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A Causal Inference Perspective for Estimating the Influence of the Romanian Competitiveness Operational Programme on Researchers' Performance

Abstract. *Research and innovation systems are essential for enabling economic growth and empowering individuals to face global challenges. This study evaluates the impact of investments in research infrastructures and activities supported by the Romanian Competitiveness Operational Programme in the 2014-2020 programming period. Based on 2021 data, our evaluation employs a causal inference approach aiming to estimate the influence of investments on the improvement of scientific knowledge and capacities, focusing on the performance of researchers. The results of the estimation show that the support granted for developing the research infrastructures led to a better integration of researchers into international research teams and an increased number of co-publications with foreign researchers. In addition, as a result of the investments in infrastructures, researchers have extended and strengthened their collaborative relationships within their organisations and generated more new research projects. Our results indicate positive effects with respect to the production of scientific knowledge, while the wider economic and societal effects cannot yet be observed.*

Keywords: *causal inference, Competitiveness Operational Programme, researchers.*

JEL Classification: O30, I23, C93, C54.

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1. Introduction

Research and innovation systems are very important drivers for economic development and for making societies more inclusive and resilient. As the research and innovation system in Romania remains chronically underfunded, the support provided through the national operational programmes was considered very important for its development (Chioncel & Del Rio, 2018). This paper presents the results of an impact evaluation of investments in research infrastructures and activities supported by the Romanian Competitiveness Operational Programme (COP) in the 2014-2020 programming period. It investigates different instruments

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and target beneficiaries, combining quantitative and qualitative methods of evaluation. The support considered in this evaluation aimed to enhance research, development, and innovation (RDI) infrastructures and capacities. Two main types of actions have been implemented under this objective, targeting: 1) the development of large research and development (R&D) infrastructures and 2) the development of R&D centres networks coordinated at national level and connected to European and international networks, as well as the provision of access to scientific publications, European and international databases. RDI capacities refer to resources that are available for the research system such as human resources and research infrastructure.

The Romanian Competitiveness Operation Programme (COP) provided support to various types of beneficiaries, such as universities and research institutes, R&D companies, innovation clusters, and infrastructures. Mai types of interventions included investments for: the construction, modernisation and expansion of laboratories and R&D infrastructures, the purchase of R&D equipment, the development of innovation activities, the purchase of ITC equipment, applications and software licenses, the creating a national repository of scientific documents and facilitating access to electronic scientific resources. Following this support, the beneficiary organisations were expected to create or modernise R&D laboratories and infrastructures, to connect with innovation clusters and with scientific resources. At the same time, researchers from the beneficiary organisations were expected to work with improved facilities and new R&D jobs to be created. Due to the support provided through the Romanian Competitiveness Operation Programme (COP), the improvement of the innovation capacity and of the knowledge and skills of the researchers, as well as the generation of new research activities were targeted. In the medium term, the expected change for the beneficiary entities was to improve their performances with respect to producing publications, new products and technologies, patents, and results transferable in economy. Another targeted change was an improvement of the collaborations and participation to research networks. Considering these expected improvements, the objective of the paper is to evaluate the impact of investments in research infrastructures and activities supported by the Romanian Competitiveness Operation Programme in the 2014-2020 programming period.

2. Literature review

Following interventions aiming to enhance the performance of the RDI sector, various impact assessment studies have been conducted in recent years. While some scholars have shown the key role of universities for regional innovation networks and assets (Benneworth & Fitjar, 2019), others studied the success of policies aiming to support clusters development (Ebbekink & Lagendijk, 2013). A challenging task is to address the system perspective, considering interventions at the project or programme level (Arnold, 2004). A relevant example is the evaluation of investments in research and technological development (RTD) infrastructures and activities supported by the European Regional Development Funds (ERDF) in the period 2007-2013. The theory-based impact evaluation indicated a positive contribution of the investments, especially in the case of the support granted to universities. On the other hand, long-term impacts such as the translation of the improved scientific knowledge into technological development and innovation have been delayed by the economic crisis (CSIL, Prognos AG & Technopolis, 2021).

