Partnering for productivity: The impact of cooperation on firm performance

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Abstract

This paper investigates the impact of cooperation with different types of collaboration partners on firm performance and productivity in Hungary, an emerging innovator country. The study focuses on how cooperation facilitates the innovation process and provides access to complementary resources. Using a difference-in-differences approach on panel data from the Hungarian Community Innovation Survey (CIS) linked to firm balance sheet data, I present an empirical analysis of the topic. I find that scientific collaboration partners can increase a firm's TFP growth by 6%-8% after 4 years. In terms of firm performance, both vertical and horizontal partners are important. Collaboration with competitors can increase a firm's value added growth by 5%-6%, while collaboration with both suppliers and customers can increase a firm's sales growth by 5%-6% after 4 years. The findings suggest that policies enhancing collaborations among innovators and their stakeholders can improve the quality of innovation in the economy.

Keywords: Innovation, Cooperation, Productivity

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1 Introduction

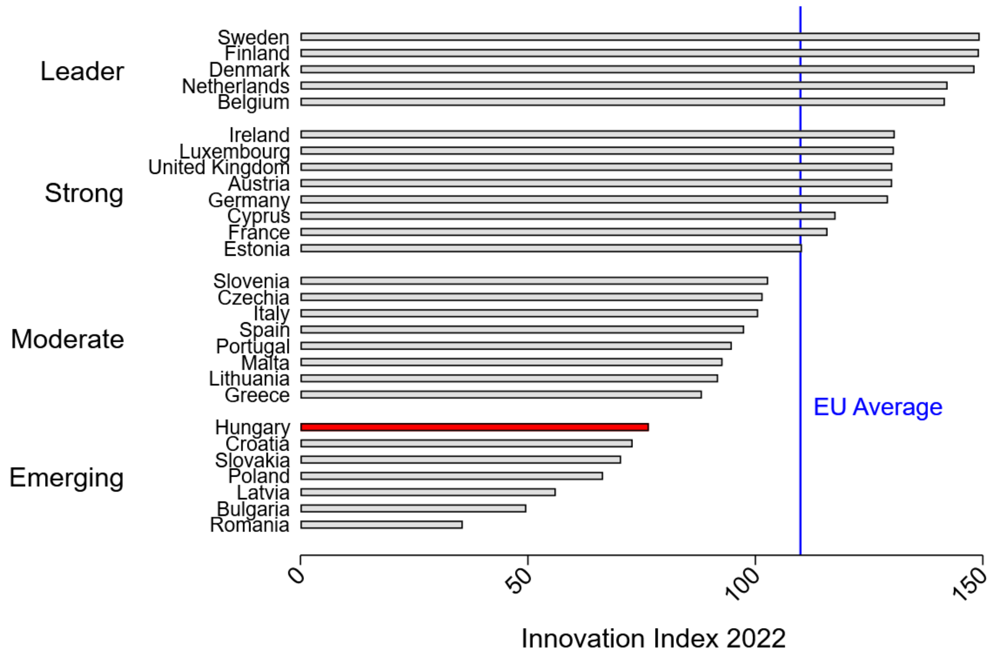
Firms are at the centre of technological change through innovation, which plays an important role in economic growth and increasing living standards (Ahlstrom, 2010; Halpern & Muraközy, 2012; Lindner et al., 2021). Firms have to use increasing resources to produce innovations, making their development activity more complicated. As the process of technological development becomes more complex, companies seek partners to complement their capabilities (Becker & Dietz, 2004). In this paper, I study the impact of cooperation with different types of collaboration partners in the innovation process on firm performance.

Cooperation between firms and other actors simplifies complex innovation processes, as it can be an opportunity to access complementary resources that contribute to faster development, improved market access, economies of scale and scope, cost and risk sharing (De Faria et al., 2010). As a result, it is crucial to understand the impact of collaboration on firm performance and productivity. As the determinants of cooperation can depend on the focus of innovation activity (Belderbos et al., 2004b), the effect of collaboration can differ in a country where firms use technology adoption to move closer to the technology frontier.

In countries where the effect of cooperation has already been studied, such as France, Germany, the United Kingdom, etc., firms are usually close to the technology frontier (Abramovsky et al., 2009; Belderbos et al., 2004a; Belderbos et al., 2004b; Belderbos et al., 2015; Capron & Cincera, 2003; Cassiman & Veugelers, 2002; De Faria et al., 2010; Nieto & Santamaría, 2007; Tether, 2002; Veugelers & Cassiman, 2005). Figure 1 shows that according to the European Innovation Scoreboard[1], Hungary is an emerging innovator and is below the average EU innovation index. In Hungary, companies rely on the adoption of technologies used in more developed countries to move closer to the technology frontier (Halpern & Muraközy, 2012). In addition, Hungarian firms are far from the productivity frontier.

[1] The European Innovation Scoreboard provides a comparative analysis of innovation performance in EU countries, other European countries, and regional neighbours. Based on their scores, EU countries fall into four performance groups: Innovation leaders, strong innovators, moderate innovators, and emerging innovators.

Figure 1: Innovation index in the European Union in 2022



Data source: European Commission - European Innovation Scoreboard

The results of Halpern and Muraközy (2012) suggest that innovative companies in countries farther away from the productivity frontier have a great productivity advantage through innovation. In Hungary, technology adoption is a significant part of firms' innovation strategies, and it is unclear whether cooperation is as valuable as in developed countries where the focus of innovation is on creating something new. Therefore, investigating the impact of collaborative innovation activities in Hungary could provide insights for similar countries. Understanding the effects of partnering with different entities would help firms and policymakers determine which cooperation partners to prioritise or subsidise to enhance productivity and promote firm growth.

To better understand the effect of collaboration with different partners on firms' performance and productivity, I perform an empirical analysis using a difference-in-differences approach on the panel data of the Hungarian Community Innovation Survey (CIS) from 2004-2016, linked to firm balance sheet data from 2000-2020.

The results of the study indicate that cooperation with different partners has varying effects on firm performance and productivity. In terms of size growth any type of cooperation except scientific collaboration has a positive link to firm growth, but it may be difficult to distinguish the effects of different partners. Also, the results of the main regression model suggest that cooperation does not directly have an effect on firm size growth, rather it is in connection with other factors which encourage firms to cooperate.

Concerning firm productivity, cooperation does not have a significant effect on labor productivity, although scientific cooperation has a marginally significant positive effect on it. On the other hand, cooperation has a significant positive effect on TFP, and this effect is mainly due to scientific cooperation. If an innovative firm cooperates with a scientific partner, it can expect around 6%-8% higher TFP growth after four years, on average, compared to an innovative firm that does not cooperate. An explanation for this effect can be related to the fact that Hungarian firms are far from the productivity frontier.

Regarding firm performance, horizontal and vertical partnerships have a positive effect on performance. Value-added growth is positively linked to competitor collaboration, while sales growth is positively associated with vertical cooperation partners, especially customer collaboration. If an innovative firm collaborates with a competitor, it can expect around 5%-6% higher value-added growth after four years, on average, compared to an innovative firm that does not cooperate. If an innovative firm collaborates with a customer or in both vertical ways simultaneously, it can expect around 5%-6% higher sales growth after four years, on average, compared to an innovative firm that does not cooperate.

