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The influence of science–industry collaboration on firms' innovative performance – evidence from the Republic of Croatia

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ABSTRACT

The theory of National Innovation System emphasizes innovation as a source of economic and productivity growth and stresses the importance of collaboration between science and industry. The basic objective of this paper was to research whether there is an interaction between Croatian companies and scientific institutions, and whether it affects an increase of innovativeness of economic entities. The results of the performed empirical research and their econometric analysis indicate a conclusion that a positive impact of the collaboration on intensity of innovation in Croatian companies is still absent. The results indicate that the system of innovation in the Republic of Croatia, when compared to developed countries, is still in a transition and that commercialisation of academic knowledge is a phenomenon paid somewhat greater attention only recently.

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1. Introduction

According to the theory of National Innovation Systems (NIS) (with main representatives such as Freeman [1987], Lundvall [1992] and Nelson [1993]), the interaction between science and economy is a recipe for an increase of the innovative capacity of economic entities. It is important to boost innovativeness because innovations are deemed, by the innovation systems theory, as a source of economic and productivity growth of comparably great importance. Many countries strive to provide an impetus for collaboration between the two sectors through their public policies. Regarding that in the Republic of Croatia there is not research of that kind, this aticle explores if such an interaction has been developed in Croatia and whether it affects the capacity of economic entities for innovation. The main goal was to research whether there is an interaction between Croatian companies and scientific institutions, what results it has achieved and whether the collaboration has an influence on an increase on the economic entities' innovativeness.

For the purposes of this article we have used the results from the empirical research conducted in 2011. The research was conducted as a part of a larger project that explored the

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intensity and quality of collaboration between Croatian scientific and business entities, for the purpose of a doctoral dissertation. The research was conducted online via the webpage www.surveymonkey.com, by the first author of this article. The survey instrument was a highly-structured questionnaire. For the purposes of this article, only the results relevant to this article's research subject were used. The survey sample encompassed 120 companies with headquarters in various counties of the Republic of Croatia, and were active in diverse industries. They were selected based on their revenue. The sample contains a total of 120 companies. The total sample was divided by companies that collaborated with the Croatian scientific sector (public institutions of higher education and public institutes), 54 companies in total (N1 sample) in the relevant three year period (2008–2010), and by companies that did not achieve any such collaboration in the relevant time period, 66 companies in total (N2 sample). Distribution of the total researched population into the two samples is exceptionally significant for testing the difference in their level of innovativeness regarding the existence of collaboration.

The initial hypothesis is that there is not a significant influence of science–industry collaboration on Croatian companies' innovativeness. Methodology applied to present the results of the research encompasses descriptive and univariate statistics (chi-square test, ANOVA F-test, Spearman's method of correlation and Pearson's correlation). The rest of the article is structured as follows: the second section provides an overview of scientific and professional literature. The third section provides an analysis of the results of the performed empirical research in the Republic of Croatia, while the final section contains a concluding summary.

2. Literature review

The theory of NIS appeared shortly after the appearance of Endogenous Growth Theory. The concept emphasises the role of endogenous factors of economic growth. However, these are no longer research and development (R&D) and education per se (linear model of innovation). The concept emphasises innovation as a main source of economic growth and the importance of collaboration (interactive model of innovation) between science and industry (Jeleč Raguž, Budimir, & Letinić, 2015, p. 99). The main feature of the concept is that the economic ability to innovate depends not only on the activities of certain entities (companies, universities, research institutions, etc.) but on how these entities collaborate as part of the system. The originators of the NIS concept were Swedish economist Beng-Åke Lundvall and English economist Christopher Freeman. According to Freeman, NIS includes a network of institutions of private and public sectors whose activities and mutual interactions initiate, import, modify and spread innovation. According to Lundvall, NIS includes key organisations that collaborate during the process of production and dissemination of innovations.

Numerous empirical studies support the idea that the interaction with scientific institutions favourably influence the innovativeness of companies (Jaffe, 1989; Mansfield, 1998; Kaufmann & Tödtling, 2001; George, Zahra, & Wood, 2002; Švarc & Lažnjak, 2003; Lööf & Broström, 2008; Yang, Motohashi, & Chen, 2009; Eom & Lee, 2010; Aissaoui, 2010; Guan & Zhao, 2013). For instance, in the late 1980s, Jaffe (1989) proved in his empirical study that university research significantly influences the number of corporate patents, especially in the fields of pharmaceutical products and preparations, medical technology, electronics, optical and nuclear technology. Mansfield (1998) published that 15% of new products

developed in the US in the observed period from 1986 to 1994 would not be developed without support from academic research (the research encompassed companies from seven different industries).

