in close coordination with **public and local authorities**. Literature has deeply analyzed the motivations inducing firms to form research joint cooperation with market actors and research organizations; instead, the investigation of the incentives to cooperate with central and local authorities is disregarded. Still state government bodies permit simultaneous R&D sharing and coordination of R&D decisions among economic agents and also provide a legal framework for cooperative agreements. Local authorities are the level of government closest to people and act consistent with its needs and interests, allowing companies to choose the most optimal and effective policy strategies and future projects. Cooperation with public and local authorities is an effective tool to support direct investment in various sectors of the economy, to harmonize the sectoral legislation and to strengthen the company's market power.

Consulting firms are actors from private sector and alternative sources of information. They are often far from innovation process, but being outside the firm consultants transmit a different knowledge regarding the context in which the company operates. They could provide a variety of inputs to the innovation process and stimulate new innovative ideas (Tether, 2002), concerning changes in organization or marketing strategies (Garcia et al., 2015).

Moreover, consultants provide innovative firms applied knowledge, specialist skills and market information, offering a complete problem solution at the any stage of innovation process. Cooperation with consultants is particularly important for large companies, which cannot solve emerging problems and do their day-to-day operations simultaneously.

The horizontal type of cooperation – collaboration with **competitors** differs from all previous types significantly, because competitors belong to the same industry sector and share similar knowledge about the market, where the firm operates (Miotti, Sachwald, 2003). The main incentive to cooperate with competitors is that their goals in project are similar due to common problems in concrete area (Tether, 2002). Having high contextual knowledge distance to specific sector (Un, Asakawa, 2015), these linkages are valuable in the development of new complex technology. Both companies are able to reduce costs and risks for the innovation process due to the necessary expenditure and economic risk sharing.

However, joint innovation project stimulates all the competitors to actually sharing the benefits from the achieved results. In this situation the lack of a strong intellectual property management and regulation at the level of a firm can be a reason not to engage in cooperation. Coordination and communication problems may also hamper cooperation with competitors. Knowledge flow is seen to be one of the fundaments of the effective cooperation, but by being competitors companies do not trust the information regarding, e.g. other partner competencies, market activities and projects, received from partners (Edwards-Schachter et al., 2012).

Finally, firms pursue different objectives when getting engaged in cooperation with external partners and often more than one goal coincidently. Different combinations of motivations prompt companies to enter into formal and informal cooperation with external partners. Nevertheless companies are often forced to delay or even abandon their collaborative projects due to various external and internal prohibitive factors.

3. Determinants of cooperative strategies

The variety of cooperative strategies implies the heterogeneity of motives behind the particular choices of collaborative partners. A complex set of factors influences a company's decision-making process and increase or reduce the likelihood to enter into a strategic cooperation agreement.

Most statistical studies show that the firm's decision to establish cooperation relationships in innovation relies heavily on the **general firm's characteristics**. The propensity to cooperate for innovation may depend on the firm's size, age, sector of activity, export orientation and other. Most of empirical studies, investigating the variety of cooperation strategies, the motives for innovation collaboration and the determinants of choice of partners include size as an explanatory variable in all empirical models (e.g. (Arvanitis, 2012; Becker, Dietz, 2002; Belderbos et al., 2004; Veugelers, Cassiman, 2005)). In order to carry out innovation activity, a mass of financial, human and technological resources are needed. Only large companies accommodate these resources. Additionally, a key reason for cooperation is a lack of complex knowledge or competencies that a firm currently lacks. It means, that primarily the firm has its own knowledge base and a range of abilities. This is inherent also only for large firms (Bayona, García-Marco, Huerta, 2001). The company's ownership could also influence its cooperation strategies. (Tether, 2002) found that companies with foreign participation are more likely to cooperate with customers and universities, while (Belderbos et al., 2004) found that a general belonging to a group increases innovation cooperation with customers and suppliers, but not with universities and scientific research organizations.

Another group of factors relates to the **competitive environment**, in which firm operates. There are two different views of how the high level of competition in the industry affects the company's decision to cooperate with other organizations. For one part, increasing concentration on the market causes the firms' desire to engage in innovation partnership, because it enables to broaden the value chain and thereby to improve a firms' competitive position (Arvanitis, 2012). For the other part, a high degree of intensity in competition attended by a risk of leaking knowledge leads to a lack of willingness to cooperate (Dachs, Ebersberger, Pyka, 2008). The strength of competitive forces is especially important in horizontal cooperation and cooperation between non-competing firms (e.g. suppliers, clients) (Belderbos et al., 2004). The level of competition could be measure directly by indicators (e.g. intensity of price competition, intensity of non-price competition) and indirectly by market structure variables (e.g. the number of competitors, prospective markets and other).

Other factors are mostly behavioral or experiential and are directly related to the firms' innovation activity. In general, the innovation capabilities of firms depend on the balance between the ability to conduct and expand in-house research and development by applying technological opportunities and the learning capacity in witch firms face the opportunities that the environment provides, which depends on firms' absorptive capacity. Technology opportunities and absorptive capacity are supply factors, which vary according to manufacturing sectors and companies and may explain cross-industry differences in innovative activity (Harabi, 2002).

Technological opportunities are "a total amount of the currently existing and exploitable external resources firms are faced with" (Becker, Dietz, 2002) and have an external influence on the innovation intensity and productivity. One of the reasons why firms engage in innovation cooperation is the lack of own resources, so the higher the availability of external knowledge, the higher firms' intra-company capabilities to develop innovations are. There are market-related (e.g. consumers, suppliers) and non-market-related (e.g. universities) sources of technological opportunities (Harabi, 2002). In this view, types of innovation play a critical role. There are different classification models of innovation types based on innovation's impact or scope, innovation source, impact to current business and also the Oslo Manual classification (OECD, Eurostat, 2005). Castellacci (2007) relates technological opportunities with the share of expenses that firms spend on R&D activities, considering differences in the levels and sources of technological opportunities may explain variations in R&D expenditures. Therefore, the level of internal R&D expenditure is concerned with the choice of beginning of a collaborative R&D activity (Franco, Gussoni, 2010).

Another determining supply factor of innovation cooperation strategies is the firm's **absorptive capacity**, which is also related to the flows of knowledge. It characterizes the "ability of a firm to identify, assimilate and exploit knowledge from the external environment" (Cohen, Levinthal, 1990). Absorptive capacity can be estimated by different indicators, such as the share of intramural innovation expenses, the importance of internally available information, the presence of a permanent R&D structure, the number and qualification of R&D staff, and has been identified by many studies as an important driver for cooperation (Badillo, Moreno, 2012; Bayona, García-Marco, Huerta, 2001; Miotti, Sachwald, 2003). Firms with higher absorptive capacity have competitive advantages over its rivals, because they are more able to recognize and adopt a larger amount of external resources (Faria, Schmidt, 2007) and are more likely to benefit from cooperation with other firms and institutions (Veugelers, Cassiman, 2005). The existence of adequate absorption capabilities helps to supplement insufficient internal resources and to increase the returns from access to external assets (Miotti, Sachwald, 2003). Nevertheless, firms' high absorptive power can hinder the cooperation, because such companies can obtain access to external knowledge without cooperating (Faria, Schmidt, 2007).

Moreover, the innovation activity is based on the spillover effects. The concept of incoming spillovers (Veugelers, Cassiman, 2005) is strongly related to the absorptive capacity of a firm, which may motivate a firm to seek innovation cooperation. Outgoing spillovers in turn are resources that can be utilized by other firms for their own purposes (Becker, Dietz, 2002). It brings risks of internal knowledge leaking out to rivals (Arvanitis, 2012). The problem of appropriability is that innovative firms are not sure that the achieved results are adequately protected, firms not participating in the cooperation project are unable to receive free access to the results (Lhuillery, Pfister, 2009) and that they will get a reasonable return for their R&D efforts (Harabi, 2002).

Consequently, **appropriability conditions** are one of a key factor of the firms' decision on cooperation with external partners. On the one hand, there is an incentive "associated with the ability to benefit from the engagement in the development of innovations" (Becker, Dietz, 2002). Companies are ready to invest in innovative activities, when they stand assured of getting the profit from introduction of new products/processes. Ineffective intellectual property protection mechanisms increase a probability of free-riding problem related to innovation investments (Belderbos et al., 2004). On the other hand, there is an efficiency effect. It lies in the fact that low appropriability conditions enable a high potential for intra-firms knowledge diffusion (Belderbos et al., 2004; Castellacci, 2007), with a possible beneficial effect on the productivity growth. Empirically, the firm's ability to appropriate returns from innovations has a positive and significant effect on the probability of innovation cooperation of any kind (Lhuillery, Pfister, 2009; Veugelers, Cassiman, 2005).

Considering that innovation is a costly and uncertain process, **public support**, which represent public financial support from local and national administrations, also shapes cooperation decisions significantly. Public support includes various measures that could be classified in different ways, for instance, direct and indirect measures, targeted, horizontal and networking measures. A distinct advantage of direct support measures (e.g. state grants, contracts within federal target programs) is that most of the expected results are measurable and could be obtained through such indicators: innovation expenditure, growth, employment and other. The level of success increases when there is a combination of direct and indirect support. Indirect support programs (e.g. tax remissions and preferences; depreciation bonuses) are flexible, limited time-span and based on the "call for proposals". Therefore, should be designed as an incentive to repurpose innovation activities, rather than a main and regular source of income.

In the light of the above, both internal characteristics and factors external to the firm drive firms to choose a particular collaboration partner. All determinants of firms' innovation cooperation strategies can be arranged into six groups that were discussed in this section. Table 1 presents a brief description of each group of factors.

Table 1

Determinants of cooperative strategies

Category	**Definition**
General firm's characteristics	Background characteristics of the firms, e.g. size, age, form of ownership, sector of activity
Level of competition	The availability of competitive advantages at the industry and firm level
Technological opportunities	Firm innovativeness: the suitability of the currently existing and exploitable external resources
Absorptive capacity	The extent to which firms can identify, assimilate and exploit knowledge from the external environment The link between the external stock of technological opportunities and the in-house capabilities
Appropriability conditions	The ability to obtain the benefits from innovation by protecting innovations from imitation
Public support	Public financial support from local and national administrations

4. Empirical research of cooperation strategies

The literature review of empirical studies of firms' cooperation strategies has shown that there are four key lines of empirical research:

(1) Motives leading to innovation and R&D cooperation
(2) Patterns of cooperative innovation and R&D strategies
(3) Factors affecting the choice of innovation and R&D cooperation partners and the likelihood to enter into a cooperation agreement
(4) An exploration of the relationship between cooperative behavior in innovation and R&D activities and firm's innovativeness and performance.