These results suggest that cooperation can have positive effects on firm performance and productivity. So, firm leaders should think about cooperation partners in their innovation strategy and policymakers can improve the quality of innovation in the economy by increasing collaborations among innovators and their stakeholders.

2 Prior studies

2.1 Collaboration in the innovation process

Firms have different partner choice strategies and their partners have varying effects on innovation. While the specific impact of a partner on the performance of a company and when precisely these collaborations are formed with a specific partner type is still under debate (Belderbos et al., 2004b; Belderbos et al., 2015). Participation in collaborative partnerships depends on several things. One of the main aspects is how companies can manage information flows.

The ability to manage the information flow is essential for proper collaboration. Firms try to maximise incoming spillovers from partners and non-partners. Firms can improve this by investing in their absorptive capacity, which refers to their ability to recognise and apply external information to commercial purposes. A higher absorptive capacity allows firms to use and apply more knowledge acquired through partnerships (Cohen & Levinthal, 1990).

According to Cohen and Levinthal (1990), knowledge accumulation improves a firm's ability to recognise and assimilate new ideas and convert them into further innovations. Experience in a learning task can influence and improve performance in some subsequent learning tasks. According to Nelson (1985), the absorptive capacity of an organisation is not resident in any individual but depends on the links between individuals' capabilities.

External knowledge is more effective when the firm improves its own internal capacity through its own R&D processes. The higher the absorptive capacity of a firm, the more able it should be to access and implement a greater amount of knowledge (Cohen & Levinthal, 1990). The capacity of companies to take advantage of knowledge generated elsewhere positively affects the probability of being a successful innovator and is associated with the decision to conduct formal collaborative research with other firms and institutions (Abramovsky et al., 2009). Absorptive capacity has a crucial role in cooperation decision, however, in some cases, cooperation can be a substitute for absorptive capacity. For example, Abramovsky et al. (2009) find that firms with lower intramural R&D intensity (lower absorptive capacity) in France and Germany are more likely to engage in collaboration with the research base. In the service sector, cooperative innovation can be a substitute for internal R&D.

Apart from maximising information inflow, minimising information outflow is also crucial. Firms make efforts to control their own knowledge spillovers to non-partners, using strategic and legal protection methods such as patents, copyright, and secrecy. These methods can help firms reduce information and knowledge leaks to non-partners. (Cassiman & Veugelers, 2002; De Faria et al., 2010).

Appropriation is a critical element in managing the information flow of the cooperative innovation process, and it varies in relevance and form across different types of relationships. In the case of firm-university cooperation, the inability to exclusively appropriate the benefits from new know-how generated is typically not a concern, as there is usually no direct competition between universities and industries in output markets. However, there is still a risk that the know-how could leak out to competitors indirectly through common partners of the scientific institution.

Imperfect appropriation can increase the benefits of cooperative agreements. When spillovers are high enough, cooperating firms will spend more on R&D and become more profitable compared to non-cooperating firms. On the other hand, imperfect appropriation increases the firms' incentive to free-ride on each other's investment (Veugelers & Cassiman, 2005).

Besides managing the information flow, other factors, such as firm and industry characteristics, also affect the decision to collaborate. For example, Abramovsky et al. (2009) find that in France and the UK, innovative manufacturing firms are more likely to cooperate with other actors than firms in the service sector. In addition, within the manufacturing sector in all four countries they analyse (France, Germany, Spain, UK), innovative firms with collaborative partners are mostly present in high-tech manufacturing sectors rather than in low-tech manufacturing sectors. De Faria et al. (2010) find that companies in high-tech industries, with higher levels of absorptive capacity and investment in innovation, who value the management of incoming spillovers, place greater value on cooperation partners in the innovation process. Although the characteristics of the company are important, the incentives of the firm are also not negligible. An important incentive can come from whether the company needs radical or just incremental innovation.

Tether (2002) find using UK CIS data that cooperation appears mainly in firms that pursue radical innovations rather than incremental innovations. In contrast, Belderbos et al. (2004a) find using Dutch CIS data that competitor and supplier cooperation generally focuses on incremental innovations, improving the productivity performance of firms. However, even if the characteristics and incentives of the companies are the same, it is not evident how important the partnership is to the companies.

De Faria et al. (2010) show using Portuguese CIS data that the determinants behind the decision to cooperate can be different from the determinants behind the importance attributed to the cooperation agreement. Cooperative firms based on similar motivations may have different levels of importance related to collaboration partners. Cooperation with other actors can have different roles and values depending on the context, so companies do not benefit equally from their collaborations. They differ not only in how equally they benefit from the partnership, they can differ with respect to time, when will the benefit of cooperation appear in their performance. As it takes time for an innovation to show its effects in firm performance and productivity, the effect of partnerships can also need a certain 'incubation time' to have an effect.

According to Belderbos et al. (2015), the dynamism of collaboration is not clear, as it may not have an immediate effect on performance. The incubation time is different depending on the type of collaboration partner. Cooperating vertically is likely to have a problem-solving background and lead to a relatively short R&D trajectory resulting in relatively fast solutions, while horizontal collaboration focusing on pre-competitive research is likely to have a longer trajectory. In scientific partnerships, there may be a mixed pattern. Projects focusing on basic and applied research are likely to have a longer time frame, but projects, where research institutes are solving technological problems faced by companies, can have immediate results.

Another aspect related to the dynamism of cooperation is the persistence of partnerships. The persistence of collaboration may also have different effects. Firms cooperating persistently with a particular type of partner are likely to have refined their interorganisational routines and have gained experience managing these types of relationship. Therefore, they can benefit from these collaborations with a bigger advantage (Belderbos et al., 2015).

Persistent collaboration can be attractive as effective learning takes place through repeated collaboration that allows for the build-up of trust. The learning effects achieved through continuity in R&D collaboration can increase the efficiency of partnering strategies (Nieto & Santamaría, 2007). In addition to this, persistent collaboration can signal that a company is reliable and trustworthy (Belderbos et al., 2015). This can be a useful way for a firm to build a reputation as a reliable partner, which can reduce the risks of partner opportunism and negative referrals or lockout of future collaborative opportunities (Nooteboom, 2003). According to Belderbos et al. (2015), these reputation effects suggest that firms that cooperate more persistently may on average be able to collaborate with more competent partners, increasing the performance effects of their R&D ties.

Recent empirical research has suggested that to understand the effect of innovation collaboration on firm performance, we need to differentiate between collaboration partners. The partner types can be vertical as supplier and customer; horizontal as competitor; and scientific, such as expert, research institution, and university (Belderbos et al., 2004b). However, it is not yet clear what the impact on firm performance is of collaboration with different partners (Belderbos et al., 2015). How do the (innovation) partner's characteristics affect the innovation's success and the productivity, growth, and sales of a firm? After summation of the literature on collaboration in innovation in general, I go into detail about the findings regarding every partner type.

