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Quadruple helix in reality: An empirical inquiry into innovation cooperation triggering competitiveness in central and northeastern Europe

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Abstract

Though innovation cooperation was rather out of business interest even almost a hundred years ago, uncertain economic conditions and crises, competitive struggle and globalisation now make it a necessity for firms to survive. Since the first systemic theories in the 1980s, scholars have developed several policy models covering innovation-focused relations of firms with researchers, institutions and other actors to spur their competitive advantages. One of them, quadruple helix, covers also societal impacts. This paper presents the results of the empirical research of such relations – the effects of five cooperation levels on five innovation forms in Slovakia, Czechia, Hungary, Estonia, Lithuania and Latvia. Applying a propensity score matching pairing method with probit model and nearest neighbour setting, a caliper of 0.2 and common support to the Eurostat's CIS microdata from 2012, 2014 and 2016 (a total of 63,615 observations), I identified that the majority of cooperation positively affected innovation processes and competitiveness. More specifically, Slovak firms benefited mainly from firm-public sector cooperation and Czech firms from the cooperation of firms with both research entities and public institutions. While Hungarian, Estonian and Lithuanian results vary by innovation form, Latvian firms got the best results from the last three cooperation levels. In general, the strongest positive effects were measured for goods innovation, while cooperation in the innovation of logistics processes had a rather negative effect in most selected countries. Finally, the research confirmed that cooperation is essential for the majority of firm innovation activities, stimulating competitiveness and business performance.

Keywords: *Innovation, Cooperation, Competitiveness, Quadruple Helix, Central Europe, Northeastern Europe*

JEL Classification: O30, C25, P13

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1 INTRODUCTION

Is a man an individualist living in a society or not? Already 18th and 19th-century political philosophers addressed some parts of the individualism-collectivism struggle when answering this question (Triandis, 2018). In general, humans want to think, receive information, and act competitively and without external influence or guide; we want "life by means of the individually initiated process of thought, of conceptual consciousness" (Machan, 2016, p. 11). However, "most people start by being collectivists, attached to their families" (Triandis, 2018, p. 14). Moreover, social interactions within the environment significantly shape their behaviour, knowledge and personal development.

Certain forms of cooperative interactions are also essential for the viability and rivalry of firms. According to Manski (2000), a part of microeconomics sees them as groups of decision-making agents equipped with their preferences, assumptions and constraints. To maximize the expected utility, these agents co-interact both inside and outside of the firm. Furthermore, the

mechanisms of economic endogeneity, learning-by-interaction, knowledge-sharing and R&D spillovers push to emerge innovation-related relationships of the firm with other actors. Such innovation cooperation allows access to complementary technological resources and other markets, fosters innovation development and increases the competitiveness of partners (de Faria et al., 2010). It also helps to systematize the entire innovation process into policy models such as triple helix or quadruple helix (Cai & Lattu, 2022).

Over the last two decades, many scholars have analysed the impacts of innovation cooperation around the world. Even so, to what extent such cooperation contributes to innovation and competitiveness in central and northeastern Europe remains unclear.

This paper clarifies the contribution with empirical research on the existence of specific quadruple helix relations in central and northeastern Europe. Research on the effect of five forms of cooperation (private/public/research/consulting/general) on five forms of innovation (goods/service/method/logistics/support) was carried out using the Eurostat's Community Innovation Survey (CIS) microdata collected in Slovakia, Czechia, Hungary, Estonia, Lithuania and Latvia in 2012, 2014 and 2016. The paper is divided as follows: the second chapter specifies the literature, the third explains the conceptual framework, data and methods, the fourth presents the results, and the fifth summarises and discusses the outcomes.

2 THEORETICAL BACKGROUND

Though today one of the most important elements of innovation processes, cooperation was not always in the game. Even Schumpeter (1934) at first looked only one way at the intra-business creation of new ideas. The significance of innovation cooperation has increased thanks to new ideas brought by the theories of endogeneity (Lucas, 1988), learning-by-doing (Arrow, 1962) and related learning-by-interaction, knowledge spillovers (Audretsch & Feldman, 1996), R&D cooperation (Cassiman & Veugelers, 2001) and national innovation systems (Lundvall, 2007). Other related systemic theories include regional innovation systems (Fritsch, 2001), clustering (Breschi & Malerba, 2001), technological systems (Bergek et al., 2015), sectoral systems (Malerba, 2002) and mission-oriented systems (Hekkert et al., 2020).

For policy application, a specific triple helix (3H) spiral-shaped model as a partnership of industry, universities and the public sector was developed by Etzkowitz and Leydesdorff (2000). Unlike standard university knowledge production – Mode 1 – and cross-organizational knowledge production – Mode 2 (Ivanova, 2014), this model tries to "capture the multiple reciprocal relationships of different innovation actors at different points of innovation process" (Arnkil et al., 2010, p. 65), without the precondition of nationality or regionality (Leydesdorff, 2012). Newer model extensions/alternations are quadruple helix (4H) (Carayannis & Campbell, 2009) as 3H plus the public, quintuple helix (5H) (Carayannis & Campbell, 2010) as 4H plus the natural environment, and neo-triple helix (Cai, 2022) integrating 3H, 4H and 5H into one biological concept of relations between gene, organism and environment. Several helix models were recently used for the analysis of regional development (Sá et al., 2018), Industry 4.0 (Steenkamp, 2019), transportation (Gkoumas & Christou, 2020) the wine industry's competitiveness (Cabrera-Flores et al., 2020), renewable energy (Lerman et al., 2021) and emerging economies (Baier-Fuentes et al., 2021).