With respect to impact studies, one has to take into consideration the need of allowing sufficient time until evaluation for the research infrastructures to reach their full potential. While the economic and societal impacts of the research infrastructures need to be assessed together with their contribution to the knowledge production (ESFRI, 2017; Florio, 2019), the time lag from the production of scientific knowledge to the technological exploitation can last more years (Finardi, 2011).

Taking into consideration the fact that this evaluation took place before the long-term impacts could be observed, the current paper focuses more on the influence of investments in research infrastructures supported by the Romanian Competitiveness Operation Programme on the improvement of scientific knowledge and capacities.

Also, following the vision of Hallonsten (2014), we use the smallest performing unit of the research system, namely the researchers. Thus, our paper aims to complement previous studies providing evaluations of the investments in research infrastructures by estimating the impact of the Romanian Competitiveness Operational Programme on researchers' performance.

The purpose of the study is to estimate the impact of investments in research infrastructures supported by the Romanian Competitiveness Operation Programme on the researchers' performance. The impact evaluation focuses on several expected outcomes related to the production of scientific knowledge, collaborative relationships, and the potential for technological exploitation.

3. Data and methods

In the evaluation, we estimated what would have happened to researchers if their organisations hadn't received COP interventions aimed at increasing scientific capacity. We created two groups of units with similar observable characteristics. The treatment group included researchers from organisations that had access to the intervention, while the control group consisted of researchers from organisations that did not receive the treatment. This approach allowed us to measure the impact of the COP on improving scientific capacity.

Data collection was carried out in 2021 through a questionnaire-based survey. Two questionnaires were designed to collect information on the covariates and the outcomes for the two groups. The target group comprised 126 researchers from organisations benefiting from COP interventions, the majority of whom were from public research institutions and higher education institutions. The control group included 135 researchers from organisations that did not benefit from COP interventions, but were eligible to participate in them.

The questionnaire was sent to the organisations with a request to distribute it among their staff involved in the research activities. Since the responses were self-selected by the researchers, there is a risk that the scientific domains may not be well represented in our sample. Researchers working in organisations supported by the COP generally fit the following profile: individuals aged 35-55 years with research experience ranging from 5-30 years, employed by national research institutions and universities. They typically conduct research in the smart specialisation areas of Energy, Environment and Climate Change, Eco-nanotechnologies, and Engineering Sciences.

We used a counterfactual approach to estimate the effects of exposure to COP interventions for the following outcomes:

- Obtaining new or improved products/methodologies/technologies;
- Obtaining results with potential transferability to the economy;
- Patent applications filed;
- Publication of scientific articles indexed in international databases;
- Co-publication of public-private scientific articles;
- Co-publication of scientific articles with foreign researchers;
- Extending and strengthening collaborative relationships within your research organisation;
- Extend and strengthen collaborative relationships with teams in other research organisations at national level;
- Integration into international research teams;
- Generating new research projects;
- Achievement of scientific promotion criteria;
- Increase visibility and professional reputation.

All these outcomes are binary variables based on the question: “To what extent has your performance in the following areas of research activity improved since you accessed/used the above infrastructures?” They take the value of "1" if the respondent evaluates the improvement as being high or very high; otherwise, they take the value of "0".

The mentioned infrastructures belong to the list:

- Newly created, equipped, or upgraded laboratories/research centres for CD activities;
- Innovation clusters developed between enterprises and other organisations to enable sharing of equipment, knowledge exchange and transfer, networking, information dissemination, and collaboration;
- ESFRI-listed open CD infrastructures (e.g. ELI NP);
- Dedicated infrastructures that provide data connections (RoEduNet);
- Scientific publications and databases for documentation via virtual environment (ANELIS PLUS).

Characteristics such as gender, age, scientific domain, regional context, and holding a PhD could influence both the outcome and the exposure, leading to biases of the true impact. To address this confounding phenomenon, we utilised the CBPS (covariate balancing propensity score) method (Imai, Ratkovic, 2014).

This method involves balancing the two groups based on their pre-treatment characteristics to remove bias in the treatment effect on the outcome. This approach falls under the weighting method for causal inference, where observations in each group are given weights to ensure comparability between the control and treatment groups. This is an advanced technique with the essential feature of simultaneously maximising the balance of the covariates and modelling treatment assignment.