2.2 Vertical cooperation

Vertical cooperation partners (suppliers and customers) are usually one of the most common partner types, also supplier and customer cooperation can be highly correlated (Abramovsky et al., 2009). Atallah (2002) shows in a theoretical model that vertical spillovers have a positive effect on R&D and welfare. Freel and Harrison (2006) find using data on small firms in Northern Britain that cooperation with customers is positively related to the success of product innovations, and cooperation with suppliers has a more significant influence on the success of process innovations.

Collaboration with suppliers tends to contribute to innovation by increasing the firm's knowledge of cost-reducing technologies, sharpening its focus on core competencies, improving the design process, and helping secure vital inputs (Belderbos et al., 2015).

If a firm cooperates with its suppliers, they can create additional opportunities for the build-up of valuable, specific, and difficult-to-imitate resources and competencies shared between a firm and its suppliers. This can strengthen the connections with the suppliers, and through development, influence its innovation competencies, and make unique products or processes.

Effective integration of suppliers into new product development efforts through collaboration can help firms achieve an advantage over competitors in terms of the cost of new product development, utilised technologies, and development time. Such supplier involvement has been shown to increase product innovation in mature industry segments and can help firms realise higher process efficiencies. Furthermore, there is evidence that collaboration with suppliers can reduce risk and lead times of product development (Nieto & Santamaría, 2007). Fritsch and Lukas (2001) found using German manufacturing firm data, that innovative effort directed at process improvement is more likely to involve cooperation with suppliers. According to Belderbos et al. (2004a), supplier cooperation significantly affects the growth of labour productivity.

Collaboration with customers can improve the commercialisation of product innovations. In cases where there are heterogeneous market needs, technology is sticky, or new products are so complex that their adaptation time is essential, customers can be instrumental in reducing the risks associated with the market introduction of new products. (Tether, 2002; Von Hippel, 1988). Customer collaboration can help improve a firm's understanding of their customers' unmet or future needs, increase the attractiveness of their products, and possibly extend the product or process life cycle (Belderbos et al., 2015). Firms that cooperate with customers may develop new competencies that are required to realise shorter lead times and market responsiveness, facilitating the innovation process. Fritsch and Lukas (2001) found that product innovations are more likely to involve cooperation with customers. Customers are important sources of knowledge for companies seeking radical innovations that facilitate the growth of innovative sales.

2.3 Horizontal cooperation

Vertical collaboration is essential, but not the only way, firms cooperate. They can also find a partner in their competitors. Collaboration with competitors plays an important role in the creation of new-to-the-market innovations by creating access to scarce external expertise on promising new technologies that precede application in future markets. It can help to resolve common technological issues, such as the development of industry standards.

Nevertheless, horizontal collaboration in the innovation process must be separated from competition-restrictive collusion. Brandenburger and Nalebuff (1996) argue that cooperation between competitors has positive welfare effects. During the cooperation, the companies do not limit the quantity or increase the prices, so they do not limit the competition, but they will compete with each other in a market increased by the cooperation or with a technology more advanced by the cooperation. However, Atallah (2002) finds in his theoretical model that the impact of a horizontal spillover on welfare is unclear.

Belderbos et al. (2004a) argue that competitor cooperation has a considerable impact on the growth of labour productivity and positively affects the growth of sales per employee of products and services new to the market, improving the growth performance of firms.

2.4 Scientific cooperation

Besides looking for other companies vertically or horizontally, firms can find collaboration partners in the scientific world. Partnerships with universities, research institutions, and experts are also not negligible. Freel and Harrison (2006) find that cooperation with public sector institutions and universities is positively related to the success of product and process innovations. Collaboration with universities, research institutes, and experts may incite the creation of radical, next-generation innovations by providing an important source of state-of-the-art, technological knowledge (Belderbos et al., 2004b). Academic research, carried out by universities and public research organisations, is complementary to a firm's innovation activities, thus significantly contributing to its ability to create innovations. It offers new technical knowledge that is needed in innovation activities aimed at developing new technologies and products (Veugelers & Cassiman, 2005).

Given the specific characteristics of scientific knowledge, R&D cooperation between science and industry is characterised by high uncertainty and information asymmetries between partners. Also, since it requires a high level of absorptive capacity, it has high transaction costs for knowledge exchange. However, Veugelers and Cassiman (2005) argue that participation in university cooperation partnerships can be attractive for companies, as it allows inexpensive and low-risk access to specialist knowledge and generic, basic R&D.

Mohnen and Hoareau (2003) found that firm size, government support, patenting, and scientific industry status contribute positively towards explaining R&D cooperation with universities relative to other types of cooperation. Capron and Cincera (2003) also confirm the importance of firm size and government support as significant drivers for R&D collaboration with universities. The nature of research projects with universities and research institutes involves fewer intellectual property rights issues. R&D cooperation with universities is more likely to be chosen by R&D intensive firms in sectors that exhibit faster technological and product development (Belderbos et al., 2004a; Belderbos et al., 2004b). When companies use public information sources, such as publications, conferences, and patents, they see them as a public good, which is a stock of knowledge. However, the firm needs a higher level of absorptive capacity to use it. The firm can acquire that knowledge through cooperation with scientific actors. Therefore, when free spillovers improve the basic R&D competence of the firm, the marginal benefit of collaborating with scientific institutions is greater, implying a higher probability of cooperation with science when firms are also sourcing public information (Veugelers & Cassiman, 2005).

Collaboration with scientific actors facilitates access to national and international knowledge networks and may support the hiring and selection of talented graduates and doctoral researchers. At the same time, collaboration with universities and research institutes can contribute to technical problem-solving that may be beneficial for process innovations (Cohen et al., 2002). As university cooperation is instrumental in creating innovations that generate sales of products that are novel to the market, it improves the growth performance of firms. A scientific collaboration partner can positively affect the growth in sales per employee of products and services new to the market (Belderbos et al., 2004a).

3 Data and methodology

I start by describing the data set and the variables I use in the empirical analysis. Then I give some descriptive statistics about the data. Finally, I give information about the estimation method and econometric specifications that I use to explain the effect of cooperation in innovation activities on firm performance and productivity.

3.1 Data

I use two main data sources, the first is the Hungarian Community Innovation Survey (CIS) from 2004-2016, and the other one is firm-level corporate income tax statements from the period 2000-2020 from the Hungarian National Tax Authority (NAV).

The Community Innovation Survey (CIS) (Mairesse & Mohnen, 2010; OECD, 2005, 2009) is a harmonised survey in the European Union collected bi-annually based on the Oslo Manual (OECD, 2005). Although there are differences in sampling methods in some countries, it covers a representative sample of manufacturing and service firms.

The survey includes several variables related to innovative input and output as well. One of the main advantages of CIS is that it provides direct, reliable, and broad measures for firms innovative activities. The survey distinguishes between different types of innovation, such as product and/or process innovation (technical aspect) or organisational innovation (Lindner et al., 2021). Also, it differentiates between different collaboration partners like suppliers, customers, competitors, universities, research institutions, or experts.