The need for helix cooperation models has *inter alia* arisen due to the absence of means needed for currently demanding innovation processes (Hernández-Trasobares & Murillo-Luna, 2020), whereas it eases acquiring particular knowledge and eliminating high costs (Triguero et al.,

2018) and advances international efforts on technology for sustainable development (Pandey et al., 2022). Cooperation stimulates innovation ability, competitiveness and living standards (Doğan, 2016, p. 70), and stimulated competitiveness leads to increasing interest in export (Adamovský et al., 2020, p. 261).

Regarding 4H applied in our research, the first three systemic actors are generally defined. However, there are many approaches to catching the fourth 4H actor, including 'external scientific experts' (Baber, 2001), 'media', 'creative industries', 'culture', 'values', 'lifestyles', 'art' and the 'creative class' (Carayannis & Campbell, 2009), 'users' (Arnkil et al., 2010), 'civil society' (Afonso et al., 2012), 'internationalisation' (Leydesdorff, 2012), again 'media' (Ivanova, 2014), 'citizen' (Campanella et al., 2017), 'society' (Galvão et al., 2017), and very broadly "an arena where triple helix actors in different value adding relationships take on different roles" (Hasche et al., 2020, p. 523). Other approaches are reviewed by González-Martinez et al. (2021). I narrow the research area to 4H consisting of entrepreneurs, public institutions, research organisations and civil society represented by non-governmental (NGOs) and consulting organisations. Along with innovation itself, the fourth actor focuses on other social roles for the support and interconnection of innovation mechanisms. Lindberg et al. (2014, p. 6), who researched NGOs as a part of 4H, call them "linking enterprises with governmental actors". The benefits of such a relationship are specified for the topics of corporate value creation (Dahan et al., 2010), social innovation (Jamali et al., 2011) or 'green' production (Brunner & Marxt, 2013).

3 CONCEPTUAL FRAMEWORK AND DATA

This paper presents empirical research on the 4H model in Slovakia, Czechia, Hungary, Estonia, Lithuania and Latvia. The primary research objective was to specify the strength and differences in the effect of five forms of cooperation (four helices + general cooperation) on five forms of innovation triggering competitive advantages. The pre-modelling assumptions were:

- reflection of the reality in 4H – all helix models represent a narrow, limited and illustrative idea of the complex system
- existence of the same or similar 4H actors – intertwined history, regional scope, development and performance of selected countries provide a good background, although there are differences in the levels of knowledge-based transformation
- data quality – CIS is conducted by local statistical offices voluntarily; only technologically innovative firms have to answer questions about their collaborators

While I focused mainly on the country-based comparison of the effects, Slovakia was selected as a reference country. Following that, the research hypotheses were:

- Product innovation: Cooperation with any 4H actor has a stronger effect on the ability to introduce new or significantly improved goods (H1) / services (H2) into the market in Slovakia than in other selected countries.
- Process innovation: Cooperation with any 4H actor has a stronger effect on the ability to introduce new or significantly improved production methods (H3) / delivery or distribution systems (H4) / support activities (H5) for firms in Slovakia than in other selected countries.

The key methodological practice was a counterfactual analysis based on the propensity score matching (PSM) pairing method of Rosenbaum and Rubin (1983). The method adjusts the selection bias of the statistical sample when pair observations affected by a certain intervention

with non-affected observations using the propensity score estimated for each observation (Randolph et al., 2014). The propensity score expresses the percentage probability of the activity being carried out if the observation is subject to intervention. I estimated the propensity scores based on the following probit equation:

$$Propensity(Innovation_{kt} = 1) = f(Icharact_{kt}) + \varepsilon_{kt} \text{ (probit)}$$

Later, I performed the pairing based on the estimated propensity scores using the nearest neighbour method with a calliper (tolerated range between the propensity scores in one group) of 0.2 (recommended by Garrido et al. (2014)) and common support (exclusion of the scores that are outside the range between intervention and control group). The pairing results in a set of information expressing the intervention effect on the behaviour of the observation:

- The average treatment effect on the treated (ATT) indicator explains the percentage effect of the intervention in the group of observations subject to intervention compared to the control group.
- Deadweight loss (DWL) explains the effect significance as the ratio of percentage changes of affected and control groups.

The models were applied to the microdata set collected via Eurostat's Community Innovation Survey (CIS) (Eurostat, 2022). The dataset consisted of the pooled cross-sectional binary structure data from Slovakia (8,962 observations), Czechia (16,267), Hungary (19,995), Estonia (5,308), Lithuania (7,082) and Latvia (6,001) for the years 2012, 2014 and 2016 (in total 63,615 observations). While the survey is conducted independently every two years, I assumed continuous behavioural changes of each respondent who participated in the survey more than once. The data collection methodology did not change in these years. Also, the nature of the research did not require tracking of the intertemporal effect. Though Eurostat also provided more recent data for 2018, the collecting methodology had changed and therefore could not be used in the analysis. Tables 1-3 specify selected intervention (cooperation levels), dependent (innovation forms) and independent (contributing to the formation of relationship) variables.