The methodology combines the propensity score condition and the covariate balancing condition. The conditional probability of receiving the treatment for a specific unit i, given the covariates, is given by:

$P(Tr_i = 1 | X_i = x)$ (1)

where X_i is a k dimensional vector of observed covariates whose support is X. The parametric estimation of this propensity score is denoted by $\pi_\beta(X_i)$.

In CBPS, the covariate balancing property is defined in terms of inverse propensity score weighting (Imai, Ratkovic, 2014):

$$\mathrm{E}\left\{\frac{Tr_i\tilde{X}_i}{\pi_\beta(X_i)} - \frac{(1-Tr_i)\tilde{X}_i}{1-\pi_\beta(X_i)}\right\} = 0$$

where $\tilde{X}_i$ is a multidimensional function of X_i. For example, considering $\tilde{X}_i = \frac{\partial \pi_\beta(X_i)}{\partial \beta^T}$ assigns higher weights to covariates that explain better treatment allocation.

To understand the balance of covariates before adjustment, we comparatively summarised their distributions within the treatment and control groups.

Table 1. Distribution of the categorical covariates

Covariate		Group	
		Treatment	**Control**
Gender	Male (%)	55.8	53.2
	Female (%)	44.2	46.8
PhD	Yes (%)	85	83
	No (%)	15	17

Source: Authors' processing.

Regarding the gender and PhD status, the differences between the two groups are not very pronounced. Based on the age density plot, we understand that there are some differences between the researchers in the two groups. The researchers in the control group tend to be younger than those in the treatment group.

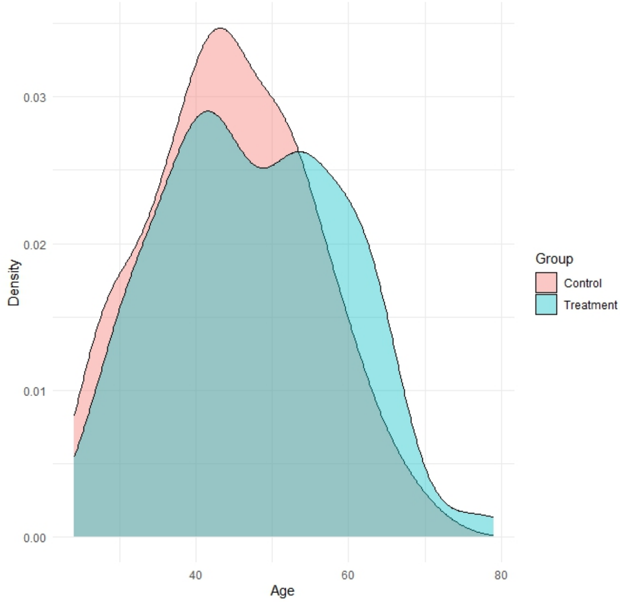

Figure 1. Density plot of age by group
Source: Authors' processing.

We decided to use regional gross domestic expenditures on research and development as a covariate instead of the respondent's region. This numeric variable more accurately captures the effect of the regional economic context on the results obtained by researchers by providing a direct measure of regional support. Moreover, from a methodological point of view, replacing a nominal variable with a numeric variable reduces the number of coefficients to be estimated. Therefore, the regional gross domestic expenditures on research and development ("gerd") in 2021, stated in euros per inhabitant, reflected the region's specific economic and developmental context. The mean and standard deviation for regional gross domestic expenditures on research and development (Table 2) reveal some imbalances that the adjustment method should correct.

Table 2. Descriptives for regional gross domestic expenditures on research and development

	Mean	Standard Deviation
Control	136.60	118.65
Treatment	115.28	117.47

Source: Authors' processing.

Regarding the scientific field in which researchers work, we constructed a binary variable defined by two categories: engineering sciences and other fields. The distribution of the responses explains why we chose this variant. Approximately 30% of the respondents are researching in the field of engineering sciences, while the other 11 fields have extremely varied weights, most of them being very poorly represented (Figure 2).