(1) Distinguishing various incentives for cooperation helps to appreciate the importance of factors determining firms' cooperation strategies (Arvanitis, 2012). In the study "How do different motives for R&D cooperation affect firm performance? – An Analysis Based on Swiss Micro Data" Arvanitis identifies seven general motives for R&D cooperation: reduction of technological risks, saving of R&D costs, shortening of development time, access to specialized technology, utilization of technological synergies, knowledge of complex technologies, utilization of public promotion grants, and investigates determinants of R&D cooperation based on these incentives by multivariate probit model. Obtained results suggest that cost-motivated cooperation has stronger positive effect on firm's productivity than technology-motivated cooperation.

Bayona, García-Marco and Huerta (2001) undertook an empirical analysis of motives that have caused manufacturing firms to cooperate in R&D. They have obtained that general firm's characteristics (size and technology sector), absorptive capacity and the recognition for obstacles have a noteworthy sway on the choice to cooperate.

With a focus on science-industry cooperation, Segarra-Blasco& Arauzo-Carod (2008) in their empirical study "Sources of innovation and industry–university interaction: Evidence from Spanish firms" have identified main determinants of cooperation with universities. These include general firm's characteristics (size and whether the firm belongs to the group), access to public funds and technological opportunities, such as R&D intensity and types of implemented innovations.

(2) Another line of empirical research is focused on the types of cooperation. Franco & Gussoni (2010) differentiate among three R&D cooperation strategies: market cooperation, science cooperation and mixed cooperation, and find that the choice of mixed cooperation is influenced by firm's size, absorptive capacity and appropriability conditions. Moreover, results

confirm that different sectors and technological trajectories lead to different strategies of cooperation.

Dachs, Ebersberger & Pyka (2008) distinguish four types of R&D cooperation strategies: collaboration with suppliers, customers, competitors and universities or research institutions to analyze differences in cooperative behavior of Finnish and Austrian companies. The results indicate that firms are strongly influenced in their decision to cooperate by the presence of horizontal and vertical spillovers, sectoral affiliation, innovative intensity, company's internal innovation strategy and also the existence of public funding.

The paper "Inter-firm R&D partnerships: an overview of major trends and patterns since 1960" by Hagedoorn (2002) analyses sectoral and international patters in R&D cooperation. A major conclusion is that firms from the developed economies participate in 99% of the R&D partnerships and collaborate mainly with companies from the Triad (North America, Europe and Asia). It could be also concluded that companies from high-technology sectors enter into cooperation agreements more often than low- and medium-tech industries (Hagedoorn, 2002).

Of particular interest is the empirical study "Who co-operates for innovation, and why? An empirical analysis" by Tether (2002). The reason for this is that unlike most of other research papers the subject is innovation (not R&D) cooperation strategies. Five cooperation strategies (customers, suppliers, competitors, universities and consultants) are investigated in a series of independent logistic regressions. Results confirm that "the relationship between innovation and cooperation is not straightforward" (Tether, 2002) and that the extent of cooperation for innovation depends basically on two things: the type of firms and what is meant by innovation.

(3) Most of empirical studies investigate factors influencing the likelihood to enter into a certain cooperation agreement. Arranz & Fdez. de Arroyabe (2008) focus on cooperative behavior for R&D of Spanish firms, distinguishing three types of R&D cooperation strategies: vertical, horizontal and institutional. Through a logit regression model authors estimate the impact of explanatory variables, grouped in four categories (sector, firm's characteristics, obstacles to innovation and the existence of public funding to encourage R&D) on the probability of a firm conducting cooperative R&D with a concrete partner. The analysis suggests that both firms and sector characteristics and the possibility to obtain public financing indicate firms' cooperation strategies. Additionally, firms seek to overcome the lack of market and technology through collaboration with suppliers and customers and high costs and risks through cooperation with rival firms.

Also for the case of Spain, Badillo & Moreno (2012) distinguish vertical, horizontal and institutional cooperation types and cooperation with other companies from the same group. Taking also into account the sector to which the firm belongs, they found that determinants of

R&D cooperation differ between manufacturing and service industries. Overall, the results indicate that the importance of incoming spillovers, public financial support and firm size play key role in the decisions to cooperate. Taking into account the heterogeneity in firms' decisions to engage in R&D cooperation, authors estimate multivariate probit models corrected for endogeneity.

Miotti & Sachwald (2003) pursue a study of inter-firm co-operative agreements, distinguishing R&D cooperation with suppliers, clients, competitors, academic institutions and foreign firms. Results support the "why–who framework, which is founded on a resource-based perspective" (Miotti, Sachwald, 2003). Results suggest that absorptive capacity, internal R&D effort and a necessity of radical innovation have a significant positive impact on the likelihood of agreements with research institutions.

Using Community Innovation Survey (CIS) data for Belgium, Cassiman & Veugelers (2002) explore the impact of incoming spillovers and the firm's ability to appropriate returns from innovations, distinguishing two cooperation strategies (vertical and institutional cooperation). Results confirm that both factors have a positive and significant effect on the probability of R&D cooperation of any kind. Later, Veugelers & Cassiman (2005) proved that cooperation in R&D with universities is complementary to other innovation activities, for instance, sourcing publicly available information, performing own R&D and interacting with market actors (suppliers and customers). Firm size and industry have positive impact on science-industry linkages, while the effect of the appropriation conditions is conflicting.

(4) Another line of empirical studies is devoted to analysis of how the engagement in innovation and R&D cooperation influence firm's innovativeness and performance. For example, Kaiser (2002) applies a nested logit framework to analyze firms' R&D cooperation in the German service sector, distinguishing between vertical cooperation and a mixed category of university and competitor cooperation. Results suggest that cooperative behavior tends to stimulate internal R&D expenditures (Kaiser, 2002). The effect is significant, but weakly.

In the paper "R&D Cooperation and Innovation Activities of Firms Evidence for the German Manufacturing Industry" Becker & Dietz (2002) focus on the effect of cooperation in R&D on company's innovation input and output and the number of firm's cooperation agreements. Obtained results confirm the importance of R&D cooperation as an innovation factor, especially for manufacturing industry. On the input side, the intensity of inter-firm R&D increases the probability and the number of collaboration partners. On the output side, cooperation in R&D enhances the probability of realizing new products (Becker, Dietz, 2002).

As for the importance of innovation cooperation for firm's innovation activity, Jaklič, Damijan & Rojec (2008) analyzed the interrelation between innovation cooperation and innovation activity of Slovenian enterprises. They confirmed that external innovation cooperation is the second important incentive for innovation activity, after R&D spending. Moreover, the efficiency varies also by type of cooperation partners. Cooperation with market actors significantly increases the probability of innovation, while innovation cooperation with universities and research organizations is not effective (Jaklic, Damijan, Rojec, 2008).

All papers investigating various R&D and innovation cooperation strategies and analyzing factors that affect the decision to cooperate and key finding of these studies are presented in Table A1 (see Appendix 1).

Based on the analysis of existing empirical studies, we can draw the following conclusions. General firm's characteristics (e.g. size, industry, group affiliation) are an important element in the propensity for R&D and innovation cooperation with each type of external partner. Sustainable competitive advantages over the other competing firms in a market refers to maintaining a dominant position in the market and affect R&D cooperation with competitors, universities and scientific research organizations favorably. At the same time the competitive environment has no effect on agreements within the supply chain. Firm's technological opportunity that refers to ease the achievement of innovations and technical improvements is of particular importance for vertical and institutional cooperation. Many of studies find that firm's absorptive capacity and incoming spillovers have a positive significant effect on the probability of R&D cooperation of any kind, especially on cooperation with universities and scientific research organizations. Appropriability conditions contribute to better likelihood of vertical and institutional cooperation. The impact of public support on the probability of R&D cooperation is very strong, especially for cooperation with customers, suppliers and knowledge production sector.

Nevertheless, there are also some limitations of previous empirical studies of innovation cooperation strategies and factors influencing firm's decision to enter into collaborative innovation.

Firstly, most of the existing literature focuses on R&D cooperation strategy and not on patterns of cooperative arrangements for innovation. However, R&D is not the same as innovation and vice versa. As provided by the Frascati Manual, R&D is "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2015) and covers basic research, applied research and experimental development. While innovation, in accordance with the approach advocated by the Oslo Manual, is an implementation of a new or significantly improved product, process, marketing or organizational method in business practices (OECD, Eurostat, 2005).

Secondly, most of these studies do not distinguish innovation cooperation on innovation activities by a concrete type of partner, instead of this researchers aggregate cooperation partners with some notable exceptions. The most frequently, researchers explore three types of cooperation strategies: vertical (suppliers and consumers), horizontal (competitors) and institutional (universities and research institutions) (e.g. Miotti & Sachwald (2003), Badillo & Moreno (2012), Belderbos et al. (2004)), or even less types of collaborative relationships.

In addition, many of research papers have in common that they explore different cooperation patterns as independent, regardless of possible correlations between the strategies that could arise out of their complementarities (e.g. Arranz & de Arroyabe, 2008; Franco & Gussoni, 2010; Tether, 2002).

In this paper we consider (1) heterogeneity of innovation cooperation strategies, by including different innovation cooperation partners, (2) eventual simultaneous relationship between various cooperation strategies and (3) the possibility of simultaneous cooperation agreements, by applying a system method of estimation for limited dependent variables.

Data and Method

1. General information on data source

The section is intended to describe tree aspects of data: (1) general description of the data source and observations, (2) the variables used in the study, and (3) how these variables change depending on the cooperation type.

The empirical work is based on the results from a specialized survey entitled “Monitoring the innovation activity of actors of the innovative process”, which the Institute for Statistical Studies and the Economics of Knowledge (ISSEK) of the National Research University Higher School of Economics (NRU HSE) has undertaken on a regular basis since 2009. The aim of the project is to develop empirical studies and to accumulate empirical knowledge about the innovation nature and types of interaction between various actors in the national innovation system.