Presenting empirical results in their paper, Kaufmann and Tödtling (2001) concluded that the interaction with science stimulates innovativeness of companies. They claimed that it is because of far greater sources of knowledge available to the companies than in cases of interactions within individual companies. However, according to the research results, a positive influence on companies' inventiveness is generated not only by universities but also by suppliers and consultants, while consumers did not impart any positive impact. George et al. (2002) have proven that companies which co-operate with universities (n = 97), unlike those which do not have such a relationship in place (n = 50), have a greater number of registered patents and significantly lower R&D costs than companies which have not developed the interaction processes.

Belderbos, Carree, Diederen, Lokshin, and Veugelers (2004) have proven that formal collaboration with universities and research institutes improves technological capabilities of R&D activities within companies, as well as their efficiency, thereby indicating that universities are significant sources of knowledge for radical innovations. Lööf and Broström (2008) have proven that co-operation with universities had a favourable effect on large Swedish companies (employing 100 people or more) in terms of their innovative sales and tendency to register patents. Furthermore, Yang et al. (2009) indicated through their empirical findings that the level of innovation of new technology-oriented companies located in a scientific park significantly exceeded innovativeness of companies found outside such parks. The reasons are networking opportunities afforded by the park and better links with scientific institutions. Using a Korean national survey aimed at innovation culture evaluation (Innovative Survey), Eom and Lee (2010) have proven a positive correlation between collaboration with universities and production innovation in innovative companies in the Republic of Korea. Using a general sample of 2171 companies found in the fifth French national innovation culture survey (French Community Innovation Survey), Aissaoui (2010) has proven that collaboration with scientific institutions has a favourable effect on intensity of innovation in French companies.

In addition to the studies that have shown a positive correlation between variables observed in this article, there are studies that failed to prove such a positive correlation (Laursen & Salter, 2004; Radas, 2005; Medda, Piga, & Siegel, 2006; Puffal & Teixeira, 2014; Jaklič, Damijan, Rojec, & Kunčič, 2014). For instance, while assessing the commercial value of academic output, Klevorick, Levin, Nelson, and Winter (1995) determined that the direct influence of academic research on innovativeness of companies is very low compared to other sources of funding. Based on the results of a national innovation culture empirical assessment survey, Laursen and Salter (2004) have proven that a very low number of companies draw direct benefits from universities as sources of information and knowledge in their innovation-related activities. The R&D departments within companies, suppliers and consumers are significantly more conventional sources of knowledge in such innovation-related activities. Using Italian manufacturing companies' data, Medda et al. (2006) have determined in their empirical study that there were favourable effects of joint research conducted with another company, while joint research with universities did not increase company productivity. Jaklič et al. (2014) analyses the importance of innovation co-operation on the innovation activity of Slovenian firms. Within innovation co-operation, a significant and

positive effect on innovation activity is confirmed especially with customers, suppliers and advisors, but not for co-operation with public universities and R&D institutes.

In the domain of Croatian science, there are several authors who have studied the science–industry collaboration, and its impact on the innovativeness of companies. Žuvela (1993) is one of the first authors to write about required co-operation of science and the economy in general terms. He analysed the significance of scientific parks for economic development as an infrastructural venue where representatives of science and business would meet. A similar conclusion also applies to Brunsko (1995) who indicated the significance of technological parks as bridges between companies and universities for development of the economy. However, neither of these authors analyse the influence of collaboration on innovativeness.

In their paper, Švarc, Grubišić, and Sokol (1996) indicate that collaboration of industry and research organisations in Croatia is at a low level and that there are significant obstacles presented by both sides. Švarc (2001) wrote about the NIS and concluded that the existing R&D system in Croatia is characterised by a lack of infrastructural institutions, financial instruments, programmes and government incentive policies aimed at the advancement of partnerships between science and the economy and the commercialisation of research results (Švarc, 2001, p. 1067).

In her paper, Radas (2005) described research results related to entrepreneurs' motives for collaboration with the scientific community, satisfaction with the collaboration and how it affected selected indicators of innovativeness. Radas determined that the intensity of science–economy collaboration in the Republic of Croatia does not contribute to an increased number of patents or a greater proportion of income generated by new products. Radas and Vehovec (2006) researched the interaction of science and industry from the scientists' point of view. Their paper primarily focuses on research of scientists' motivation for the co-operation and their perception of obstacles.