The main constraint of the database comes from the structure of the survey. The different waves represent innovative activities of firms in the preceding 3 years; for example, in the survey made in 2014, firms were asked questions about the years 2012-2013-2014, and in the survey made in 2012, firms were asked questions about the years 2010-2011-2012. I use the data in every CIS wave in the year it was collected and the year before that. For example, if the CIS wave was collected in 2014, then I use its data in the years 2014 and 2013. For 2012, which I have data from the CIS 2014 and CIS 2012 waves, I use the data that come from the CIS 2012 wave.

Most of the questions are only asked from companies that have reported a positive innovative output or some kind of innovation activity. In the case of cooperation variables, only product or process innovative firms or firms with ongoing or abandoned innovation activity are asked if they collaborate with any partners in the innovation process. That means that the effect of cooperation on firm performance should be interpreted as an additional effect on top of innovation's effect, since I can predict the effect of cooperation for only innovative firms.

I merge the Hungarian CIS data with Hungarian firm balance sheet data from 2000-2020. The balance sheet data comes from administrative tax declaration forms, from the Hungarian National Tax Authority. The dataset includes all Hungarian companies that use double-entry bookkeeping. The sample covers more than 95% of employment and value added of the business sector and about 55% of the whole economy in terms of GDP. The dataset includes the most important balance sheet items and information on a wide range of matters such as ownership, employment, industry at the 2-digit NACE code[2], and the location of the headquarters. Nominal variables are deflated with the appropriate 2-digit industry-level deflators from OECD STAN[3] (Bisztray et al., 2022).

Using the balance sheet data I estimate labour productivity as the natural logarithm of value added divided by the employee. As the Centre for Economic and Regional Studies (KRTK)[4] has extensively cleaned and harmonised the data, the version of the firm balance sheet dataset available for me already contains firm total factor productivity (TFP) estimations. For the estimation of TFP, the Levinsohn-Petrin procedure was applied for each 2-digit NACE industry separately (Ackerberg et al., 2015; Levinsohn & Petrin, 2003). To make the TFP estimation more accurate, estimation was made on the entire balance sheet dataset from 2000-2020, with at least 10 000 observations per year (Bisztray et al., 2022). Table A1 in the appendix describes in detail the variables that I use.

[2]https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

[3]https://www.oecd.org/sti/ind/stanstructuralanalysisdatabase.htm

[4]https://krtk.hu/en/homepage/

3.2 Descriptive statistics

Table 1 describes the number of firms in the waves of the CIS, and the number of firms that were innovative, innovative but not cooperative and cooperative (with different partner types). Scientific cooperation partners can be a university, a research institute, or an expert. The number of firms included in a wave is increasing, it is between 3950 and 7270. The number of innovative firms is usually increasing as well, but the proportion of cooperative firms is constantly changing. The number of cooperative firms is between 472 and 673, which means the proportion of cooperative firms is between 7.5% and 12.5%. The most common collaboration partner is the supplier and the least common is the competitor in every wave.

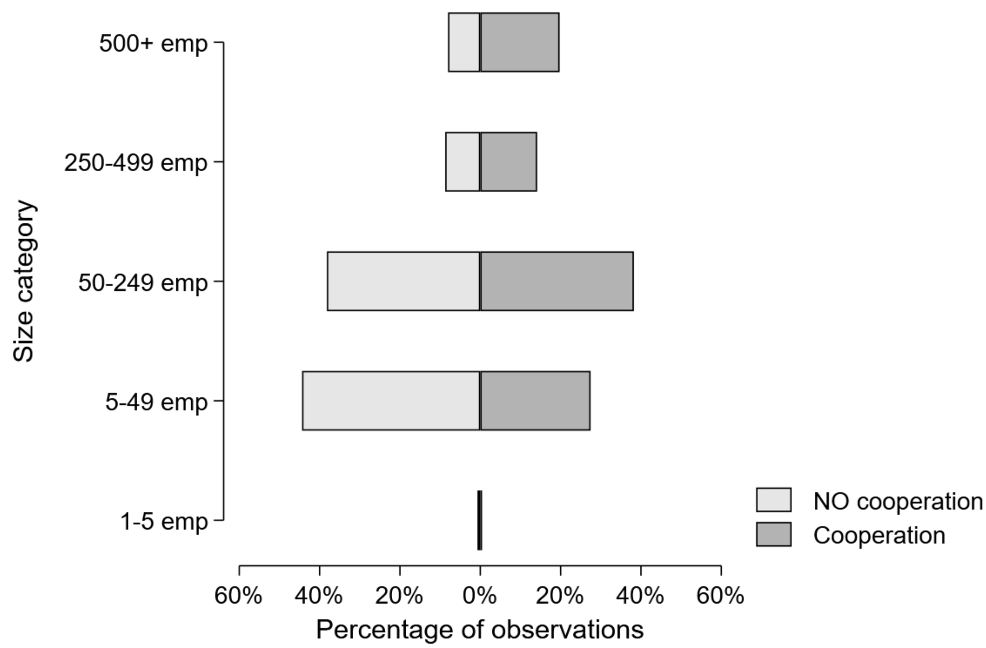
Table 1: Number of firms in the CIS waves

Wave	All	Inn	NO Co	Co	Supplier	Customer	Competitor	Science
2002-2004	3950	1420	971	472	354	251	179	243
2004-2006	5094	1707	1139	596	392	248	183	380
2006-2008	5390	1599	971	673	458	314	237	424
2008-2010	5120	1589	989	641	426	309	245	414
2010-2012	5482	1659	1141	550	393	292	187	314
2012-2014	7243	1676	1161	549	395	238	140	235
2014-2016	7270	1970	1450	547	427	309	208	278

Summary statistics of non-cooperative and cooperative observations are reported in Table 2. The observations are on firm-year level. I find differences between cooperative and non-cooperative observations, and these differences are usually consistent with the findings in the literature, that which firms are more prone to collaborative innovation activity.

Cooperative firms, especially the ones that cooperate with scientific actors, are bigger on average than non-cooperative but innovative firms. Figure 2 shows the distribution of the firms' size in cooperative and non-cooperative observations. While almost half of the non-cooperative observations have below 50 employees, more than one-third of the cooperative observations have over 250 employees.

Figure 2: Size distribution of cooperative and non-cooperative observations



There are more foreign and exporter firms within cooperative observations than non-cooperative observations. Less than one-third of the non-cooperative observations are owned by foreigners, the same rate is above 40% in the case of cooperative observations with any partner type except competitor.

Using the own R&D activity as a proxy for absorptive capacity, I find on average a bigger absorptive capacity in cooperative observations than in non-cooperative observations. While only 27% of the non-cooperative observations has own R&D activity, in the case of cooperative observations, this number is more than 60%, and in the case of scientific cooperation, it is more than 70%. Furthermore, one-third of cooperative observations (more than 40% of the competitor and scientific cooperative observations) do the R&D activity continuously, while the same number is only 12% in the case of non-cooperative observations.

A higher rate of cooperative observations reported that they have funding from local authorities, the government, or the EU than non-cooperative observations. In the case of competitor and scientific collaboration partners, it is close to 50%.