The monitoring of the manufacturing and services industries adapts techniques from integrated European research into technology levels and innovative activity in industry (the European Manufacturing Survey, organized by a consortium of 16 research centers and universities in EU and beyond, coordinated by Fraunhofer ISI, Germany) and international standards on statistical measures of innovation. It expands the original framework with a number of specialized modules that ensure the methodological compatibility with CIS, but also provide a basis for assessing the respondents’ experience of participating in the official innovation surveys.

The survey in 2014-2015 focuses on the innovation activities of the manufacturing and service sector companies. The surveys sample includes 1324 firms, 1206 of which are manufacturing firms representatively reflecting the innovation cooperation patterns in Russian manufacturing. Data are weighted based with the population characteristics derived from the Federal State Statistics Service (Rosstat) that includes the information on the number of enterprises in each industry sector and size group. The brief sample characteristics are presented in Table 2 in Appendix 2.

2. Variables definition

The model specification derives the available survey indicators for the system of motives described in the previous sections.

The dependent variables represent the cooperative behavior of the manufacturing firms and contain information about the cooperation partner. We consider 9 types of firms: firms that carry out vertical cooperation with (1) customers, (2) raw materials and components suppliers and (3) providers of services; horizontal cooperation with (4) competitors; institutional cooperation with (5) universities and (6) scientific/ research organizations and enterprises that are engaged in partnership for innovation with (7) related value-chain members, (8) consulting firms and (9) public and local authorities.

The response variables are constructed from a question “Did you engage this type of cooperative partner during the implementation of innovations?” The number of partner types chosen was not limited allowing the firms to indicate cooperation with various partners simultaneously. All dependent variables are dichotomous, taking the value 1 if the firm cooperates for innovation with indicated partner and 0 otherwise.

More than half (53.5%) of firms in the sample prefer to collaborate with several partners simultaneously. About 30% cooperate simultaneously with two or three external partners, while 8.6% of the firms in the sample cooperate with more than 5 different partners. Therefore, the analysis of both decision stages should be sequential.

Table 3

Descriptive statistics for explanatory variables

	Total sample	
	Russia N[a]=805	
	Mean	**SD**
Cooperation with:		
Customers	0,7801	0,4144
Raw materials suppliers	0,7429	0,4373
Related value-chain members	0,3752	0,4845
Providers of services	0,3317	0,4711

Competitors	0,1925	0,3945
Research organizations	0,2708	0,4446
Universities	0,2224	0,4161
Consulting firms	0,0907	0,2873
Public and local authorities	0,2286	0,4202

Table 3 describes the sample by showing the allocation of firms' preferences about innovation cooperation partners. More than 70% of firms in Russian manufacturing prefer to cooperate with customers and raw materials suppliers. A significant proportion is also engaged in innovation cooperation with related value-chain members (37%), providers of services (33%) and knowledge production sector (more than 20%).

The descriptive statistics for the weighted sample are presented in Figure 1, characterizing cooperative behavior of Russian innovative manufacturing firms.

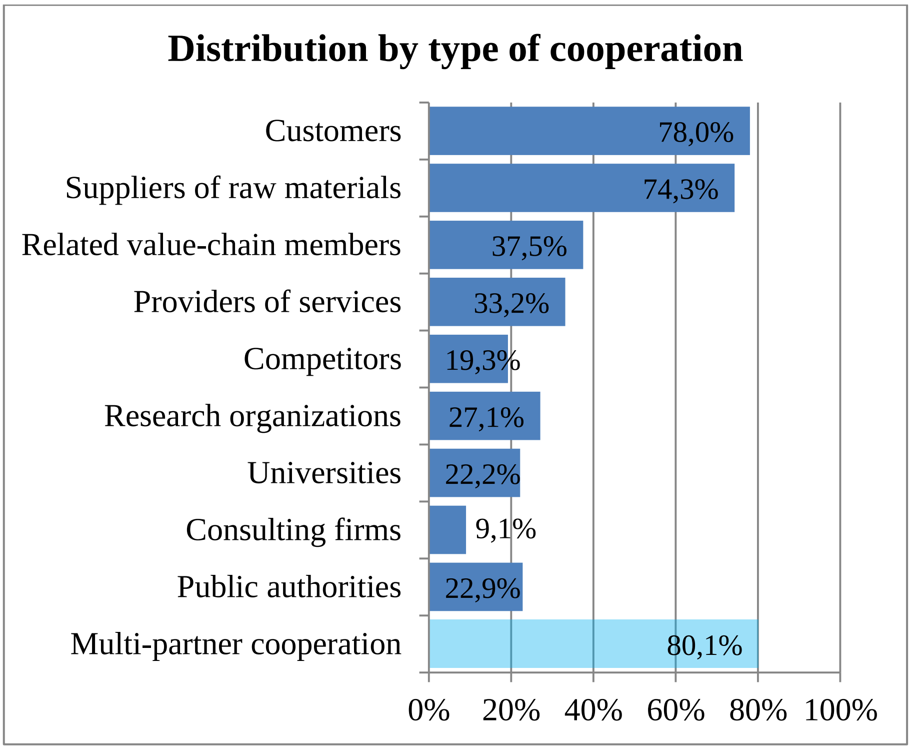

Fig.1 Population of the alternative cooperation modes in relative terms

Notes: Decision-making process among **innovative** firms in Russian manufacturing

From an aggregate point of view, almost all innovative firms in Russian manufacturing are engaged in innovation cooperation, while 80% of them prefer to cooperate with several types of partners simultaneously.

Potential determinants of cooperative behavior patterns (explanatory variables) are divided into six categories pursuant to the review of theoretical work and previous empirical studies. We include variables that are representative of (1) firm-specific characteristics, (2) market performance, firm's (3) technological opportunities and (4) absorptive capacity, (5) appropriability conditions and (6) public support measures.

The first group of factors relates to the general firm's characteristics and is meant to capture the influence of general company characteristics on the firm's decision-making process about cooperation partner selection. Most of empirical studies (e.g. Bayona, García-Marco & Huerta (2001); Miotti & Sachwald (2003)) show that the propensity to cooperate is directly proportional to the size of the firm. The size (*size*) of the firm is captured by the number of employees and included in the model as a continuous variable. With the purpose to analyze the impact of firm's age (*age*), we take account of the young companies established during the last five years. To analyze the impact of ownership type on patterns of cooperation, we include two dummy variables, one for state-owned enterprises (*state*) and one for foreign ownership (*foreign*). Two variables assessing the operating results as a rate of changes in the staffing level in the last three years (*growth*) and as a return on sales (*ROS*) index are included in the empirical model to examine the impact of firm's performance results on cooperation activity. The ratio of return on sales indicates how much profit a firm makes after paying for variable costs of production, but before interest and tax. ROS can take positive and negative values. Moreover, all industry dummies, characterizing various manufacturing sectors, were included in the econometric analysis.

The second group of factors is related to the competitive environment, also known as a market structure, in which the firm operates. Conditions in which your business competes are characterized by the number of competitors, which provide products or services similar to yours, distribution of competitive advantages between market players and the firm's market level strategies. We construct two dummy variables: when there is a monopolistic competition (less than 2 direct competitors) (*c_monopoly*) and when there is an oligopoly competition (from 2 to 5 competitors) (*c_oligopoly*). Other companies in the sample are purely competitive firms. To capture the influence of market development strategies, variables for four prospective markets are included: local (*m_local*), regional (*m_regional*), national (*m_national*) and foreign (*m_foreign*). We also include dummy variables for different types of competitors' competitive advantages: price advantage (*a_price*), quality edge (*a_quality*), higher novelty of products and services (*a_novelty*) and other strengths of competitors (*a_other*).

Technological opportunity characteristics are the third group of factors influencing firm's partner selection strategies. We include dummy variables to measure the firm's investment intensity in innovation. They are based on a question that asks companies to indicate the share of total innovation expenditures in the total turnover. We classify low intensity (*low_int*), when the quota of expenditures is less than 2.5%; medium intensity (*medium_int*) with the faction of turnover between 2.5% and 10% and the high intensity (*high_int*), when companies spend more than 10% of its total turnover on innovation activity. Moreover, we include a measure to indicate types of innovation, which in corporate management's opinion are strategically important for business development: a dummy indicating the permanent engagement in innovation activity (*regular_inn*) and two dummies for product innovation (*product_inn*) and for process innovation (*process_inn*).

Characteristics of the firm's absorptive capacity are the fourth defining category. To approximate the firm's ability to access and to implement a large amount of external knowledge, we include the number of employees with a specialized secondary education (*staff*_special) and with a university or doctor's degree (*staff*_high). In the questionnaire, firms rated the company's management team's attitude to attract external partners and to cooperate with them on different stages of innovation development and implementation on a 5-point scale from negative (1) to positive (5). Catching the variable (*own effort*) we consider if the majority of implemented innovations were developed predominately by firms' own.

To define the innovation culture of firms a dummy variable (*inn_culture*) was constructed. It takes a value one, when the company's top management welcomes the involvement of external partners and cooperation. Furthermore, we include a dummy variable (*co_stand_procedures*). It possesses a value one, when the company has developed standard procedures for interaction with external partners in innovation.

Another group of factors, determining the cooperation partner selection strategies, is dedicated to appropriability conditions. The survey data allows analysis of the capacity of enterprises to protect the rents from their innovation activity. Companies were asked to outline the most important methods of intellectual property protection that are used in the company. We distinguish between two types of protection: formal (e.g. registration and patenting) and informal (through secrecy, lead time or complexity) methods of IPR protection and include two dummy variables (*app_formal*) and (*app_informal*) in the empirical model on the right-hand side of the equations.

Finally, the involvement of government in innovation activity through various support mechanisms can also have an impact on patterns of cooperative innovation strategies. As strong linkages between cooperation partners are core paths for technology transfer and commercialization and as their development requires time and sustained public and private efforts, both disciplined internal support (at the firm level) and public support play a crucial role in successful cooperation. We construct three dummy variables, taking the value one if a firm received one of three groups of public support measures during the period from 2011 to 2014. There are horizontal measures (*PS_horizontal*), such as tax remissions and preferences; depreciation bonuses; subsidizing of interest rates on loans; networking measures (*PS_networking*), for instance, technology platforms and regional innovation clusters creation and targeted measures (*PS_targeted*), including contracts within federal target programs, state grants and targeted support for training innovation managers.