The literature review presented an overview of scientific papers that dealt with the influence of the science–industry collaboration on innovativeness of companies. First, the papers that proved a positive connection were presented, and then papers that proved a negative connection. A conclusion which may be drawn from the review of Croatian publications is that Croatian authors have not yet sufficiently tackled the topic. Until this article, in addition to the paper by Radas, there was no scientific-based knowledge about the intensity of collaboration and its influence on innovativeness of companies in Croatia. Radas (2005) explored the attitudes of entrepreneurs about the researched impact. This article explores not only the attitudes of entrepreneurs, but the researched sample of firms in Croatia is divided into two groups, those who had collaboration and of those who did not. Then, according to the objective indicators, such as number of innovations and patents in a company, the differences in their innovativeness are tested.

3. The results of the empirical research in the Republic of Croatia

3.1. Methodological framework of the research

The fundamental research issue of this article is whether the collaboration between science and the economy contributes to increased innovativeness of economic entities in the Republic of Croatia. Therefore, the object of the research was to explore and analyse the results of such interactions and their impact on the innovativeness of companies, i.e.,

to research the link between economic entity innovativeness indicators on one hand and existence of collaboration on the other. An acceptable method for evaluating the impact of collaboration on innovative economic practices entails comparing innovativeness of companies that collaborated with scientific institutions and of those that had no such collaboration. The empirical research was conducted online with a highly structured questionnaire as a survey instrument.

The research sample contains 54 companies (N1 sample) which collaborated with the scientific sector in the relevant three years (2008–2010) and 66 companies which did not achieve any such collaboration in the relevant period (N2 sample). Distribution of the total researched population into the two samples is significant for testing the difference in the level of innovativeness. The structure of the researched population by their fields of activity and the achieved collaboration is presented in Table 1.

Difference of innovativeness levels of the N1 (collaboration existed) and the N2 (collaboration absent) samples was tested for the purpose of this article. Indicators that allowed testing of the previously mentioned differences are the total numbers of innovations in a company in the relevant three years (2008–2010), new products and services introduced to the market and new production processes introduced in the company. The article employs the term innovation in a narrow sense because the monitoring of innovativeness in Croatian companies is still insufficiently developed. In addition to the above, innovations in a broader sense also encompass expanding into new markets in the country or abroad, organisational structure changes, marketing concept modifications, new processes with the offer of goods and services, implementations of new strategies, i.e., everything new and contributing to the development of business. The inventiveness levels variations have also been tested according to the total number of patents registered by the company in the same period in addition to the number of new products, services and production processes. Descriptive and univariate statistics (chi-square test, ANOVA F-test, Spearman's method of correlation and Pearson's correlation) have been used to analyse the research results.

Table 1. The structure of the surveyed companies according to their activity (according to National Classification of Activities [NKD], version 2007).

Activity of the company (NKD 2007)	N1 companies (collaboration existed)	N2 companies (collaboration absent)	The total number of companies (N1+N2)
A Agriculture, forestry and fishing	0	2	2
B Mining and quarrying	0	2	2
C Manufacturing	26	24	50
D Electricity, gas, steam and air conditioning supply	1	1	2
E Water supply, sewerage, waste management and remediation activities	1	1	2
F Construction	5	1	6
G Wholesale and retail trade; repair of motor vehicles and motorcycles	2	10	12
H Transportation and storage	1	2	3
I Accommodation and food service activities	1	0	1
J Information and communication	6	11	17
K Financial and insurance activities	1	1	2
M Professional, scientific and technical activities	8	10	18
N Administrative and support service activities	0	1	1
P Education	1	0	1
R Arts, entertainment and recreation	1	0	1
Total	54	66	120

Source: Results of the empirical research.

3.2. Empirical analysis of impact of collaboration to economic innovative performance

An answer to the question of whether collaboration of science and the economy impacts economic innovative practice in the Republic of Croatia required a more detailed analysis of responses provided through the survey. In order to test the differences between innovativeness of companies where the co-operation existed and those where it was absent, it was necessary to distribute the sample in two sets based on the responses provided through the survey. The surveyed companies included 54 (45%) which responded that the collaboration existed in the relevant period, while 66 companies (55%) responded that they did not have any kind of the relevant collaboration.

The surveyed companies were then asked if they had introduced a new or significantly improved product/service to the market and/or a new production process in the company in the relevant three years (2008–2010). The number of companies which responded affirmatively to the question is presented in Table 2.