Table 2: Characteristics of non-cooperative and cooperative firms

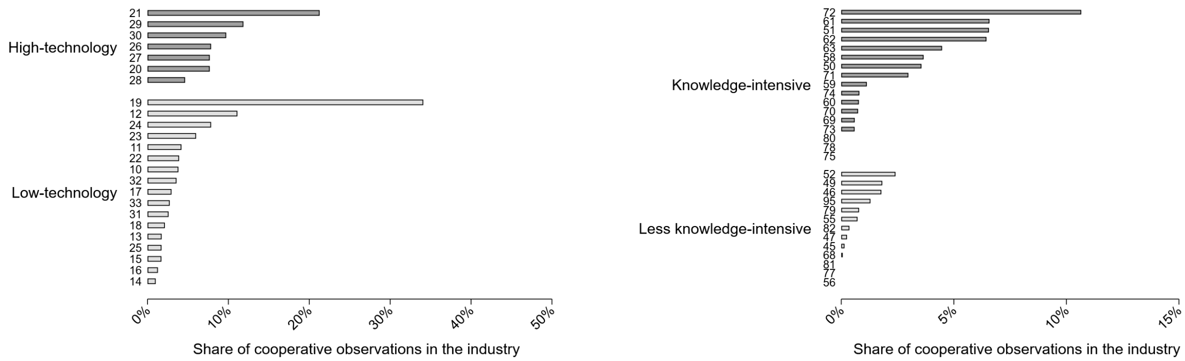
Variable	NO Co	Co	Supplier	Customer	Competitor	Science
Size	4.2060	4.9028	4.8924	4.8851	4.8486	5.2706
Foreign	0.3292	0.4033	0.4203	0.4257	0.3665	0.4172
Exporter	0.6954	0.7670	0.7718	0.7922	0.7434	0.7884
Own R&D	0.2690	0.6172	0.6056	0.6772	0.6918	0.7207
Cont. own R&D	0.1221	0.3421	0.3388	0.3957	0.4228	0.4519
Occ. own R&D	0.1469	0.2751	0.2668	0.2815	0.2690	0.2688
Funding	0.1734	0.4352	0.4376	0.4365	0.4844	0.4965
Labour prod.	8.5209	8.7739	8.7807	8.7388	8.7862	8.9019
TFP	7.1736	7.4844	7.4543	7.4044	7.5057	7.6541
log Sales	14.0471	14.9796	14.9799	14.9095	14.9185	15.4814
log Value added	12.7386	13.7069	13.7023	13.6553	13.6750	14.2101
Number of observations	15 644	8 056	5 690	3 922	2 758	4 576

Note: The numbers are the means of the variables, except the number of observations.

Figure 3 shows the proportion of cooperative observations in the manufacturing and service industries. The numbers on the vertical axis are 2-digit NACE industry codes. I classified manufacturing industries into high- and low-technology and service industries into knowledge-intensive and less knowledge-intensive using Eurostat indicators[5]. In accordance with the literature, in manufacturing industries, there is a higher proportion of cooperative observations. Furthermore, I find that most high-tech and knowledge-intensive industries are characterised by a higher rate of cooperative observations than low-tech and less knowledge-intensive industries (Abramovsky et al., 2009; De Faria et al., 2010). Although I also find high rates in low-tech industries as well, like Manufacture of coke and refined petroleum products (21), Manufacture of tobacco products (12), Manufacture of basic metals (24), and Manufacture of other non-metallic mineral products (23).

[5] https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf

Figure 3: The proportion of cooperative observations in manufacturing and service industries



(a) Manufacturing

(b) Service

Table 3 shows that there is a high correlation between different partner types. Firms usually do not collaborate with only one type, they choose more of them, and some of the firms even cooperate with every partner type. The strongest connection is between vertical cooperation types, such as supplier and customer cooperation. It is in line with the literature. As a consequence of that, I analyse in detail the vertical partnerships.

Table 3: Correlation between cooperation partner types

	Supplier	Customer	Competitor	Science
Supplier	1			
Customer	0.6590	1		
Competitor	0.5397	0.6055	1	
Science	0.5136	0.4907	0.4736	1

3.3 Methodology

Similarly to Caroli and Van Reenen (2001) and Lindner et al. (2021), I use a difference-in-difference type identification strategy on the panel data. In the results section I will discuss 2 regression types, the base regression and the main regression.

The *base regression* model I use is the following.

$$\Delta y_{it} = \delta inn_{it} + \beta CO_{it} + \phi y_{it-2} + \lambda_{kt} + \varepsilon_{it} \tag{1}$$

On the left-hand side Δy_{it} is the change between year $t+4$ and t at firm i in outcome y, such as TFP, labour productivity, log of value-added, log of sales and size. As I use the difference on the left-hand side, I am conditioning all unobservable characteristics that do not change over time. I winsorize the dependent variable on the 1st and 99th percentiles in all regression settings, to handle outliers.

On the right-hand side $inn_{i,t}$ is a variable that takes the value one if firm i makes product, process, or organisational at time t. CO_{it} is a dummy variable that is equal to one if firm i cooperates with any type of collaboration partner at time t. In addition to cooperation in general, I put each type of partner in separate regression. Therefore, instead of cooperating with any partner, CO_{it} is equal to one if the company cooperates with a specific type of partner at time t. The types of collaboration partner can be supplier, customer, competitor, or scientific. In the case of scientific cooperation, the dummy variable equals one if the firm cooperates with a university, a research institution or an expert in year t. Regarding the vertical collaboration partner types, I define 2 new categories. *Vertical* cooperation category means that the firm cooperates at least in one vertical way, that is, with its supplier or customer. While *Both vertical* cooperation category means that the firm cooperates with its supplier and its customer at the same time.

I put the lagged value of the outcome variable y_{it-2} to capture initial firm heterogeneity and to control for the fact that the growth rate can depend on firm characteristics. I also put the interaction of year and industry fixed effects into the regression (λ_{kt}).

The *main regression* model I use is the following.

$$\Delta y_{it} = \delta inn_{it} + \boldsymbol{\beta CO}_{it} + \boldsymbol{\gamma W}_{it} + \phi y_{it-2} + \lambda_{kt} + \varepsilon_{it} \tag{2}$$

Compared to the base regression, $\boldsymbol{CO}_{it}$ is a vector containing dummy variables indicating the types of collaboration partners that the firm i has cooperated with, including suppliers, customers, competitors, and scientific institutions. So, instead of putting the specific partner types separately in separate regressions, now I include all of them simultaneously.

Also, I add control variables to the regression, $\boldsymbol{W}_{it}$ is a vector containing control variables. I use a proxy variable to control for a firm's absorptive capacity. The proxy variable shows whether firm i does in-house R&D and whether the firm does it continuously or occasionally. I also have a control variable on whether the firm received funding from local authorities, the government, or the EU. It is also important to control whether a firm is an exporter because exporters are under increased pressure from the greater global competition, which can be an incentive for them to cooperate, and they are already more productive.