Depending on firm's internal and external characteristics, there seems to be different preferences as regard to cooperation partners. Furthermore, to explore the relation between explanatory variables and a concrete pattern of cooperative innovation strategies, we include each explanatory variable in all nine equations. Explanatory variables cover all groups of shaping factors and affect the probability that a company will enter into cooperation agreement, either with specific actor or with several partners simultaneously.

For the more detailed construction of the response and explanatory variables, see Table A3 in the Appendix 3. The means and standard deviations for the each group of determinants are presented in Table A4 in the Appendix 4.

3. Estimation methodology

The firm's decision is modeled using a system of dichotomous (binomial) choice models. Still firms have an opportunity to cooperate with various external partners for innovation, either with a specific actor or with several partners simultaneously. Modeling of such decision process is a formidable task that requires more sophisticated econometric approach.

The empirical model consists of nine simultaneous binary choice equations. Each equation represents a concrete type of innovation cooperation strategies: cooperation with customers (*y1*), raw materials suppliers (*y2*), related value-chain members (*y3*), providers of services (*y4*), competitors (*y5*), scientific organizations (*y6*), universities (*y7*), consulting firms (*y8*), public and local authorities (*y9*), respectively.

The balance between costs and benefits influences a company's decision to enter into a cooperation agreement with each of partner. Assuming that the differences between benefits and costs are linearly dependent on a set of explanatory characteristics, contained in x, we have:

$$y_{im}^{*} = \beta_m{}' x_{im} + \varepsilon_{im}$$

$$m = \overline{1,9} \quad i = \overline{1,n} \quad n = 1206$$

$\varepsilon_{i,m}$ are error terms distributed as multivariate normal, each with a mean of zero, and variance – covariance matrix Σ, where Σ has values 1 on the leading diagonal and correlations $\rho_{j,m} = \rho_{m,j}$ as off-diagonal elements.

Since the dependent variables are not directly observable and take only two values (cooperate and not cooperate), binary variables are defined to summarize the signs of cooperation.

$$y_{im} = \begin{cases} 1, \text{if } y_{im}^{*} > 0 \\ 0\text{, otherwise} \end{cases}$$

In this instance, from nine equations there are 81 joint probabilities corresponding to the 81 combinations of different patterns of cooperative behavior ($y_{im} = 1$) and non-cooperative ($y_{im} = 0$).

Moreover, strategies of cooperation for innovation are not independent and not contradictory. The reasons for this are, firstly, the existence of simultaneous cooperation agreements with different partners, and secondly, that there are heterogeneities in the factors influencing the firm's decision to engage in cooperation. There could be possible correlations between various innovation cooperation strategies due to complementarities (positive correlation) and substitutability (negative correlation) (Belderbos et al., 2004). Since there is a possible correlation between equations, the error terms in the model are likely to be correlated too. If there are no cross-equation correlations between the error terms, the estimation of a univariate model will lead to unbiased, effective and consistent results. If however error terms are correlated across the equations, estimation of coefficients obtained from the ordered probit models is expected to be consistent, but inefficient. Moreover, there is a strong likelihood that the assessed values of standard errors of the regression model coefficients will be calculated incorrectly what can eventually lead to the wrong conclusions.

There are two possibilities to test the interdependence between different innovation cooperation strategies. Firstly, if all non-diagonal cross-equation correlations (*rhos*) are not equal to zero, it means that the outcome variables and the error terms in all equations are correlated. Secondly, a null-hypothesis that the all the contemporaneous correlations across equations are equal to zero versus an alternative can be tested based on likelihood ratio test (LR test). The null-hypothesis is rejected, when the calculated LR test statistic is larger than a Chi-Square percentile with (*k-1*) degrees of freedom. The percentile corresponds to the confidence level.

As a result, two issues to consider in the estimation are (1) the possible interdependence of partner selection strategies and (2) possibility to engage in multiple cooperation agreements simultaneously. The analysis of the propensity to establish different models of cooperative innovation strategies in separate models will lead to the inefficient estimation results.

According to this background we employ a multivariate probit model to analyze the determinants of firm's decision to collaborate with a specific actor or with several partners simultaneously.

Consider the M-equation multivariate probit model:

$$y_{im} = \begin{cases} 1, \text{if } \beta_m{}' x_{im} + \varepsilon_{im} > 0 \\ 0\text{, otherwise} \end{cases}, m = 1, \ldots, M$$

The y_{im} might represent outcomes for M different choices coincidently and alternatively M outcomes on the same choice at M different points of time. Hence, the multivariate probit model may be used to analyze a univariate probit model for cross-sectional times-series (panel) data allowing for a free correlation structure over time (Cappellari, Jenkins, 2003).

From *M* equations there are *M***M* joint probabilities corresponding to the *M***M* possible combinations of success ($y_{im} = 1$) and failures ($y_{im} = 0$) (Cappellari, Jenkins, 2003; Wooldridge, 2002, pp. 500–504). These probabilities are the basis for the maximum likelihood estimation that depends on the M-variate standard normal distribution function (Greene, 2012, pp. 792–793). In the case of normal distribution the log-likelihood function is given by:

$$L(\beta) = \prod_i (F(\frac{X^{(i)}\beta}{\sigma}))^{y_i}(1 - F\left(\frac{X^{(i)}\beta}{\sigma}\right))^{1-y_i}$$

While model identification, estimated parameters are in units of σ, so the marginal effects of binary choice models are not equal to the coefficients of explanatory variables.

To evaluate the M-dimensional normal integrals in the likelihood function simulation methods are used. The most widely used probit simulator is called the Geweke-Hajivassiliou-Keane (GHK) smooth recursive conditioning simulator. By means of GHK simulator a multivariate normal distribution function are expressed as the product of sequentially conditioned univariate normal distribution functions (Greene, 2012, pp. 792–793), using Cholesky factorization (Cappellari, Jenkins, 2006). Critically, the GHK simulator operates on utility differences and the utility of a different alternative is subtracted depending on which probability is being simulated (Train, 2003, pp. 139–152). The GHK simulator is usefulness and the most accurate in the settings. In the context of a multivariate probit model, the simulated probabilities are in the interval from 0 to 1; are unbiased, asymptotically normal and efficient; also the simulator is a continuous and differentiable function of the model's parameters(Cappellari, Jenkins, 2003).

The simulated maximum likelihood (SML) estimator is asymptotically consistent as the number of draws and the number of observations that tend to infinity. Moreover, the maximum simulated likelihood estimator id asymptotically equivalent to the true maximum likelihood estimator as a ratio of the square root of the sample size ($\sqrt{n}$) to the number of draws (*R*) tend to zero. The number of draws (*R*), used by the GHK simulator, is a vital choice in the estimation. (Cappellari, Jenkins, 2003) recommend that, for as long as the number of draws (*R*) is greater than the square root of the sample size ($\sqrt{n}$) parameter estimates are robust to different initial seed values. We adopt this rule in our estimation and assume the number of draws equal to 28 ($\sqrt{805} \cong 28$). We check the robustness of the results by using different numbers of draws 5, as a default, and 100.

The empirical model was estimated using STATA 14 and the *mvprobit* package that is based on the method of SML discussed above. The *mvprobit* model estimates provide also measures of correlation between the errors of each of the equations involved: the off-diagonal elements (correlations) of the variance-covariance matrix $rho_{ji} = rho_{ij}$ and $rho_{ii} = 1$, where $i = 1 \dots M$. Significantly, there is a possibility to calculate conditional and unconditional expectations, and marginal effects on both expectations. The results of the *mvprobit* procedure present also the LR test statistic that is essential to examine whether there are cross-equation correlations between the error terms or not.

Using the estimated regression coefficients predicted probability of admission can be calculated. Nevertheless, ways in which we can interpret individual regression coefficients are limited. Estimated coefficients do not quantify the effect of explanatory variables on the probability that the response variables take on the value one. Only the sign of coefficients could be interpreted, for example positive sign means that an increase in the predictor leads to an increase in the predicted probability.

Findings

The overall measurement results of the multivariate probit model described in the previous section are summarized in Table 4. The estimated model examines the impact of 54 covariates on the firm's decision between nine innovation cooperation strategies and considers the possibility to collaborate with several partners at the same time.

Table 4

Multivariate probit regression of cooperation partners choice

	Customers	Suppliers of raw materials	Related value-chain members	Providers of services	Rival firms	Research org.	University	Consulting firms	Public & local authorities
General firm's characteristics									
Log_size	-0.0240	0.0213	0.00133	0.0300	-0.0115	**0.0946****	**0.116****	-0.000226	0.0441
	(0.0437)	(0.0413)	(0.0388)	(0.0389)	(0.0438)	(0.0463)	(0.0467)	(0.0570)	(0.0429)
Age_less 5	**-0.427****	-0.0996	0.00809	-0.0449	0.269	**-0.661****	**-1.005****	-0.219	-0.0287
	(0.218)	(0.222)	(0.212)	(0.216)	(0.227)	(0.326)	(0.398)	(0.367)	(0.248)
Foreign	**-0.354***	**-0.409****	-0.0149	-0.100	0.237	-0.358	-0.163	0.155	-0.120
	(0.197)	(0.195)	(0.196)	(0.197)	(0.214)	(0.233)	(0.238)	(0.250)	(0.213)
State	-0.201	**-0.298***	0.211	0.0498	-0.129	**0.574*****	0.245	0.315	**0.412*****
	(0.174)	(0.163)	(0.157)	(0.159)	(0.181)	(0.179)	(0.173)	(0.206)	(0.159)
Food and Beverages	0.0475	-0.329	**-1.021*****	-0.322	-0.186	0.321	0.406	0.646	0.176
	(0.250)	(0.251)	(0.259)	(0.243)	(0.270)	(0.364)	(0.380)	(0.404)	(0.288)
Textiles, clothing and shoes	0.171	0.0761	**-0.616****	-0.316	-0.167	0.269	0.314	0.192	0.141
	(0.279)	(0.277)	(0.266)	(0.261)	(0.289)	(0.393)	(0.397)	(0.441)	(0.306)
Wood and paper	0.256	-0.397	**-0.484***	-0.326	-0.339	0.425	0.256	0.376	0.208
	(0.292)	(0.281)	(0.285)	(0.283)	(0.326)	(0.407)	(0.415)	(0.463)	(0.320)
Printing and Publishing	0.492	-0.0384	**-0.606****	0.0932	-0.268	-0.594	0.276	0.405	0.497
	(0.303)	(0.279)	(0.278)	(0.269)	(0.315)	(0.508)	(0.417)	(0.453)	(0.306)