Tab. 1 – Intervention (cooperation) variables. Source: based on the data from Eurostat (2022)

Variable	Research name	Description and structure
co	General cooperation	Firms cooperate with any ecosystem actor. CIS variable called "Cooperation arrangements on innovation activities".
co_first	First-level cooperation	Firms cooperate with other firms within an enterprise group, with suppliers of equipment, materials, components, or software, with clients or customers from the private sector or with competitors or other enterprises in the sector.
co_second	Second-level cooperation	Firms cooperate with clients or customers from the public sector or undertake innovation activities as part of a contract to provide goods or services to a public sector organization.
co_third	Third-level cooperation	Firms cooperate with universities or other higher education institutes, or with government, public or private research institutes.
co_fourth	Fourth-level cooperation	Firms cooperate with consultants or commercial labs.

Tab. 2 – Dependent (innovation) variables. Source: based on the data from Eurostat (2022)

Variable	Research name	Description and structure
inpdgd	Product innovation: goods	Introduced onto the market new or significantly improved good. CIS variable "inpdgd".
inpdsv	Product innovation: services	Introduced onto the market new or significantly improved service. CIS variable "inpdsv".
inpspd	Process innovation: production methods	Introduced new or significantly improved method of production in the firm. CIS variable "inpspd".
inpslg	Process innovation: logistic, delivery or distribution system	Introduced new or significantly improved logistic, delivery or distribution system in the firm. CIS variable "inpslg".
inpssu	Process innovation: supporting activities	Introduced new or significantly improved supporting activities in the firm. CIS variable "inpssu".

Tab. 3 – Independent (supportive) variables. Source: based on the data from Eurostat (2022)

Variable	Description and structure
gp	Firm is a part of an enterprise group. CIS variable "GP".
ho_d_0	Headquarters is abroad or not. CIS variable "HO" amended to determine whether the headquarters is located abroad or in the home country.
ENMRG	Firm merged with another firm or took over another firm. CIS variable "ENMRG".
ENOUT	Firm was sold, closed or contracted out some of its functions. CIS variable "ENOUT".
MARLOC	Firm sells goods and/or provides services at specific geographic markets – local/regional market (within country). CIS variable "MARLOC".
MARNAT	As previously – national market (other country regions). CIS variable "MARNAT".
mareur	As previously – other EU/EFTA/CC market. CIS variable "MAREUR".
maroth	As previously – all other countries. CIS variable "MAROTH".
orgbup	Organisational innovation – new business practices for organising procedures. CIS variable "ORGBUP".
orgwkp	As previously – new methods of organising work responsibilities and decision making. CIS variable "ORGWKP".
orgexr	As previously – new methods of organising external relations. CIS variable "ORGEXR".
mktdgp	Marketing innovation – significant changes to the aesthetic design or packaging. CIS variable "MKTDGP".
mktpdp	As previously – new media or techniques for product promotion. CIS variable "MKTPDP".
mktpdl	As previously – new methods for product placement or sales channels. CIS variable "MKTPDL".
mktpri	As previously – new methods of pricing goods or services. CIS variable "MKTPRI".

4 RESULTS

Finally, I developed five model variants for all selected countries and each country individually using STATA 15. The outcomes (ATT and DWL) are printed for each cooperation level, innovation form and country in Figures 1-10.

4.1 Product innovation – goods

The first model results (Figures 1 and 2) point in general to the strongest positive effects in the last two forms of cooperation – a 14% effect was measured for fourth-level cooperation and 11% for third-level cooperation. Positive ATT was also identified for other cooperative forms. In Slovakia, chosen as our reference country, second-level cooperation dominates (ATT 20.2%, DWL 142.55%), while other countries achieved weaker results in this category. An interesting result from Slovakia is a slightly negative effect of first-level cooperation (ATT -1.26%) caused probably by not quite well-functioning goods-innovation-oriented relations or higher competition between Slovak firms triggered by other factors. The outcome of the DWL calculation, 97.71%, confirms this.