The effects of innovation and cooperation can take time to materialize (Belderbos et al., 2015). A 4-year period should be sufficient to observe the impact of cooperation and innovation on firm performance. Therefore, I estimate the mid-term impact of cooperation on firm performance and productivity.

The identification assumption is the following: If firms that were innovative and cooperated 4 years before year t have not cooperated, then their average performance change would be the same as the average change of firms that were innovative 4 years before year t, but have not cooperated. Also, I can control for other characteristics, in which the two groups are different, such as absorptive capacity, funding, exporting, and industry.

4 Results

Figures 4-6 present the beta estimates of different partner types in the case of the base regression (Equation 1). The beta estimates of different cooperation partner types are presented in one figure for different outcomes to make it easier to compare with each other. However, they come from regressing the different outcome variables on the collaboration partners separately.[6] The error bars show the 95% confidence intervals around the point estimates.

In the case of size growth (Figure 4), there is a significant positive effect of cooperation. In addition, all of the partner types seem to have a significant positive effect, except scientific partners. The effects of significant partner types are close to each other and close to the overall cooperation effect. If an innovative firm cooperates with any partner type (except scientific collaboration partner), then on average its size growth will be around 4% higher after 4 years, than if it would have not cooperated. As there is a high correlation between partner types, it may indicate that any type of cooperation has a positive link to firm growth (except scientific cooperation), and we cannot distinguish between different partners.

Turning to the firm productivity in Figure 5, I find that cooperation does not have a significant effect on labour productivity. However, scientific cooperation has a positive coefficient that is marginally significant. On the other hand, cooperation has a significant effect on TFP, and it is in connection with scientific cooperation. If an innovative company cooperates with a scientific partner, then on average its TFP growth will be around 6% higher after 4 years, than if it would have not cooperated.

[6] For example, in Figure 4 Cooperation beta estimate comes from regression:

$$\Delta y_{it} = \delta inn_{it} + \beta Cooperation_{it} + \phi y_{it-2} + \lambda_{kt} + \varepsilon_{it}$$

While Supplier beta estimate in the same figure comes from regression:

$$\Delta y_{it} = \delta inn_{it} + \beta Supplier_{it} + \phi y_{it-2} + \lambda_{kt} + \varepsilon_{it}$$

In terms of firm performance (Figure 6), I find that horizontal and vertical partnerships have a positive effect on performance. Value added growth is in connection with competitor collaboration, while sales grow is related to vertical cooperation partners, especially customer collaboration. If an innovative firm collaborates with a competitor, then on average its value added grow will be around 6% higher after 4 years, than if it would have not cooperated. If an innovative firm collaborates with a customer or in both vertical way at the same time, then on average its sales grow will be around 6% higher after 4 years, than if it would have not cooperated.

Figure 4: Results of the base regression (size)

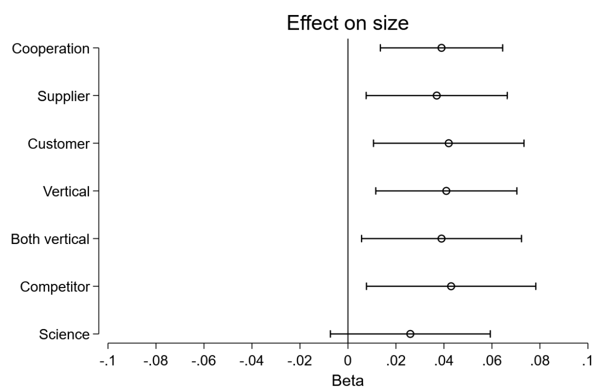
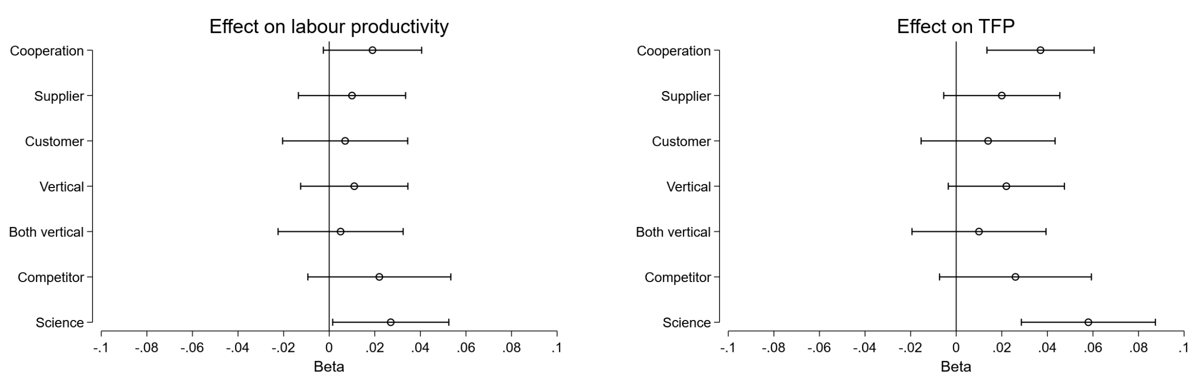
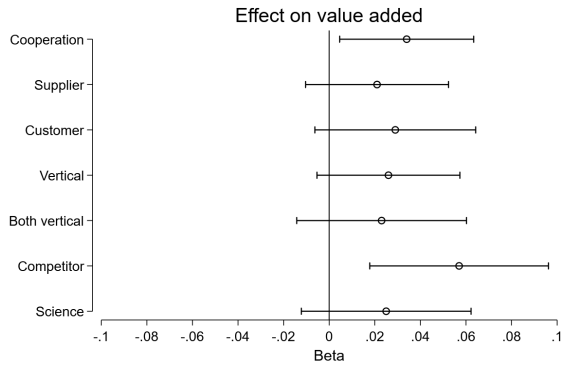


Figure 5: Results of the base regression (productivity)

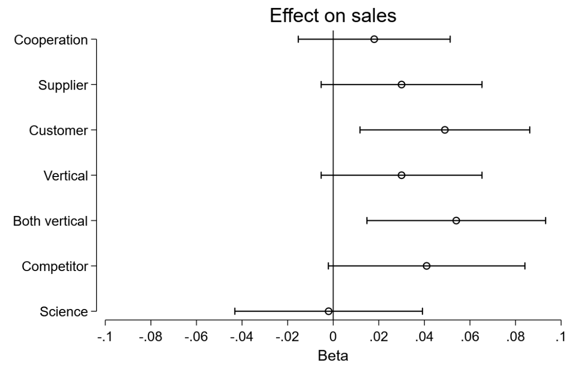


(a) (b)

Figure 6: Results of the base regression (performance)



(a)



(b)

After the results of the base regressions, I turn to the results of the main regression models. Tables 4-8 present the results of the main regressions (Equation 2), in which I put the different types of partners on the right-hand side simultaneously and also add control variables to the regression. There are about 48 000 - 55 000 observations in each regression. The number of observations is changing because there is missing data for some firms for different left-hand side variables. Recall that the interpretation of the effects of innovation and cooperation is additive. If a firm cooperates with a specific partner type and has a significant effect, it means it is an effect in addition to the effect of innovation, as I can estimate the effect of cooperation only if a firm innovates.