Petrochemistry, coal and nuclear fuel	-0.255	0.276	0.241	-0.144	-0.148	-0.0372	-0.0234	0.0232	0.126
	(0.362)	(0.390)	(0.362)	(0.363)	(0.421)	(0.470)	(0.509)	(0.594)	(0.417)
Rubber, plastics and nonmetallic goods	0.213	-0.0899	-0.348	-0.100	-0.170	0.497	0.0792	0.137	0.119
	(0.279)	(0.278)	(0.265)	(0.263)	(0.299)	(0.388)	(0.417)	(0.494)	(0.328)
Chemical production	0.339	0.0631	**-0.677****	0.0204	0.185	**0.925****	**0.712***	0.202	0.154
	(0.296)	(0.294)	(0.279)	(0.268)	(0.290)	(0.369)	(0.382)	(0.444)	(0.318)
Pharmaceuticals	0.0892	0.443	-0.123	-0.187	0.0267	**1.047*****	**1.386*****	0.657	0.283
	(0.306)	(0.329)	(0.293)	(0.293)	(0.320)	(0.387)	(0.397)	(0.447)	(0.329)
Metallurgy	**0.552***	0.0639	-0.236	0.177	0.0165	**0.762****	0.493	0.168	0.105
	(0.315)	(0.294)	(0.280)	(0.275)	(0.307)	(0.379)	(0.401)	(0.492)	(0.325)
Metallic products	0.351	0.0268	-0.120	-0.0304	-0.163	0.536	0.385	-0.00129	-0.174
	(0.287)	(0.276)	(0.259)	(0.258)	(0.291)	(0.370)	(0.385)	(0.470)	(0.325)
Machinery and Equipment	**0.479***	0.143	-0.248	-0.167	0.0919	**0.776****	**0.820****	0.259	0.0905
	(0.276)	(0.267)	(0.249)	(0.248)	(0.273)	(0.354)	(0.362)	(0.427)	(0.295)
Precision instruments and computers	**0.766****	0.133	0.344	0.269	0.101	**1.043*****	**1.270*****	0.349	-0.0321
	(0.355)	(0.310)	(0.293)	(0.289)	(0.321)	(0.385)	(0.390)	(0.461)	(0.329)
Railway transport and shipbuilding	0.163	-0.100	-0.452	-0.249	-0.211	0.0140	0.0432	0.106	-0.393
	(0.310)	(0.300)	(0.290)	(0.286)	(0.323)	(0.403)	(0.418)	(0.484)	(0.344)
Automobiles	**0.882****	-0.00104	-0.0568	-0.0733	-0.141	0.430	**0.775***	0.497	0.315
	(0.417)	(0.347)	(0.335)	(0.323)	(0.392)	(0.432)	(0.430)	(0.507)	(0.383)
Aircraft and space	0.490	0.171	0.368	0.350	**0.753***	**1.542*****	**1.280*****	**0.965***	0.298
	(0.410)	(0.406)	(0.373)	(0.361)	(0.400)	(0.486)	(0.458)	(0.514)	(0.400)
ROS2 (0-2%)	-0.195	0.0901	**0.739*****	0.141	0.377	-0.412	-0.461*	0.155	-0.212
	(0.260)	(0.231)	(0.237)	(0.223)	(0.262)	(0.264)	(0.260)	(0.338)	(0.231)
ROS3 (2-5%)	-0.200	-0.0684	**0.500****	0.128	0.341	-0.0306	-0.319	-0.103	-0.204
	(0.244)	(0.213)	(0.223)	(0.208)	(0.246)	(0.239)	(0.233)	(0.320)	(0.215)
ROS4 (5-10%)	-0.326	0.0211	**0.652*****	0.157	0.266	-0.103	-0.276	-0.102	-0.332
	(0.249)	(0.218)	(0.227)	(0.211)	(0.249)	(0.243)	(0.237)	(0.319)	(0.220)
ROS5 (> 10%)	**-0.511****	-0.0321	**0.445***	0.0643	0.155	0.0204	0.116	-0.0683	-0.225
	(0.257)	(0.229)	(0.238)	(0.225)	(0.267)	(0.256)	(0.248)	(0.333)	(0.232)
Growth_1 (>30%decrease)	-0.0958	0.0669	0.000796	0.217	0.332	0.448	-0.134	-0.726	0.176
	(0.348)	(0.306)	(0.290)	(0.302)	(0.328)	(0.353)	(0.366)	(0.608)	(0.319)
Growth_2 (10-30% decrease)	0.0463	0.312	-0.150	**0.440****	0.242	**0.595*****	-0.0406	-0.0543	-0.132
	(0.213)	(0.199)	(0.190)	(0.196)	(0.215)	(0.226)	(0.221)	(0.294)	(0.207)
Growth_3 (+/- 10%)	-0.0478	0.253	-0.204	**0.322****	0.137	0.0259	**-0.314***	0.0251	-0.237
	(0.166)	(0.155)	(0.152)	(0.160)	(0.176)	(0.187)	(0.176)	(0.235)	(0.163)
Growth_4 (10-30% increase)	0.0720	0.272	0.138	**0.355***	0.215	0.302	-0.313	-0.0273	-0.124
	(0.210)	(0.197)	(0.188)	(0.196)	(0.215)	(0.222)	(0.219)	(0.287)	(0.202)
Growth_5 (>30% increase)	-0.348	-0.449*	-0.188	0.390	0.365	**0.665****	**-0.649***	0.189	-0.360
	(0.289)	(0.268)	(0.284)	(0.281)	(0.291)	(0.306)	(0.343)	(0.375)	(0.313)
Competitive environment									
C_monopoly	-0.240	-0.163	-0.0220	**-0.243***	**-0.408****	0.0923	-0.165	-0.137	-0.131
	(0.151)	(0.144)	(0.142)	(0.143)	(0.171)	(0.164)	(0.168)	(0.218)	(0.156)
C_oligopoly	-0.0543	-0.0295	-0.00158	-0.0698	-0.110	0.0300	0.102	-0.0596	-0.148
	(0.127)	(0.120)	(0.114)	(0.113)	(0.126)	(0.131)	(0.131)	(0.169)	(0.124)
M_local	-0.0344	0.0348	0.0587	0.229	-0.0564	0.112	-0.178	**0.500****	-0.0107
	(0.153)	(0.148)	(0.145)	(0.141)	(0.164)	(0.183)	(0.184)	(0.227)	(0.158)
M_regional	0.0737	0.0700	**0.252****	0.0574	0.0901	-0.00966	**-0.254***	0.0932	-0.00497
	(0.129)	(0.124)	(0.121)	(0.120)	(0.136)	(0.146)	(0.152)	(0.176)	(0.134)
M_national	-0.00594	-0.00146	0.00427	0.0833	0.156	0.199	0.255	**0.524****	0.202
	(0.158)	(0.150)	(0.143)	(0.141)	(0.162)	(0.176)	(0.176)	(0.233)	(0.157)
M_foreign	0.0816	-0.00353	-0.0657	-0.105	-0.0129	0.184	-0.158	**0.383****	0.00433
	(0.163)	(0.153)	(0.144)	(0.145)	(0.160)	(0.159)	(0.158)	(0.192)	(0.154)