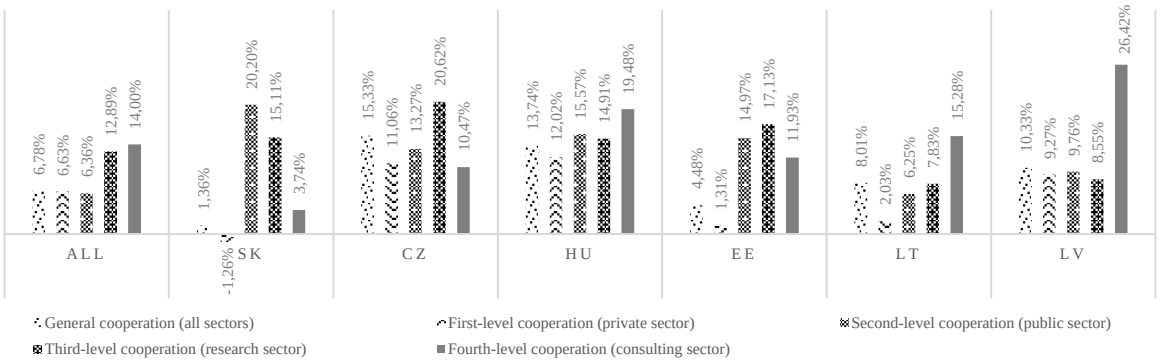

Fig. 1 – ATT for product innovation – goods. Source: own PSM calculations

Czechia and Estonia reached the best results in firm-research sector cooperation (CZ: ATT 20.62%, DWL 135.59%; EE: ATT 17.13%, DWL 152.44%) and Latvia, Hungary and Lithuania in firm-consulting sector cooperation (LV: ATT 26.42%, DWL 168.29%; HU: ATT 19.48%, DWL 141.44%; LT: ATT 15.28%, DWL 140%). The best overall first-level cooperation was found in Hungary (ATT 12.02%, DWL 125.1%). On the contrary, the worst results, though positive, were identified for firm-firm cooperation in Estonia (ATT 1.31%, DWL 103.58%), Lithuania (ATT 2.03%; DWL 105.13%) and Hungary (ATT 12.02%, DWL 125.18%), for firm-research sector cooperation in Latvia (ATT 8.55%, DWL 115.15%) and firm-consulting sector in Czechia (ATT 10.47%, DWL 115.68%). The worst overall second-level cooperation was calculated for Lithuania (ATT 6.25%, DWL 114.29%).

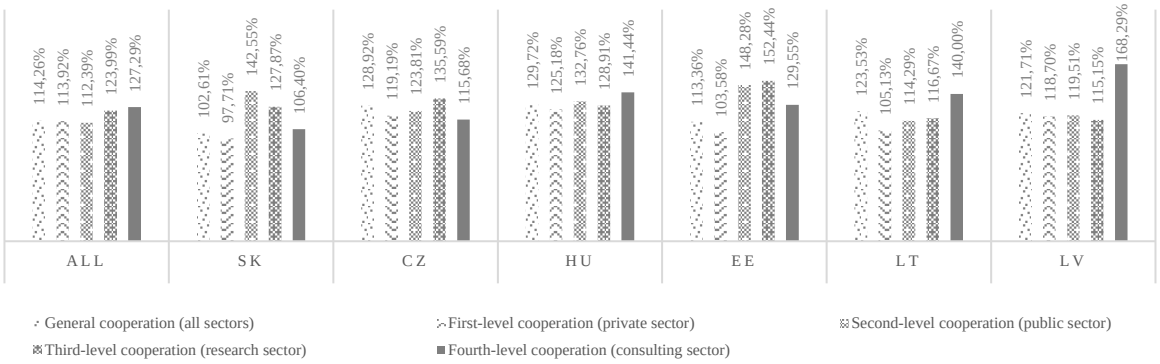

Fig. 2 – DWL for product innovation – goods. Source: own PSM calculations

4.2 Product innovation – service

Concerning the second form of product innovation, I identified the largest positive general effect in the case of second-level cooperation (ATT 9.38%, DWL 124.73%). This relationship also dominated in all individually monitored countries (Figures 3 and 4). The largest effect was measured in Latvia (ATT 18.29%, DWL 160%), followed by Estonia (ATT 17.11%, DWL 160.38%), Slovakia (ATT 16.16%, DWL 141.03%) and Lithuania (ATT 15%, DWL 136.36%). By contrast, our reference country showed the worst result in first-level cooperation (ATT 3.78%, DWL 112.57%).

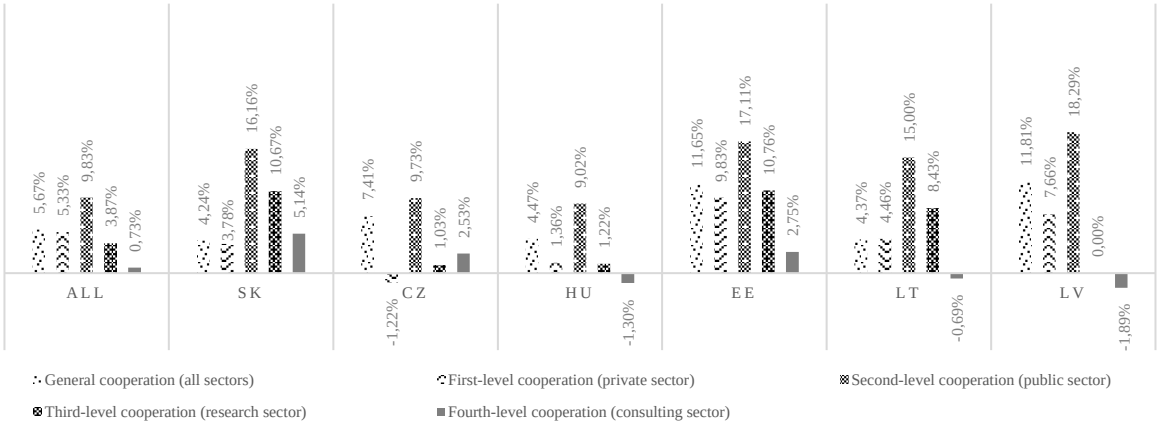

Fig. 3 – ATT for product innovation – service. Source: own PSM calculations

While Slovakia and Estonia had positive effects measured for all cooperation levels, I found slightly negative results for firm-firm relations in Czechia (ATT -1.22%, DWL 96.58%) and firm-consulting sector relations in Latvia (ATT -1.89%, DWL 94.87%), Hungary (ATT -1.3%, DWL 96 .24%) and Lithuania (ATT -0.69%, DWL 98.39%). The best-functioning first-level and third-level links are in Estonia (ATT 9.83%, DWL 147.17%; ATT 10.76%, DWL 138.57% respectively) and fourth-level links in Slovakia (ATT 5.14%, DWL 115.49%). The worst second-level cooperation outcomes were calculated for Hungary (ATT 9.02%, DWL 125.58%). Finally, Latvia did not experience any effect of firm-research sector cooperation on innovation and competitiveness.