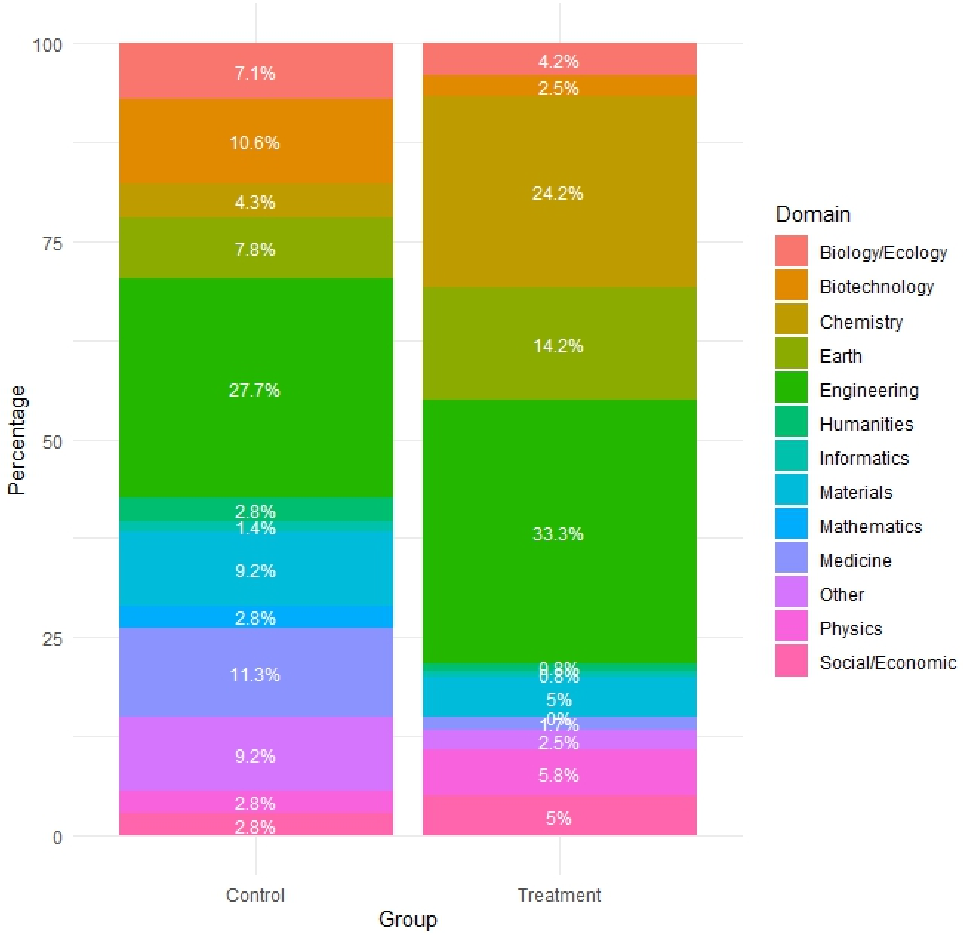

Figure 2. Research field distribution
Source: Authors' processing.

4. Empirical results

This paper's findings are based on estimating the Average Treatment Effect on the Treated (ATT).

Balancing weights were estimated using WeightIt (Greifer, 2023a) and CBPS packages (Fong et al., 2022), and covariate balance was assessed using cobalt (Greifer, 2023b), all in R (R Core Team, 2023). Absolute standardised mean difference is used to assess the similarity between the two groups before and after CBPS based adjustments. As a rule of thumb, a standardised difference of less than 10% shows a negligible imbalance (Stuart, Lee, and Leacy, 2013).

The point estimates reported in the next table are the exponentiated coefficients of the logit model, showing the impact on the odds ratio. Bias, standard errors, and confidence intervals are based on 1000 bootstrap replicates.

The summary plot shows the balance of covariates before and after adjustment. It highlights the improvement in balance after adjustment, with all variables being brought below the 10% threshold. As a result, the difference in outcome between exposed and unexposed researchers is attributed to the COP interventions, revealing the causal effect.