A_price	-0.113	0.129	-0.0637	-0.00941	0.132	0.0878	0.0954	0.101	-0.0741
	(0.125)	(0.121)	(0.114)	(0.113)	(0.123)	(0.134)	(0.135)	(0.166)	(0.126)
A_quality	0.171	**0.401****	0.144	0.183	**0.408****	-0.220	0.0387	**0.775*****	-0.149
	(0.206)	(0.203)	(0.179)	(0.175)	(0.185)	(0.215)	(0.212)	(0.221)	(0.195)
A_novelty	0.00171	0.0526	0.161	0.137	-0.0844	0.177	-0.224	0.116	0.0345
	(0.141)	(0.134)	(0.127)	(0.124)	(0.140)	(0.147)	(0.158)	(0.182)	(0.138)
A_other	-0.0915	0.00777	**0.251****	-0.0110	0.157	-0.0116	0.114	0.150	0.0149
	(0.129)	(0.124)	(0.119)	(0.117)	(0.129)	(0.142)	(0.140)	(0.167)	(0.130)
Technological opportunity									
Low_int	0.0712	-0.000719	0.112	-0.0541	0.200	0.0348	0.0859	-0.0471	-0.0700
	(0.145)	(0.137)	(0.137)	(0.135)	(0.153)	(0.163)	(0.168)	(0.208)	(0.149)
Medium_int	0.219	0.215	0.157	-0.109	0.0175	0.0234	**0.281***	0.0972	-0.102
	(0.146)	(0.140)	(0.135)	(0.134)	(0.154)	(0.159)	(0.161)	(0.193)	(0.148)
High_int	0.162	0.0815	-0.0584	-0.173	-0.0785	0.105	-0.0176	-0.234	-0.264
	(0.185)	(0.176)	(0.171)	(0.169)	(0.193)	(0.200)	(0.209)	(0.253)	(0.189)
Regular_inn	0.0705	0.146	**0.238***	0.0848	0.239	0.130	-0.238	0.104	0.110
	(0.129)	(0.124)	(0.124)	(0.123)	(0.146)	(0.153)	(0.149)	(0.191)	(0.140)
Product_inn	0.102	-0.0437	**-0.414****	0.187	0.412	-0.253	-0.0441	-0.455	-0.145
	(0.203)	(0.201)	(0.204)	(0.210)	(0.272)	(0.249)	(0.245)	(0.284)	(0.224)
Process_inn	-0.203	**1.081****	-0.238	**-0.909***	0.0257	-0.217	-0.394	4.018	0.548
	(0.477)	(0.470)	(0.494)	(0.482)	(0.655)	(0.534)	(0.525)	(106.5)	(0.660)
Absorptive capacity									
Own_effort	0.00712	0.00431	-0.141	-0.151	-0.161	**-0.748*****	**-0.381*****	**-0.297****	-0.0173
	(0.112)	(0.108)	(0.103)	(0.103)	(0.115)	(0.116)	(0.118)	(0.141)	(0.111)
Staff_special	**0.00369***	-0.000986	0.00212	0.00297	0.00153	-0.00130	-0.00110	-0.00219	-2.69e-06
	(0.00222)	(0.00214)	(0.00208)	(0.00208)	(0.00242)	(0.00249)	(0.00247)	(0.00322)	(0.00229)
Staff_high	-0.00104	**-0.00414***	0.00108	-0.00216	0.00247	0.00350	0.00138	0.00156	0.00198
	(0.00239)	(0.00233)	(0.00228)	(0.00233)	(0.00266)	(0.00269)	(0.00265)	(0.00328)	(0.00250)
Inn_culture	**0.226***	-0.0802	0.0618	0.0532	**0.231***	**0.268***	**0.488*****	**0.566*****	0.0886
	(0.124)	(0.121)	(0.117)	(0.116)	(0.132)	(0.144)	(0.145)	(0.190)	(0.130)
Co_stand_ procedures	0.149	0.134	0.0985	-0.0141	0.0388	**0.274***	-0.182	-0.0166	**0.259****
	(0.124)	(0.120)	(0.115)	(0.114)	(0.129)	(0.143)	(0.142)	(0.175)	(0.130)
Appropriability conditions									
App_formal	-0.174	0.148	0.116	0.0768	0.0373	**0.351****	0.0130	**0.371****	0.0223
	(0.123)	(0.115)	(0.113)	(0.112)	(0.128)	(0.136)	(0.138)	(0.185)	(0.125)
App_informal	**0.331*****	0.103	**0.287*****	**0.349*****	0.0335	**0.273****	**0.430*****	0.246	0.180
	(0.117)	(0.112)	(0.109)	(0.107)	(0.120)	(0.131)	(0.133)	(0.168)	(0.119)
Public Support									
PS_horizontal	-0.193	0.0194	-0.0613	0.0975	-0.0484	0.102	0.0192	**0.358****	0.143
	(0.136)	(0.132)	(0.127)	(0.125)	(0.140)	(0.142)	(0.145)	(0.163)	(0.131)
PS_networking	**0.669*****	0.0683	0.220	0.0243	0.0887	**0.389***	**0.412****	0.116	**0.443****
	(0.231)	(0.191)	(0.179)	(0.179)	(0.198)	(0.211)	(0.203)	(0.237)	(0.181)
PS_targeted	0.0548	-0.0623	0.0673	0.142	-0.0940	-0.0938	0.0754	**-0.412****	**0.444*****
	(0.139)	(0.131)	(0.125)	(0.124)	(0.141)	(0.143)	(0.142)	(0.186)	(0.130)
Constant	0.573	-0.832	-0.709	-0.594	**-2.246*****	**-2.260*****	**-1.476****	-6.753	**-1.858****
	(0.605)	(0.587)	(0.612)	(0.592)	(0.796)	(0.686)	(0.664)	(106.5)	(0.752)
	Rho1	Rho2	Rho3	Rho4	Rho5	Rho6	Rho7	Rho8	
Rho /2	**0,256*****								
	(-0,0684)								
Rho /3	**0,173****	**0,387*****							
	(-0,0688)	(-0,0701)							
Rho /4	**0,230*****	**0,583*****	**0,469*****						
	(-0,0717)	(-0,0783)	(-0,0665)						

Rho /5	**0,581*** **	**0,471*** **	**0,348*** **	**0,574*** **					
	(-0,1100)	(-0,0884)	(-0,0726)	(-0,0768)					
Rho /6	0,0227	0,0889	**0,183** **	**0,209*** **	**0,142***				
	(-0,0821)	(-0,0787)	(-0,0723)	(-0,0735)	(-0,0821)				
Rho /7	**0,308*** **	**0,138***	**0,166** **	**0,242*** **	**0,269*** **	**0,77*** **			
	(-0,0897)	(-0,0812)	(-0,0727)	(-0,0730)	(-0,0808)	(-0,0945)			
Rho /8	-0,0782	**0,195***	**0,238** **	**0,510*** **	**0,304*** **	**0,390*** **	**0,435*** **		
	(-0,0973)	(-0,103)	(-0,0942)	(-0,102)	(-0,101)	(-0,107)	(-0,1000)		
Rho /9	0,132	**0,133***	0,0896	**0,220*** **	**0,329*** **	**0,506*** **	**0,623*** **	**0,586*** **	
	(-0,0824)	(-0,075)	(-0,0689)	(-0,0679)	(-0,0771)	(-0,0868)	(-0,0905)	(-0,1090)	
* significant at 10%; ** significant at 5%; *** significant at 1% Standard errors in parentheses									
Number of observations = 805 Wald chi2 (486) = 729.36									
Likelihood ratio test of rho21 = rho31= rho41= rho51= rho61= rho71= rho81= rho91= rho32= rho42= rho52= rho62= rho72= rho82= rho92= rho43= rho53= rho63= rho73= rho83= rho93= rho54= rho64= rho74= rho84= rho94= rho65= rho75= rho85= rho95= rho76= rho86= rho96= rho87= rho97= rho98 = 0: chi2(36) = 552.67 Prob > chi2 = 0.0000									

Firstly based on the multivariate probit model estimates can be concluded that the error terms are correlated across most of all equations. As can be seen from the Table 4, there is a statistical significance of most correlation coefficients (ρ) between the perturbation terms. If correlation coefficients are statistically significantly different from zero, it suggests that equations are best modeled together. It confirms the need for multi-equation estimation. Moreover, this finding is consistent with other scientific studies.

Statistically significant correlation coefficients have positive signs, ranging from 0.133 to 0.623. It corroborates that companies most likely view various cooperation strategies as complementary rather than alternatives. These finding are consistent with other scientific studies, for example Belderbos et al. (2004) and Baddilo & Moreno (2012) for the case of the Netherlands and Spain respectively. Nevertheless, another reason for this is an unobserved firm heterogeneity.

The null hypothesis, that there are no cross-equation correlations between the error terms, is rejected also based on the Likelihood-ratio test. The p-value is equal to zero ($p = 0.000$) and the absolute value of the LR test statistic is 552.67 (36 degrees of freedom) is greater than the critical value. Consequently, we can reject the null hypothesis at the 1% level of significance. This result supports that there is interdependence in innovation cooperation strategies and makes a case of the joint estimation through multivariate probit model.

The explanatory variables introduced into the estimated model have different effects according to the innovation cooperation strategies. It confirms the heterogeneity between the different pattern of cooperative innovation strategies in Russian manufacturing, and hence the need to analyze them separately.

The results of the econometric analysis show that *general firm's characteristics* have substantial influence on the likelihood of innovation cooperation with all types of external partners. Thus foreign and state-owned enterprises less often cooperate within the supply chain (with customers and suppliers), while state ownership stimulates innovation cooperation with research organizations and public authorities. Other important determinants are size and firm's age. Small and Young companies rarely engage in innovation cooperation with knowledge production sector and clients. Moreover, the results suggest that Rate of business growth and Profitability of sales affect the probability of cooperation differently. Declining and low growth rates stimulate innovation cooperation with providers of services and research organizations, while stable high business growth has a negative impact on the likelihood to enter into cooperation with suppliers of raw materials and universities. The decision of innovation cooperation with related value-chain members is significantly positive reliant on the Return on Sales (ROS) ratio. A company operates efficiently and can reduce costs or mitigate risks by signing a contract with subcontractors to perform part or all of their obligations.

The second group of factors "*level of competition*" consists of variables such as market structure, firm's market level strategies and different types of competitors' competitive advantages. The findings highlight that generally competition is a source of innovation cooperation with market actors. Imperfectly competitive markets, characterizing by the existence of less than two sellers and many buyers, interfere cooperation both with rivals (because there are practically no competitors) and providers of services. A market development strategy has a significant positive effect on cooperation with consulting firms, while there is no statistically significant effect of market level strategies on other types of innovation cooperation. Another subject of interest was how the superiority of competitors in price, quality and other things may affect firm's cooperative behavior. The obtained results show that competitive advantages of competitors are inconsiderable in firm's decision-making process about cooperation partners. Only the lack of competitive advantage in quality of products stimulates firms to cooperate with their competitors and consulting firms.

As for the factors characterizing firm's *technological opportunities*, almost 70% of manufacturing firms in Russia implement innovation on a regular basis. This notwithstanding, regular innovation does not determine firms' innovation cooperation strategies, excepting the cooperation with related value-chain members. An implementation of a new or significantly upgraded production or delivery method (process innovation) has a positive impact on cooperation with raw materials and components suppliers and a significant negative impact on cooperation with providers of services, while there is no significant effect of innovation type on the science-industry cooperation. The analysis indicates that the effect of the firm's investment intensity in its innovation activity does not affect the choice of innovation cooperation partner.

However, cooperation with universities requires high financial expenses especially that the share of total expenditure on innovation activities in the total turnover is 2.5%-10%.

The forth group of determinants of innovation cooperation strategies is "*absorptive capacity*". The results confirm that the degree of firms' involvement in the process of innovation development and implementation has a substantial influence on the cooperation partner selection procedure. Negative statistical coefficients show that while cooperation with knowledge production sector and consultants, firms validate their efforts. Regarding the staff quality, generally no significant effects are found for the whole sample. At the same time, company's internal innovation culture is one of the most important drivers for cooperation. If corporate culture embraces cooperation in innovation, firms enter into cooperation with customers, universities and research organizations and consulting firms more likely. The existence of standard procedures for collaboration also has a strong positive effect on innovation cooperation with public authorities and research organizations, because these cooperation agreements are characterized by high level of control, responsibility and long cooperation period.

The finding also highlights a strong positive impact of *appropriability conditions* on firms' cooperative behavior. Companies protecting intellectual property in a research partnership by means of both formal and informal mechanisms enter into cooperation with various external partners more likely. The econometric results suggest that influence of informal protection methods is statistically significant in most cooperation strategies such as cooperation with knowledge production sector, customers, providers of services and related.