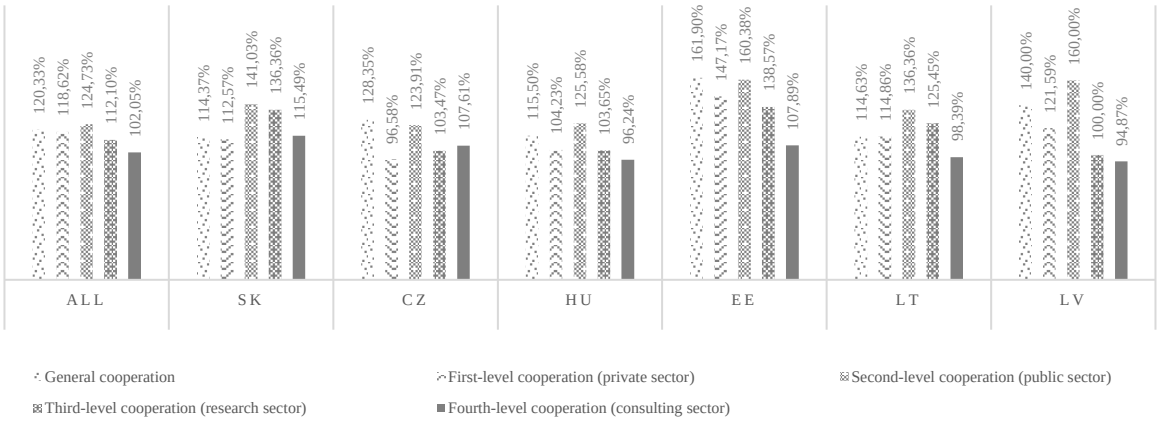

Fig. 4 – DWL for product innovation – service. Source: own PSM calculations

4.3 Process innovation – production method

Regarding the first form of process innovation, in all selected countries except Estonia and Lithuania, I recorded only positive effects (Figures 5 and 6), with general cooperation (ATT 11.65%, DWL 126.46%) and first-level cooperation (ATT 11.63%, DWL 125.88%) having the greatest influence. In Slovakia, I again found the strongest effects of second-level cooperation (ATT 13.13%, DWL 131.71%), followed by third-level cooperation (ATT 10.22%, DWL 122.77%). The weakest effect, however still positive, was calculated for direct cooperation of firms with other firms (ATT 3.24%, DWL 106.90%).

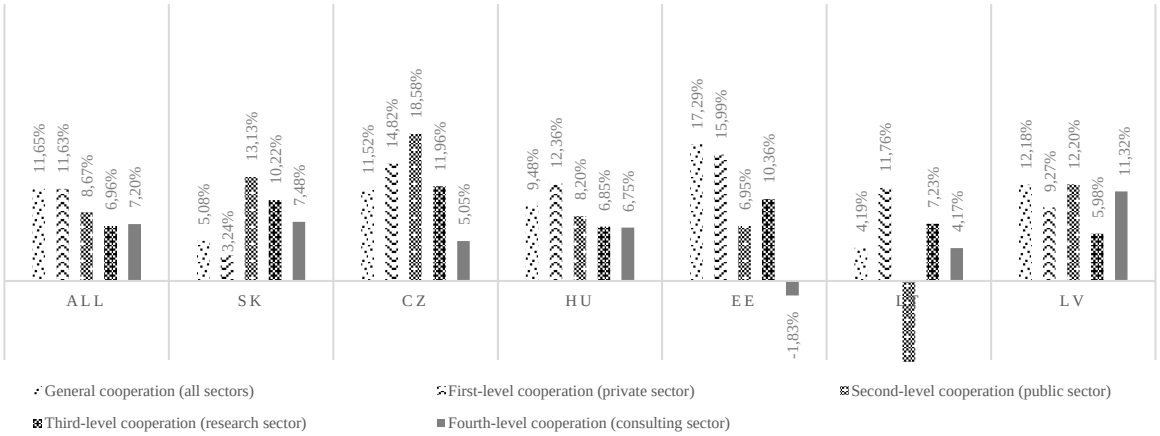

Fig. 5 – ATT for process innovation – production method. Source: own PSM calculations

The relations of firms with firms had the strongest positive effects in Estonia (ATT 15.99%, DWL 140.13%), with public sector and research institutions in Czechia (ATT 18.58%, DWL 137.5%; respectively ATT 11.96%, DWL 123.2%) and with consulting organisations in Latvia (ATT 11.32%, DWL 116.9%). Although positive, firm-firm cooperation least helped in Slovakia (ATT 3.24%, DWL 106.9%) and firm-research sector in Latvia (ATT 5.98%, DWL 109.72%). The most negative effects were calculated for firm-public sector in Lithuania (ATT -11.25%, DWL 85.48%) and firm-consulting sector in Estonia (ATT -1.83%, DWL 96.55%).