Since the responses came from two samples, discrepancy between the responses was tested. On average, 42.6% of the companies in the N1 sample (co-operation existed) introduced one of the above forms of innovation, while 40.4% companies in the N2 sample (co-operation absent) implemented innovations. It is apparent there is no significant difference in innovativeness of the companies regardless of their co-operation.

In the following response, the surveyed companies were required to indicate the total number of implemented innovations and registered patents in the company in the relevant period. According to the number of innovations indicator, the lowest value in both samples N1 and N2 amounts to 0, while the maximum value is 20. The most frequent response provided was 0 (Mo = 0). According to the number of registered patents indicator, the lowest value in the sample N1 is 0 and the highest is 5, while in the sample N2 the lowest value is 0 and the highest one is 1. The most frequent responses of those surveyed in both samples were 0.

The responses indicate significant deviations in terms of achieved innovativeness of the surveyed companies in both samples. The reason for such great deviations of innovativeness is most probably to be found in the structure of the sample encompassing companies in diverse fields of activities. According to the responses provided by the surveyed sample, the most inventive companies belong to C, J and M classifications of activities (in accordance with the National Classification of Activities [NKD] of 2007), i.e., manufacturing (C), information and communications activities (J) and professional, scientific and technical activities (M). The difference of innovativeness between the two samples was further tested in accordance with indicators presented in Table 3. The difference was tested using the

Table 2. Companies that have implemented some form of innovation (N1 and N2 sample) (2008–2010).

Has your company introduced some of these forms of innovation in a period of three years (2008–2010)?				
	N1 companies (collaboration existed)	Share in N1 (%)	N2 companies (collaboration absent)	Share in N2 (%)
Yes, new or significantly improved product	22	40.7	25	37.9
Yes, new or significantly improved service	23	42.6	26	39.4
Yes, new or significantly improved production process	24	44.4	29	44.0
Total	69	42.6	66	40.4

Source: Results of the empirical research.

Table 3. Implemented innovations and registered patents according to the N1 and N2 samples (2008–2010).

	N1 companies (collaboration existed) (54 companies)			N2 companies (collaboration absent) (66 companies)		
	Total	M_o	M_e	Total	M_o	M_e
Number of innovations	236	0	3	183	0	2
Number of registered patents	9	0	0	4	0	0

Source: Results of the empirical research and authors' calculations.

Table 4. Results of Chi-Square test.

Statistic	DF	Value	Prob
Chi-Square	20	12.4977	0.8979
Likelihood Ratio Chi-Square	20	11.2527	0.9394
Mantel-Haenszel Chi-Square	1	0.7890	0.3744
Phi Coefficient		0.3686	
Contingency Coefficient		0.3458	
Cramer's V		0.2606	

Source: Authors' calculations based on the results of the empirical research.

chi-square test. A zero hypothesis (H0) entails an assumption that there is no statistically significant difference between the samples, while an alternative hypothesis (H1) entails an assumption that there is a statistically significant difference between the samples. The test results are provided in Table 4.

Since the chi-square test indicates a p-value of 0.8979, there is no reason to discard the zero hypothesis and it should be accepted. Therefore, one arrives at the conclusion that there is no difference in innovativeness of the two observed sets, i.e., between those companies which collaborated with scientific institutions and those which had no such co-operation in place. The above chi-square test results prove that the existing forms of collaboration of Croatian scientific institutions and economic entities still fail to bring about an increased innovativeness of the economic entities. The same conclusion is reached using the ANOVA F-test (p-value of 0.6712).

In order to glean a more comprehensive insight into the object of the research, the article analyses survey responses about respondents' own assessment of intensity, quality and influence of the collaboration on innovativeness of the company. The respondents were requested to assign specified variables grades of 1 (very low) through 5 (very high). Only the N1 sample was used to test the hypothesis because those respondents indicated, at the very beginning of the questionnaire, they collaborated with research entities. The respondents who indicated that there was no such co-operation did not answer this type of question. The objective was to find out whether there is a correlation between the assessed intensity of the collaboration and its impact on innovativeness of the company in the opinion of the entrepreneurs. The co-operation intensity was assessed with the average grade of 2.8, and the impact of such co-operation on innovativeness of the companies, according to the entrepreneurs' opinion, was also awarded a low average grade of 2.7. Since the average grades are uniform, the Spearman's correlation method was applied to determine if there is a statistically significant link between objective innovativeness indicators (the number of achieved innovations and the number of registered patents) associated with the companies and variables of collaboration intensity, quality and impact on innovativeness. The results are presented in Table 5.

Table 5. Spearman's correlation of number of innovations and patents with (I) assessed intensity, (II) quality of collaboration and its (III) impact on innovativeness.