Moreover, the results suggest that *public financial support* from local and national administrations is an essential factor of cooperation. The analysis revealed that science industry linkages and cooperation with public authorities and clients can be enhanced by means of networking measures, such as technology platforms, regional innovation clusters. Innovation cooperation with market actors is statistically independent of public support measures.

In line with the initial assumptions, the obtained results show that innovation cooperation strategies are interdependent but the effects the covariates is multifold, varying within the partner types.

Conclusion

This paper focuses on the variety of cooperative innovation strategies in the Russian manufacturing. We explore nine possible patters of collaboration for innovation: horizontal (competitors), vertical (customers, raw materials suppliers, providers of services), institutional (universities and research organizations), cooperation with the related value-chain members, consulting firms and public entities. We have also considered a possibility of multi-partner cooperation and an eventual simultaneous relationship between cooperation strategies.

This article provides evidence for the ongoing discussions on the factors influencing company's decision-making process to enter into a strategic innovation cooperation agreement with a specific external partner with a particular emphasis on heterogeneities of determinants' impact across different cooperation strategies. Factors influencing the firms' choice are divided into six categories (general firm's characteristics, competitive environment, technological opportunities, absorptive capacity, appropriability conditions and public supports) pursuant to the review of theoretical work and previous empirical studies.

The descriptive statistics for the weighted sample show that almost all innovative firms in Russian manufacturing are engaged in innovation cooperation, while 80% of them prefer to cooperate with several partners simultaneously. It suggests that Russian manufacturing companies tend to create an extensive partner networks. Despite this fact, less than a third of innovations are implemented in cooperation with external organizations, showing that development and implementation of innovations is not a primary goal for cooperative firms.

Most of previous studies investigated firms' innovation cooperation strategies and their determinants using univariate estimation. However, it does not consider that firms take simultaneously the decisions to cooperate with various partners and choices of the type of cooperation partner are interdependent. The econometric modelling of various innovation cooperation strategies and factors determining them has confirmed the incorrectness of studying different cooperative strategies separately, because they are interdependent (significantly different from zero correlation coefficients). It indicates that various cooperation decisions tend to be viewed by the firms as complementary rather than substitutes and suggests that equations are best modeled together and confirms the need for multi-equation estimation.

The obtained results are broadly consistent with other studies and confirm that the level of absorptive capacity and appropriability conditions have statistically significant and positive effect on the likelihood of Russian manufacturing firms engagement in cooperation agreements with various external partners. The results confirm that corporate governance's attitude for cooperation and availability of standard procedures for cooperation have string positive impact on cooperation with knowledge production sector, consulting firms and public authorities. Moreover, while cooperating with these partners, companies highly appreciate their efforts in innovation process. The use of informal methods of intellectual property protection stimulates innovation cooperation both with the knowledge production sector and within the supply chain.

The estimates indicate effects of size and age on the cooperation patterns. Smaller and younger companies rarely engage in innovation cooperation with knowledge production sector.

The healthy competitive regime seems to provide favorable conditions for innovation cooperation. As for the factors characterizing firm's technological opportunities and innovativeness, the econometric analysis revealed that basically technological opportunities don't have significant impact on firms' cooperative strategies. The last but not the least category is public financial support from local and national administrations. The analysis revealed that networking measures are promoting factors for innovation cooperation with universities, research organizations and also public authorities.

The revealed heterogeneity of the impact of endogenous and exogenous conditions for the cooperation with different actors challenges the wide-spread simplified perception of 'openness' as a one-dimensional characteristic of the innovation strategy. This should be taken in mind as a framing consideration in the theoretical modelling of the innovation processes as well as the practical policy development aimed at intensified networking.

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Appendix 1

Table A1

Review of empirical studies on R&D and innovation cooperation

Authors, Year of publication	Title	Country, Survey Years	Dependent Variables	Independent Variables	Methodology	Key Findings
Faria and Schmidt, 2007	International cooperation on innovation: empirical evidence for German and Portuguese firms	Germany and Portugal, 1998-2000	Cooperation types: Domestic partner Foreign partner	Export status, part of a group, absorptive capacity (in-house R&D activities, the skill level of firms' employees), innovation intensity, incoming and outgoing knowledge spillovers, size, industry, public funding	Bivariate probit model	Statistically significant variables: 1. Domestic partner: size (+), industry (+), part of a group (+), absorptive capacity (+), public funding (+), outgoing spillovers (+) 2. Foreign partner: size (+), export status (+), part of a group (+), absorptive capacity (+), public funding (+), outgoing spillovers (+)
Veugelers and Cassiman, 2005	R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing	Belgium, 1993	Cooperation with universities	Size, ownership, constraints (risk and cost), own R&D capacity, public funding, vertical cooperation, appropriability conditions (strategic and legal), incoming spillovers, export intensity, cooperation with universities at industry level	Instrumental probit model	Statistically significant variables: 1. Cooperation with universities: const (-), size (+), foreign (-), cost (-), risk (+), cooperation with universities at industry level (+), public funding (+), vertical cooperation (+) 2. Cooperation with universities (correction for endogeneity for the complementary strategies): const (-), risk (-), cooperation with universities at industry level (+), public funding (+)
Kaiser, 2002	An empirical test of models explaining research expenditures and research cooperation: evidence for the German service sector	Germany, 1995	Binary choice between cooperation and non-cooperation	Horizontal and vertical spillovers, research productivity, the generality of the research approach, market demand	Nested multinomial logit (NMNL) and Multinomial logit model (MNL)	Statistically significant variables: 1. Mixed cooperation: R&D generality-approach (>3) (+), strong decrease in sales (+), increase in sales (+), eastern German firms (+) 2. No cooperation: size (-), transport sector (-), R&D generality-approach (>3) (-), R&D productivity science (-), horizontal spillovers (-)

Table A1 continued

Miotti and Sachwald, 2003	Co-operative R&D: why and with whom? An integrated framework of analysis	France, -	Cooperation types: horizontal, vertical, institutional	Size, part of a group, industry, public funding, market share, permanent R&D, constraints (risk and cost), lack of information (market and technological)	Logit regression model	Statistically significant variables: 1. Vertical cooperation: const (-), size (+), part of a group (-), lack of market information (+) 2. Cooperation with public institutions: const (-), size (+), public funding (+), permanent R&D (-), science (+), cost (-) 3. Horizontal cooperation: const (-), size (+), public funding (+), high-tech industry (+), cost (+)
Dachs, Ebersberger and Pyka, 2008	Why do firms cooperate for innovation? A comparison of Austrian and Finnish CIS3 results	Finland and Austria, 1995	1) Innovation activity; Product innovation, Process innovation 2) Cooperative behavior: any partner, suppliers, customers, competitors, universities and research institutions	Size, part of a group, industry, export status, innovation expenditure, diversification of the innovative efforts, hampering factors (internal and economic), internal knowledge flow, basicness of R&D, appropriability conditions (strategic and formal), public funding, incoming spillovers, innovation type, speed of technological development, labor productivity	Multivariate logit model	Statistically significant variables (ex. Finland): 1. Collaboration with suppliers: const (-), public funding (+), diversification of the innovative efforts (+), process and product innovation (+), internal knowledge flow (+), appropriability conditions (strategic and formal) (+), incoming horizontal and vertical spillovers (+) 2. Collaboration with customers: const (-), public funding (+), appropriability conditions in industry (-), process and product innovation (+), diversification of the innovative efforts (+), appropriability conditions (strategic and formal) (+), incoming horizontal and vertical spillovers (+) 3. Collaboration with competitors: const (-), public funding (+), labor productivity (+), process innovation (+), innovation expenditure (+), horizontal incoming spillovers (+) 4. Collaboration with universities and research organizations: const (-), public funding (+), labor productivity (+), continuous of R&D (+), product innovation (+), diversification of the innovative efforts (+), internal knowledge flow (+), appropriability conditions (+), incoming horizontal (-) and vertical (+) spillovers, basicness of R&D (+)

Table A1 continued

Badillo and Moreno, 2012	What Drives the Choice of Partners in R&D Cooperation? Heterogeneity across Sectors	Spain, 2006-2008	Cooperation types: horizontal, vertical, institutional Group cooperation	Size, part of a group, sector, public support, R&D intensity, appropriability conditions (legal), incoming spillovers, constraints (risk and cost), lack of qualified personnel, export intensity	Multivariate probit model	Statistically significant variables: 1. Vertical cooperation: const (-), incoming spillovers (+), legal protection (+), R&D intensity (+), subsidies (+), part of a group (+), size (+) 2. Cooperation with public institutions: const (-), incoming spillovers (+), R&D intensity (+), risk (-), subsidies (+), part of a group (+), large size (+), industrial sector (-) 3. Horizontal cooperation: const (-), incoming spillovers (+), R&D intensity (+), subsidies (+), part of a group (+), size (+), industrial sector (-) 4. Group cooperation: const (-), incoming spillovers (+), legal protection (+), risk (-), public finding - subsidies (+), size (+), industrial sector (-), part of a group (+)
Franco and Gussoni, 2010	Firms' R&D cooperation strategies: the partner choice	Italy, 2002-2004	Cooperation types: market, science, mixed	Incoming spillovers, appropriability, size, sector, export status, costs of innovation, subsidies - public funding, participation in a multinational group, permanent R&D	Multinomial logit model	Statistically significant variables: 1. Market vs Mixed cooperation: const (+), size (-), subsidies (-), incoming spillovers (-), appropriability conditions (-), permanent R&D (-), export status (+), manufacturing industry (+) 2. Science vs Mixed cooperation: const (-), incoming spillovers (-), export status (+), manufacturing industry (+) 3. Market vs Science cooperation: const (+), size (-), subsidies (-), appropriability conditions (-), permanent R&D (-)