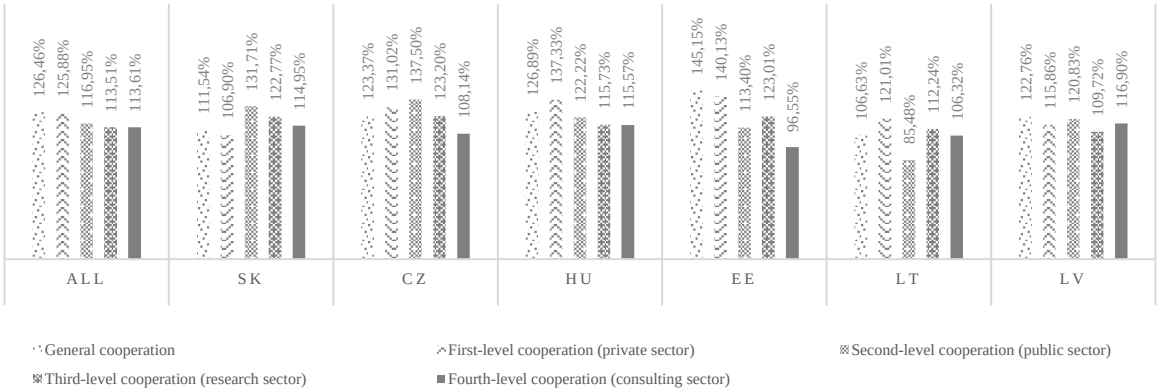

Fig. 6 – DWL for process innovation – production method. Source: own PSM calculations

4.4 Process innovation – logistics, delivery or distribution system

Unlike previous results, this innovation form brought much more significant pessimistic results (Figures 7 and 8). For the first time, I noticed a negative effect in the general results, specifically for third-level cooperation (ATT -0.18%, DWL 99.32%). In Slovakia, a slightly negative impact was recorded for general cooperation (ATT -0.68%, DWL 97.55%). At the same time, second-level and fourth-level cooperation did not bring any additional effect on this form of innovation at all. The best outcome of the reference country was measured for firm-research sector cooperation (ATT 5.33%, DWL 119.67%).

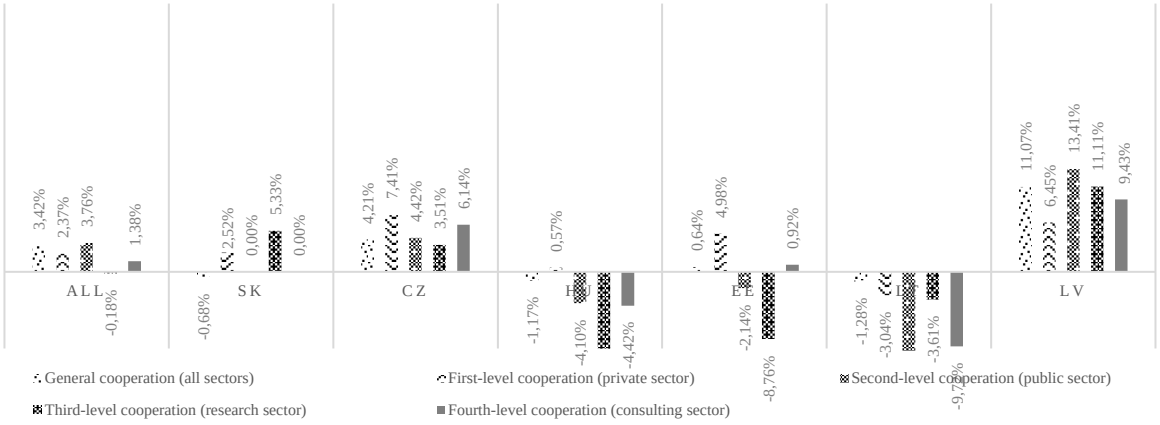

Fig. 7 – ATT for proc. innovation – log., del. or dist. system. Source: own PSM calculations

For first-level cooperation, the strongest effect was found in Czechia (ATT 7.41%, DWL 131.02%) and the weakest in Lithuania (ATT -3.04%, DWL 84.54%). While Latvia dominated in other cooperation levels (firm-public sector ATT 13.41%, DWL 133.33%; firm-research sector ATT 11.11%, DWL 134.21%; firm-consulting sector ATT 9.43%, DWL 123.81%), Lithuania had the worst results in second-level and fourth-level cooperation (ATT -13.75%, DWL 56%; respectively ATT -9.72%, DWL 70.21%) and Hungary in third-level cooperation (ATT -10.02%, DWL 64.35%).