	Total number of innovations in company	Number of registered patents
(I) Intensity of science–economy collaboration (2008–2010)	0.00529 Insignificant correlation	0.24782 Slight correlation
(II) Quality of science–economy collaboration (2008–2010)	0.01534 Insignificant correlation	0.28181 Slight correlation
(III) Impact of the collaboration on innovativeness of the company	0.05619 Insignificant correlation	0.31814 Slight correlation

Source: Authors' calculations based on the results of the empirical research.

Table 6. Pearson's correlation of number of innovations and patents with assessed (I) intensity, (II) quality of collaboration and its (III) impact on innovativeness.

	Total number of innovations in company	Number of registered patents
(I) Intensity of science–economy collaboration (2008–2010)	–0.06314 Insignificant correlation	0.40387 A moderate correlation
(II) Quality of science–economy collaboration (2008–2010)	–0.08012 Insignificant correlation	0.34733 Slight correlation
(III) Impact of the collaboration on innovativeness of the company	0.01206 Insignificant correlation	0.26861 Slight correlation

Note: The interpretation of the correlation coefficient is the same as in Table 5.
Source: Authors' calculations based on the results of the empirical research.

The interpretation of the correlation coefficient:

- From 0 to + –0.2 – non- or insignificant correlation
- From + –0.2 to + –0.4 – slight correlation
- From + –0.4 to + –0.7 – a moderate correlation
- From + –0.7 to + –1 – strong correlation

The results of the Spearman's correlation indicate that the assessed collaboration intensity has no statistically significant correlation with the overall number of innovations in the companies (r = 0.00529), and that there is a slight correlation to the number of patents registered by the companies (r = 0.24782). The results, considering they are close to zero, point to a conclusion that there is almost no correlation between the relevant variables. The same results were also achieved through determination of correlation of the assessment of quality and the company inventiveness indicators. There is an insignificant correlation of the quality assessment with the total number of innovations in companies (r = 0.01534), and a slight correlation with the number of registered patents (r = 0.28181). Furthermore, there is no correlation between the assessed impact on innovativeness of the companies and the total number of innovations in the companies (r = 0.05619), while there is a slight correlation with the number of registered patents (r = 0.31814). The identical conclusions have also been derived using Pearson's correlation (Table 6).

Pearson's correlation coefficients once again confirm insignificant or slight correlations between the objective inventiveness indicators (the number of implemented innovations and registered patents) and the variables of intensity, quality and impact of co-operation on the inventiveness of the economic entities.

4. Conclusion

The basic objective of this article was to research whether there is an interaction between Croatian companies and scientific institutions, and whether it has an influence on the innovativeness of companies. In 2011, the empirical research was conducted online using the survey questionnaire.

A literature review of the available empirical research revealed the existence of contradictory results – a large portion of authors have proven a positive correlation between the co-operation and firms' innovativeness through their research and analyses, but a number of authors failed to prove it. A review of Croatian scientific literature leads to the conclusion that research of that type is still insufficiently represented in Croatia.

The research results presented in this article failed to prove any positive correlation between relevant variables. Based on the analysed responses provided by entrepreneurs, it is concluded that the existing forms of collaboration between Croatian scientific institutions and companies exhibit no statistically significant influence on innovativeness of the companies. The surveyed companies in Croatia were divided into two samples. Sample one refers to the companies that have collaboration with the Croatian scientific sector, and sample two refers to the companies that did not have such collaboration. The difference in their innovativeness was than tested through indicators such as: introduction of innovations in a company in the relevant period, the total number of implemented innovations and patents in a company in the relevant period, the scores of intensity, quality and influence of collaboration on company's innovativeness. After the statistical testing it is determined that there is no difference in their innovativeness (according to the number of innovations and patents in the observed period), regardless of the existence of collaboration with the scientific sector.

The main limitations of this study lie in a small sample of Croatian firms that have participated in this research. Many firms in Croatia do not have a database about their innovativeness so they could not be a part of the research. Future research should not be based on the online survey, but on interviewing the relevant persons in the firms in order to obtain a greater sample and more relevant research results.

Based on the empirical analysis provided in the article, we conclude that the collaboration of science and companies in Croatia has not yet produced an efficient knowledge/technology transfer as has been observed in some developed countries. The reason can probably be found in the fact that collaboration is a relatively recent topic in the Republic of Croatia and thus the expected results are yet to be achieved. Therefore, monitoring and improvements of the collaboration are urged as the fundamental recommendation of this article and proposed as the topic of future scientific papers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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