Starting with the effect of cooperation on firm size growth, column (1) of Table 4 shows that without control variables cooperation coefficient is significant. After adding control variables, the estimated beta becomes smaller and loses its significance in column (4). Furthermore, none of the estimated effects of different partners are significant, with or without controls. This suggests that cooperation does not directly have an effect on firm size growth, rather it is in connection with other factors which encourage firms to cooperate, like higher absorptive capacity, funding, or higher pressure of global competition, but also induces higher firm growth.

Table 5 shows the results in the case of labour productivity, and they are far from the findings in the literature (Belderbos et al., 2004a). The effect of innovation on the growth of labour productivity is 1.3% while the effect of cooperation on labour productivity is 1.9%. These effects are only weakly significant even without controls (column (1)). After controlling for other factors (column (4)), does not change the coefficient estimations roughly, but the significance vanishes. However, if I regress labour productivity only on innovation and the lag of labour productivity with the interaction of industry and time fixed effects (it is not presented in the tables), I find a small but significant effect of innovation, which is around 2%. This can indicate that the effect of innovation and cooperation on labour productivity cannot be distinguished. It may come from the fact that labour productivity enhancing collaborative activities (e.g. developing a new technology that is useful for the entire value chain that increases worker efficiency beyond innovation) do not occur when firms just adopt technologies, rather it is more typical when firms want to push the technology frontier. As Hungary is far from the technology frontier, the labour productivity of Hungarian firms cannot benefit from these activities, as they do not take place here.

On the contrary, cooperation has a significant effect on the other productivity indicator, TFP. Table 6 shows that without control variables, the effect of cooperation on TFP growth is approximately 4%, and if I separate the effect by partners, in every (vertical partner) setting, only scientific cooperation remains significant. After adding control variables, the effect of cooperation and scientific collaboration remains significant and even slightly increases. It suggests that scientific partnership is related to the growth of TFP in a firm. Leaving everything else constant, if a firm cooperates with a scientific actor in its innovation activity, then its TFP will grow around 6%-8% more after 4 years than if it had not cooperated with a science actor.

An explanation for this effect is related to the fact that Hungarian firms are far from the productivity frontier. Firms try to get closer to the frontier, and the simplest way to do this is to work together with actors that have sufficient knowledge. As competitors, suppliers, and customers in the country are also far from the frontier, the only partners that have the required expertise are scientific institutions. Scientific partners have the necessary human capital or advanced tools that are essential to increase the productivity of companies.

With respect to firm performance, vertical and horizontal partners seem to be important. As Table 7 shows, in the case of value added, the collaboration of competitors seems to have the biggest and only significant effect. Even after controlling for other factors, if a firm cooperates with its competitor, then its value added will grow 5%-6% more, after 4 years. A good reason for that positive effect on value added can be that collaboration between competitors usually happens to tackle common technological issues, to create new-to-the-market innovation (Belderbos et al., 2004a; Belderbos et al., 2004b). It obviously reduces cost if they share the required R&D process between each other. Lower costs then increase the value added of firms in the collaboration.

Table 8 shows that, in the case of sales growth, vertical partners have a significant effect. Within vertical connections, the only significant is the case where a firm collaborates in both ways (columns (4) and (8)), with its suppliers and customers at the same time. Ceteris paribus, if a firm cooperates in both vertical ways, then its sales will grow 6% more, after 4 years. Vertical cooperation can improve product development, and especially collaboration with customers can increase the attractiveness and commercialisation of new products (Belderbos et al., 2015; Fritsch & Lukas, 2001; Tether, 2002). If firms can commercialise their products more easily, then it will increase their sales. This may be a possible explanation for this positive effect on firm sales.

An interesting phenomenon is that scientific collaboration partners can increase the productivity growth of firms without necessarily increasing their sales growth. A possible explanation for this is that scientific partners play a crucial role in creating innovative products that may replace outdated ones, leading to no net increase in sales. According to Belderbos et al. (2004a), firms that collaborate with scientific actors often produce new-to-the-market innovations, and although these products may be more efficiently produced, they may not necessarily lead to increased sales. Thus, while the productivity of firms may increase, their sales may remain constant.

Table 4: Results of the main regression (size)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation	0.118***	0.120***	0.119***	0.123***	0.100***	0.101***	0.100***	0.102***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
Cooperation	0.039***				0.023			
	(0.013)				(0.014)			
Supplier		0.020				0.011		
		(0.020)				(0.020)		
Customer		0.019				0.020		
		(0.022)				(0.022)		
Vertical			0.033*				0.024	
			(0.018)				(0.017)	
Both vertical				0.021				0.020
				(0.020)				(0.020)
Competitor		0.017	0.020	0.025		0.015	0.020	0.020
		(0.022)	(0.021)	(0.021)		(0.022)	(0.021)	(0.021)
Science		0.003	0.002	0.010		-0.009	-0.009	-0.006
		(0.020)	(0.020)	(0.020)		(0.021)	(0.021)	(0.021)
Dep. lag	-0.027***	-0.027***	-0.027***	-0.027***	-0.040***	-0.040***	-0.040***	-0.039***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Control variables	No	No	No	No	Yes	Yes	Yes	Yes
Industry#Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	54,682	54,682	54,682	54,682	54,682	54,682	54,682	54,682
R^2	0.076	0.076	0.076	0.076	0.081	0.081	0.081	0.081

Standard errors are clustered at the firm level and are reported in parentheses.

Dependent variable is the change between year $t + 4$ and t in firm size, and winsorized at 1st and 99th percentiles.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Results of the main regression (labour productivity)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation	0.013*	0.014*	0.014*	0.014*	0.011	0.013	0.013	0.013
	(0.008)	(0.007)	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
Cooperation	0.019*				0.019			
	(0.011)				(0.012)			
Supplier		0.001				0.002		
		(0.016)				(0.017)		
Customer		-0.013				-0.015		
		(0.019)				(0.019)		
Vertical			-0.003				-0.003	
			(0.015)				(0.015)	
Both vertical				-0.017				-0.018
				(0.018)				(0.018)
Competitor		0.016	0.011	0.019		0.017	0.012	0.019
		(0.020)	(0.019)	(0.020)		(0.020)	(0.019)	(0.019)
Science		0.026	0.024	0.027*		0.027	0.025	0.027*
		(0.016)	(0.016)	(0.016)		(0.017)	(0.017)	(0.017)
Dep. lag	-0.123***	-0.124***	-0.124***	-0.124***	-0.125***	-0.125***	-0.125***	-0.125***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Control variables	No	No	No	No	Yes	Yes	Yes	Yes
Industry#Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50,589	50,589	50,589	50,589	50,589	50,589	50,589	50,589
R^2	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119

Standard errors are clustered at the firm level and are reported in parentheses.