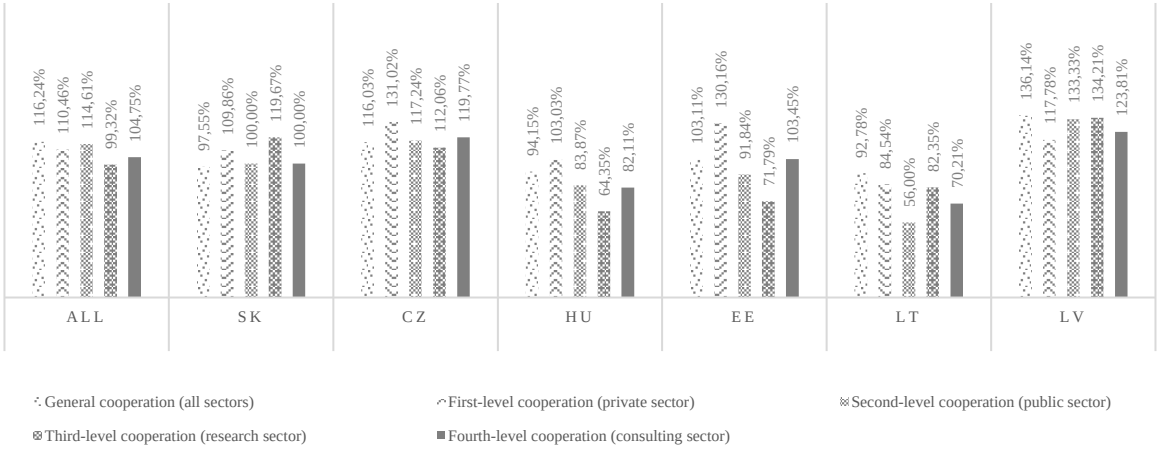

Fig. 8 – DWL for proc. innovation – log., del. or dist. system. Source: own PSM calculations

4.5 Process innovation – support activities

For the last innovation form (Figures 9 and 10), modelling outcomes for all countries indicated some positive effects for first-level (ATT 7.65%, DWL 121.55%) and fourth-level cooperation (ATT 6.96%, DWL 116.29%). On the contrary, cooperation with research institutions brought a slightly negative effect (ATT -0.42%, DWL 99.01%). Though certain negative effects I also calculated for other forms of cooperation, most of the results seem to be positive. In Slovakia, I identified purely positive effects with the strongest general cooperation (ATT 7.29%, DWL 119.11%), followed by fourth-level cooperation (ATT 5.61%, DWL 111.43%). The worst result was measured for firm-research sector relations (ATT 3.11%, DWL 107.14%).

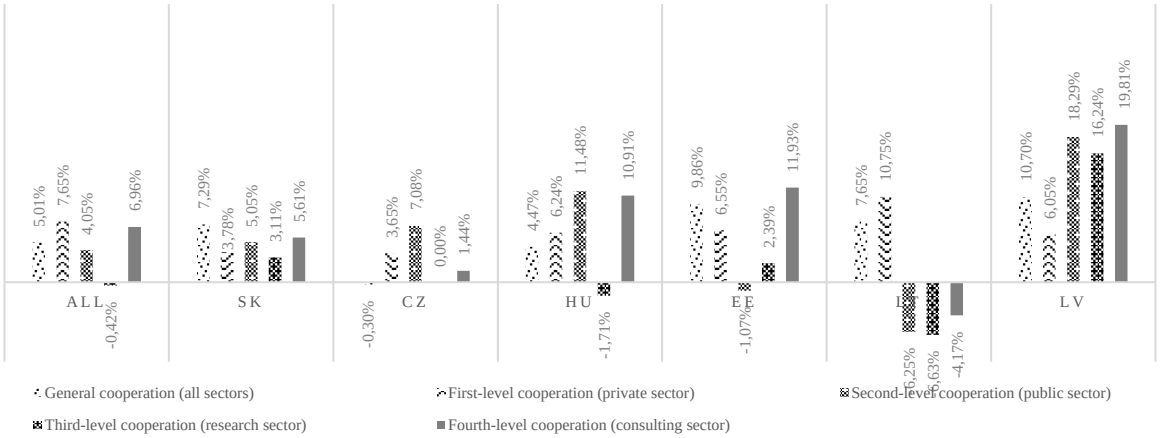

Fig. 9 – ATT for process innovation – support activities. Source: own PSM calculations

The outcomes confirmed contradictory numbers for Lithuania – the best overall effect measured for firm-firm cooperation (ATT 10.75%, DWL 121.54%) and the worst, and negative, effects measured for other levels (firm-public sector ATT -6.25%, DWL 89.8%; firm-research sector ATT -6.63%, DWL 88.04%; firm-consulting sector ATT -4.17%, DWL 93.33%). While Czechia had not-so-good results for firm-firm relations (ATT 3.65%, DWL 108.31%), Latvia dominated in other calculations (firm-public sector ATT 18.29%, DWL 142.86%; firm-research sector ATT 16.24%, DWL 143.18%; firm-consulting sector ATT 19.81%, DWL 151.22%).

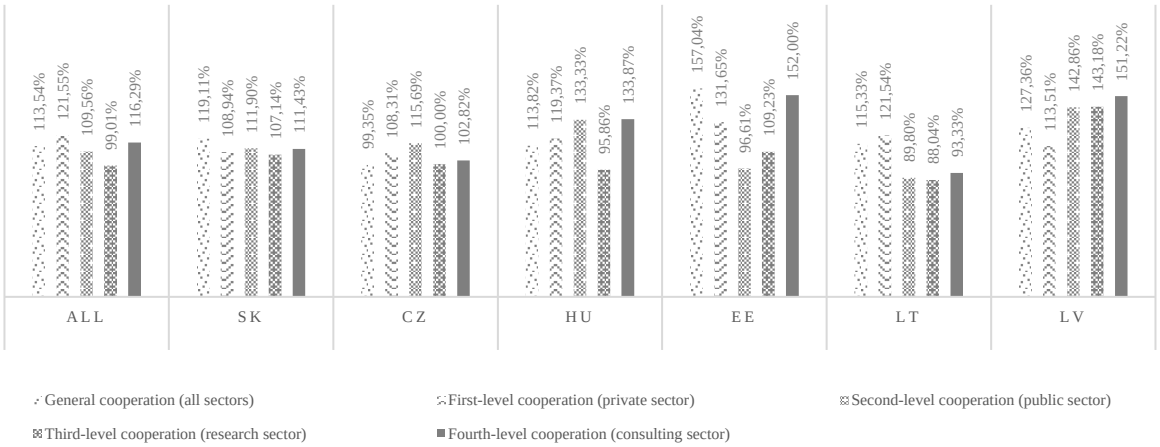

Fig. 10 – DWL for process innovation – support activities. Source: own PSM calculations