Table A1 continued

Belderbos, Carree, Diederen, Lokshin and Veugelers, 2004	Heterogeneity in R&D Cooperation Strategies	Netherlands1996 and 1998	Cooperation types: horizontal, vertical, institutional	Incoming spillovers (vertical, horizontal, institutional), industry outgoing spillovers, R&D intensity, size, industry, ownership, part of a group, constraints (organizational capability, risk, cost), speed of technological change, internal knowledge flows, R&D subsidy	Multivariate probit model	Statistically significant variables: 1. Vertical cooperation: const (-), horizontal (-), vertical (+), institutional (+), incoming spillovers, R&D intensity (+), R&D intensity squered (-), size (+), organizational capability constraint (+), risk constraint (+), service (+), part of a group (+), R&D subsidy (+) 2. Cooperation with public institutions: const (-), institutional incoming spillovers (+), R&D intensity (+), size (+), organizational capability constraint (+), speed of technological change (+), R&D subsidy (+) 3. Horizontal cooperation: const (-), institutional incoming spillovers (+), size (+), industry average firm size (+), risk constraint (+), speed of technological change (+), service (+), foreign multinational (-)
Arranz and Fdez. de Arroyabe, 2008	The choice of partners in R&D cooperation: An empirical analysis of Spanish firms	Spain, 1997	Cooperation types: horizontal, vertical, institutional	Size, part of a group, industry, permanent R&D, incoming spillovers (science), external R&D, obstacles (risk and cost), lack of market information and technological information, public funding	Logit regression model	Statistically significant variables: 1. Vertical cooperation: const (+), size (+), part of a group (+), high-tech, medium-high-tech industry (+), public funding (+), lack of market and technology (+) 2. Cooperation with public institutions: const (+), part of a group (+), high-tech, medium-tech industry (+), external R&D (+), public funding (+) 3. Horizontal cooperation: const (+), size (+), permanent R&D (+), high-tech industry (+), cost (+), risk (+), public funding (+)

Table A1 continued

Tether, 2002	Who co-operates for innovation, and why. An empirical analysis	United Kingdom, 1997	Cooperation types: customers, suppliers, competitors, universities, consultants, other	Size, ownership, part of a group, sector, R&D intensity, type of innovation, obstacles (risk, cost, internal, regulations), lack of information on market and technology, lack of qualified personnel	Logistic regression	Statistically significant variables: 1. Cooperation with suppliers: const (-), size (+), utilities (+), low-tech-services (-), R&D at least on an occasional basis (+), continuous and high intensity R&D (+), lack of customers responsiveness to innovation (+), lack of technology (-), obstacles risk and finance (+) 2. Cooperation with customers: const (-), foreign (+), high-tech manufacturing and services (+), R&D at least on an occasional basis (+), continuous R&D (+),'new to the market' innovations (+), lack of customers responsiveness to innovation (+), lack of information on markets (+) 3. Cooperation with competitors: const (-), size (+), utilities (+), high and low-tech services (+), R&D at least on an occasional basis (+), continuous R&D (+), 'new to the market' innovations (+), lack of customers responsiveness to innovation (+) 4. Cooperation with universities: const (-), size (+), part of a group (+), utilities (+), high-tech manufacturing (+), low-teck services (-), R&D at least on an occasional basis (+), continuous R&D and high intensity (+) 5. Cooperation with consultants: const (-), size (+), foreign (+), utilities (+), high and low-tech services (+), R&D at least on an occasional basis (+), continuous R&D (+), obstacles risk and finance (+) 6. Other cooperation types: const (-), new firm (+), size (+), utilities (+), medium-tech manufacturing (+), high-tech services (+), obstacles risk and finance (+)

Appendix 2

Table A2

Sample characteristics

Manufacturing sector	All enterprises	Innovation-active	Has at least one cooperation partner
Food and Beverages	115	83	81
Textiles, clothing and shoes	102	58	58
Wood and paper	82	50	47
Printing and Publishing	76	47	46
Petrochemistry, coal and nuclear fuel	45	21	20
Rubber, plastics and nonmetallic goods	88	55	53
Chemical production	82	54	53
Pharmaceuticals	58	41	40
Metallurgy	73	51	50
Metallic products	95	60	60
Machinery and Equipment	117	94	93
Precision instruments and computers	60	44	44
Railway transport and shipbuilding	61	43	43
Automobiles	35	27	27
Aircraft and space	27	23	22
Other manufacturing	90	54	53
Total	**1206**	**805**	**790**

Appendix 3

Table A3

Construction of the variables

Response variables			
	Variable	**Type**	**Construction**
Patterns of cooperation	y1	Dummy	One, if a firm cooperates with customers
	y2	Dummy	One, if a firm cooperates with raw materials suppliers
	y3	Dummy	One, if a firm cooperates with sub-contracting enterprises
	y4	Dummy	One, if a firm cooperates with providers of services
	y5	Dummy	One, if a firm cooperates with competitors
	y6	Dummy	One, if a firm cooperates with research organizations
	y7	Dummy	One, if a firm cooperates with universities
	y8	Dummy	One, if a firm cooperates with consulting firms
	y9	Dummy	One, if a firm cooperates with public and local authorities
Explanatory variables			
	Variable	**Type**	**Construction**
General Firm's Characteristics	Size	Continuous	Average number of employees in 2013 (at least 10)
	Age_less 5	Dummy	One, if a firm was established after 2010
	Ownership		
	Foreign	Dummy	One, if a firm has foreign ownership
	State	Dummy	One, if a firm has state ownership
	Rate of business growth		
	> 30% decrease	Dummy	One, if an average annual rate of changes in staffing level in the last 3 years is more than 30% decrease
	10-30% decrease	Dummy	One, if an average annual rate of changes in staffing level in the last 3 years is 10-30% decrease
	minor variation (+/- 10%)	Dummy	One, if an average annual rate of changes in staffing level in the last 3 years is in interval +/- 10%
	10-30% increase	Dummy	One, if an average annual rate of changes in staffing level in the last 3 years is 10-30% increase
	> 30% increase	Dummy	One, if an average annual rate of changes in staffing level in the last 3 years is more than 30% increase
	Profitability of sales		
	0-2%	Dummy	One, if the return on sales in 2013 (before income taxes) is 0-2%
	2-5%	Dummy	One, if the return on sales in 2013 (before income taxes) is 2-5%

Table A3 continued

	5-10%	Dummy	One, if the return on sales in 2013 (before income taxes) is 5-10%
	>10%	Dummy	One, if the return on sales in 2013 (before income taxes) is more than 10%
Competitive Environment	Market structure		
	Monopoly	Dummy	One, if a firm has no direct competitors or has less than 2
	Oligopoly	Dummy	One, if a firm has 2-5 principal competitors
	Prospective market		
	Local	Dummy	One, if the prospective end market is local
	Regional	Dummy	One, if the prospective end market is regional
	National	Dummy	One, if the prospective end market is national
	Foreign	Dummy	One, if the prospective end market is foreign
	Competitors' advantages		
	Price	Dummy	One, if competitors have distinct price advantages
	Quality	Dummy	One, if competitors have distinct quality advantages
	Novelty	Dummy	One, if competitors have distinct novelty advantages
	Other	Dummy	One, if competitors have other advantages
Technological Opportunities	Investment intensity in innovation		
	High	Dummy	One, if the share of total expenditure on innovation activities in the total turnover in 2013 is less than 2.5%
	Medium	Dummy	One, if the share of total expenditure on innovation activities in the total turnover in 2013 is from 2.5 to 10%
	Low	Dummy	One, if the share of total expenditure on innovation activities in the total turnover in 2013 is more than 10%
	Importance of innovation types for business success		
	Regular innovation	Dummy	One, if regular innovation are important for firm's business success
	Product innovation	Dummy	One, if product innovation are important for firm's business success
	Process innovation	Dummy	One, if process innovation are important for firm's business success
Absorptive Capacity	Staff qualification		
	Specialized secondary education	Share	Number of employees with a specialized secondary education in the total staff number
	Tertiary education and higher	Share	Number of employees with a university or doctor's degree in the total staff number

Table A3 continued

	Positive corporate governance's attitude for cooperation	Dummy	One, if the company management welcomes the involvement of external partners and cooperation in various stages of development and implementation of innovations
	Availability of standard procedures for cooperation	Dummy	One, if the firm has standard procedures for innovation cooperation
	Own effort	Dmmy	One, if the majority of implemented innovations were developed predominately by firms' own.
Appropriability Conditions	The firm uses formal methods of IPP	Dummy	One, if the firm uses formal methods of intellectual property protection
	The firm uses informal methods of IPP	Dummy	One, if the firm uses informal methods of intellectual property protection
Public Support	Indirect	Dummy	One, if the firm received indirect public support between 2011-2012
	Direct	Dummy	One, if the firm received direct public support between 2011-2012

Appendix 4

Table A4

Descriptive statistics for dependent variables

	Total sample	
	Russia N[a]=805	
	Mean	**SD**
General firm's characteristics		
Log_Size	5,4383	1,4881
Age_less5	0,0547	0,2274
Ownership		
Foreign	0,0696	0,2546
State	0,1304	0,3369
Rate of business growth (Number of employees)		
> 30% decrease	0,0335	0,1801
10-30% decrease	0,1329	0,3397
Minor variation (+/- 10%)	0,5081	0,5002
10-30% increase	0,1528	0,3600
> 30% increase	0,0398	0,1955
Profitability of sales		
0-2%	0,1652	0,37161
2-5%	0,3019	0,45935
5-10%	0,2708	0,44465
>10%	0,1925	0,39455
Level of competition		
Market structure		
Monopoly	0,1963	0,3974
Oligopoly	0,3081	0,4619
Prospective market		
Local	0,28	0,448
Regional	0,40	0,490
National	0,63	0,482
Foreign	0,19	0,394
Competitors' advantages		
Price	0,29	0,452
Quality	0,09	0,284
Novelty	0,19	0,394
Other	0,2447	0,4302
Technological Opportunities		
Investment intensity in innovation		
Low	0,3081	0,4619
Medium	0,3193	0,4665
High	0,1354	0,3424
Importance of innovation types for business success		
Regular	0,7466	0,4352
Product	0,9217	0,2687
Process	0,9876	0,1108
Absorptive capacity		
Staff qualification		
Specialized secondary education	40,622	24,765

	33,520	23,588

Table A4 continued

Tertiary education and higher		
Positive corporate governance's attitude for cooperation	0,6870	0,4640
Availability of standard procedures for cooperation	0,6547	0,4758
Own effort	0,6373	0,4811
Appropriability conditions		
The firm uses formal methods of IPP	0,6112	0,4878
The firm uses informal methods of IPP	0,5988	0,4904
Public support		
Horizontal measures	0,2435	0,4294
Networking measures	0,0944	0,2926
Vertical measures	0,2708	0,4446

[a] N: number of innovation active firms operating in the manufacturing sector

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