Dependent variable is the change between year $t+4$ and t in labour productivity, and winsorized at 1st and 99th percentiles.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Results of the main regression (TFP)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation	0.050***	0.052***	0.051***	0.052***	0.047***	0.050***	0.050***	0.051***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)
Cooperation	0.037***				0.041***			
	(0.012)				(0.013)			
Supplier		0.004				0.006		
		(0.017)				(0.017)		
Customer		-0.019				-0.021		
		(0.020)				(0.020)		
Vertical			-0.001				0.001	
			(0.016)				(0.016)	
Both vertical				-0.024				-0.024
				(0.019)				(0.020)
Competitor		0.001	-0.006	0.005		0.005	-0.003	0.010
		(0.022)	(0.020)	(0.022)		(0.022)	(0.020)	(0.022)
Science		0.064***	0.061***	0.065***		0.067***	0.064***	0.068***
		(0.017)	(0.017)	(0.017)		(0.018)	(0.018)	(0.018)
Dep. lag	-0.151***	-0.151***	-0.151***	-0.151***	-0.159***	-0.159***	-0.159***	-0.159***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Control	No	No	No	No	Yes	Yes	Yes	Yes
Industry#Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	48,928	48,928	48,928	48,928	48,928	48,928	48,928	48,928
R^2	0.138	0.138	0.138	0.138	0.139	0.140	0.139	0.140

Standard errors are clustered at the firm level and are reported in parentheses.

Dependent variable is the change between year $t+4$ and t in TFP, and winsorized at 1st and 99th percentiles.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Results of the main regression (Value added)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation	0.092***	0.096***	0.095***	0.096***	0.082***	0.050***	0.050***	0.051***
	(0.011)	(0.011)	(0.011)	(0.010)	(0.012)	(0.009)	(0.009)	(0.009)
Cooperation	0.034**				0.026			
	(0.015)				(0.016)			
Supplier		-0.002				-0.007		
		(0.022)				(0.022)		
Customer		0.002				0.004		
		(0.024)				(0.024)		
Vertical			0.007				0.001	
			(0.019)				(0.019)	
Both vertical				-0.012				-0.011
				(0.023)				(0.023)
Competitor		0.053**	0.050**	0.059**		0.052**	0.050**	0.056**
		(0.026)	(0.025)	(0.026)		(0.026)	(0.025)	(0.026)
Science		0.008	0.005	0.010		0.004	0.003	0.005
		(0.022)	(0.022)	(0.021)		(0.022)	(0.022)	(0.022)
Dep. lag	-0.021***	-0.021***	-0.021***	-0.021***	-0.030***	-0.030***	-0.030***	-0.030***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Control	No	No	No	No	Yes	Yes	Yes	Yes
Industry#Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50,221	50,221	50,221	50,221	50,221	50,221	50,221	50,221
R^2	0.103	0.103	0.103	0.103	0.104	0.105	0.105	0.105

Standard errors are clustered at the firm level and are reported in parentheses.

Dependent variable is the change between year $t + 4$ and t in value added, and winsorized at 1st and 99th percentiles.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Results of the main regression (Sales)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation	0.121***	0.120***	0.120***	0.122***	0.110***	0.109***	0.109***	0.109***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)
Cooperation	0.018				0.010			
	(0.017)				(0.018)			
Supplier		0.012				0.008		
		(0.025)				(0.025)		
Customer		0.045				0.045*		
		(0.027)				(0.027)		
Vertical			0.029				0.024	
			(0.022)				(0.022)	
Both vertical				0.057**				0.057**
				(0.024)				(0.024)
Competitor		0.023	0.038	0.023		0.021	0.036	0.019
		(0.027)	(0.026)	(0.027)		(0.027)	(0.026)	(0.027)
Science		-0.033	-0.029	-0.030		-0.040	-0.036	-0.039
		(0.025)	(0.025)	(0.024)		(0.025)	(0.025)	(0.025)
Dep. lag	-0.011***	-0.010**	-0.010**	-0.010**	-0.022***	-0.021***	-0.021***	-0.021***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Control	No	No	No	No	Yes	Yes	Yes	Yes
Industry#Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	54,783	54,783	54,783	54,783	54,783	54,783	54,783	54,783
R^2	0.088	0.089	0.088	0.088	0.091	0.091	0.091	0.091

Standard errors are clustered at the firm level and are reported in parentheses.

Dependent variable is the change between year $t+4$ and t in sales, and winsorized at 1st and 99th percentiles.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5 Conclusion

The purpose of this study is to investigate the effect of cooperation on firm performance and productivity. The findings demonstrate that cooperation with different types of partners can have significant impacts on firm performance and productivity in Hungary, an emerging innovator country.

Specifically, scientific collaboration partners can increase a firm's TFP growth by 6%-8% after 4 years. In terms of firm performance, both vertical and horizontal partners are important. Collaboration with competitors can increase a firm's value added growth by 5%-6%, while collaboration with both suppliers and customers simultaneously can increase a firm's sales growth by 5%-6% after 4 years.

These results provide valuable information for decision makers and firms on which cooperation partners to prioritise or subsidise to increase productivity and firm performance. The findings may also be applicable to other similar countries that rely on technology adoption to approach the technology frontier.

However, it is essential to note that the effects of collaboration can depend on the stage of technological development in the country. In addition, the time required for cooperation to exert its effect can be different in an emerging innovator country. Also, if collaboration with partners has significantly positive effects, then it is interesting why there are firms that do not collaborate with other actors. From the policymakers' point of view, it could be useful to know more about firms that cannot or do not want to cooperate with other actors. Therefore, further research should investigate the dynamism of cooperation effects and the hampering factors of collaboration.

Overall, this study contributes to the literature on cooperation and innovation by providing evidence from an emerging innovator country, where the determinants and impacts of cooperation may differ from those in developed countries.

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Appendix

Table A1: Variable description

Variable	Description
Innovative	Equals 1 if the firm is product, process, or organization innovative
NO cooperation (NO Co)	Equals 1 if the firm is product, process, or organization innovative and does not cooperate with any type of partner
Cooperation (Co)	Equals 1 if the firm cooperates with any type of partner
Supplier	Equals 1 if the firm cooperates with its supplier
Customer	Equals 1 if the firm cooperates with its customer
Competitor	Equals 1 if the firm cooperates with its competitor
Science	Equals 1 if the firm cooperates with a scientific actor (university, research institution, expert)
Vertical	Equals 1 if the firm cooperates with its supplier OR customer
Both vertical	Equals 1 if the firm cooperates with its supplier AND customer
Size	Log employee
Foreign	Equals 1 if at least 10% of the firm is held by foreigners
Exporter	Equals 1 if the firm reported positive exports
Own R&D	Equals 1 if the firm reported that it has in-house R&D activity
Cont. own R&D	Equals 1 if the firm reported that it continuously has in-house R&D activity
Occ. own R&D	Equals 1 if the firm reported that it occasionally has in-house R&D activity
Funding	Equals 1 if the firm reported that it has received funding (from local authorities, government, or the EU)
Value added	Sales and the capitalized value of self-manufactured assets minus materials, cost of goods sold and other costs.
Labour prod.	Labour productivity - Log value added/employee
TFP	Total Factor Productivity estimated with Levinsohn and Petrin (2003) method, by industry