5 CONCLUSION AND DISCUSSION

Several empirical studies have investigated the impacts of cooperation on innovation activities and competitiveness. This paper enlarges this empirical base by relative analysis of the effects of innovation cooperation in Slovakia, Czechia, Hungary, Estonia, Lithuania and Latvia reflecting the specific quadruple helix model application. I used counterfactual analysis for measuring the effect of five cooperation levels (general/private/public/research/consulting) on five innovation forms (goods/service/method/logistics/support). The research was based on firm microdata from the Eurostat's Community Innovation Survey carried out in 2012, 2014 and 2016. While the outcomes pointed to many significant differences between selected countries, the paper's implications for businesses and policymakers are summarised below:

- Product innovation – goods: stronger positive effects of the consulting sector (Latvia), public institutions (Slovakia) and research organisations (Czechia); firm-firm relations have a weak to negative (in Slovakia) impact. H1 fully confirmed for second-level cooperation and partially for third-level (only Czechia and Estonia with better results).
- Product innovation – services: best impacts measured for firm-public institutions (Latvia, Estonia, Slovakia and Lithuania with an effect of over 10%), the worst (and negative) for firm-consulting sector (Latvia, Hungary and Lithuania) and firm-firm (Czechia). H2 fully confirmed for fourth-level cooperation and partially for third-level (only Estonia with better results) and second-level (only Latvia and Estonia with better results).
- Process innovation – production method: both best and worst impacts measured for firm-public institutions (Czechia, Slovakia and Latvia with an over-10% effect; Lithuania with a strongly negative result) and a negative result was also found for fourth-level cooperation in Estonia. H3 partially confirmed for second-level cooperation (only Czechia with better results), fourth-level (only Latvia with better results) and third-level (only Czechia and Estonia with better results).
- Process innovation – logistics, delivery or distribution system: the worst overall results; only Latvia and Czechia have all cooperation levels in positive numbers; the strongest positive effects were measured for second-level and third-level cooperation in Latvia, the worst result found for firm-public institutions in Lithuania. H4 partially confirmed for third-level cooperation (only Latvia with better results) and second-level (only Latvia and Czechia with better results; Slovakia with no change).
- Process innovation – support activities: Latvia has again the best outcomes – strongest cooperation effects found for firm-consulting sector and firm-public sector; negative results calculated for Lithuania (second-level, third-level and fourth-level), Hungary (third-level) and Estonia (second-level). H5 partially confirmed for third-level cooperation (only Latvia with better results).

In summary, most cooperative activities brought positive effects on innovation and competitiveness in analysed countries. Slovak firms benefited mainly from the cooperation with public sector and Czech with research organisations and public institutions. While Hungarian, Estonian and Lithuanian results are diverse, Latvian firms benefited from the last three cooperation levels.

Regional-based research on innovation cooperation and its effects on competitive advantages covers several motives. However, the application of helix models is rather limited. Selecting some related papers, Prokop et al. (2021) confirmed positive effects of public funding on the efficiency of knowledge- and cooperation-based resources in Czechia, Odei and Stejskal (2018) pointed to the need for Hungarian manufacturing firms to rely on cooperation with clients and customers, and Rõigas et al. (2018) found that public funding in Slovakia, Czechia, Hungary, Estonia and Lithuania increased the propensity to cooperate with domestic universities (from our selection, only Latvia did not have a positive result). While cooperation is also stimulated through the creation of clusters, Pavelkova et al. (2021) did not confirm the significant effect of clustering on the financial performance of firms in traditional sectors in Czechia. From other European-based studies, Hernández-Trasobares and Murillo-Luna (2020) recently used 3H to confirm the positive synergic effects of cooperation on product, process or combined business innovation in Spain. The methodology of this research is close to ours. According to Medeiros et al. (2020), decomposing the four 4H dimensions showed that industry, government and university have a greater impact on innovation and entrepreneurship in northern than in southern Europe. Kowalski et al. (2022) explained the importance of cooperation for innovation performance based on the analysis of cluster cooperation additionality in Poland. Audretsch

and Belitski (2020) pointed to the high importance of knowledge spillovers for firm productivity in the United Kingdom. Pennacchio et al. (2018) found strong and positive effects of non-competitive collaborations with suppliers, clients and private research institutes in Italy. Jaklič et al. (2014) identified stronger impacts of vertical cooperation with firms than with competitors, universities or public research institutions in Slovenia. Ramadani et al. (2019) confirmed that knowledge spillovers and skilled workers have a positive and statistically significant impact on innovation and performance in the European Union and Balkan transition economies. Finally, according to this paper and other discussed studies, cooperation is essential for the majority of business innovation activities, leading to increased productivity, competitiveness and business performance.

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