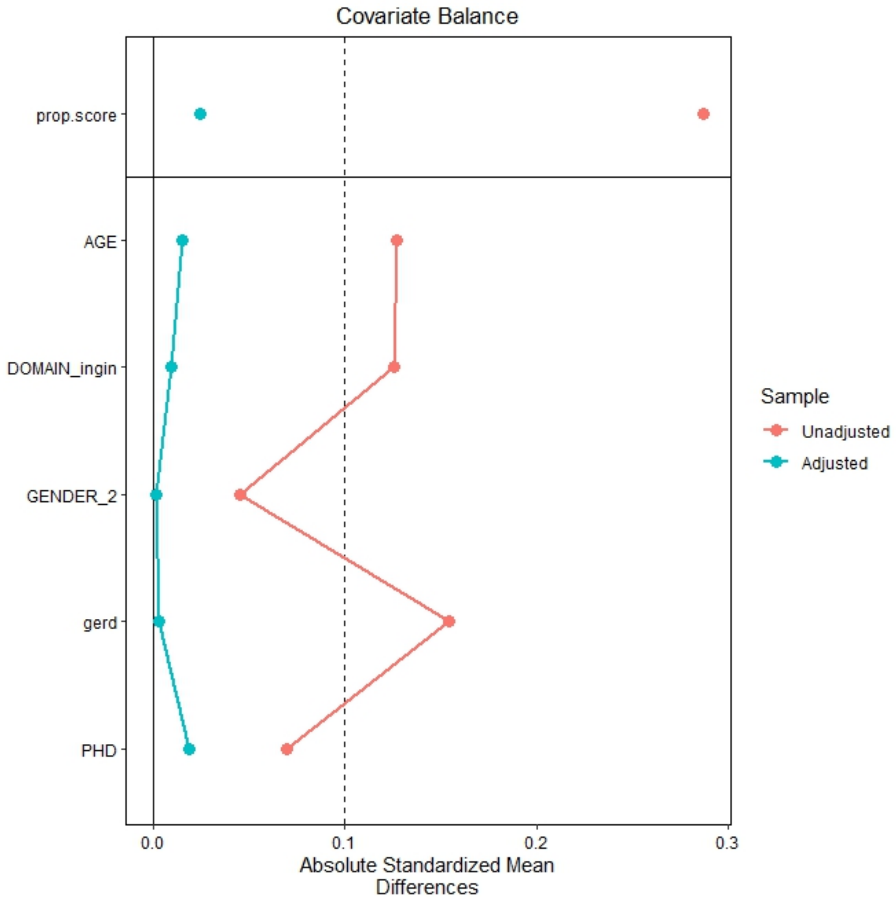

Figure 3. Covariate balance
Source: Authors' processing.

Table 3. Estimation results- significant impact

Outcome	ATT estimate	Bias	Standard Error	Confidence interval	
Co-publication of scientific articles with foreign researchers	2.49	0.17	0.87	1.39	4.84
Extending and strengthening collaborative relationships within your research organisation	1.94	0.14	0.74	1.09	3.81
Integration into international research teams	2.32	0.21	0.74	1.38	4.31
Generating new research projects	1.83	0.16	0.63	1.02	3.48

Source: Authors' processing.

The results of the analysis indicate that the support granted through COP increases the odds of:

- co-publication of scientific articles with foreign researchers.
- extending and strengthening collaborative relationships within organisation.
- integration into international research teams.
- generating new research projects.

According to the 95% confidence intervals obtained using the bootstrap technique, the ATT coefficients assigned to these outcomes are statistically significant. The other eight outcomes did not show a significant impact.

The highest impact is encountered by the outcome measuring co-publication of scientific articles with foreign researchers. Hence, receiving support within the COP project increases the odds of co-publishing with foreign researchers by 2.5 times for the participants. At the same time, the odds of integrating into international research teams are increased by 2.3 times for the researchers from organisations benefitting from COP interventions.

The main limitations of our study are due to the reduced sample sizes. To address this, we need to increase the number of observations in the control and treatment groups. This will allow us to investigate the heterogeneity of the treatment and reveal the variability of the effect on different researchers' characteristics. It would also be interesting to see if there are discrepancies between different smart specialisation areas. Some outcomes may show a significant impact only for specific groups, making the effect non-significant for the entire target group.

5. Conclusions

The present study evaluates the impact of investments in research infrastructures on the researchers' performances. The evaluation results show that COP investments, aimed at modernising R&D laboratories and capacities, led to increased number of scientific articles with foreign researchers, improved collaborative relationships with colleagues and foreign researchers, and a higher number of proposed research projects. On the one hand, the obtained results highlight the key role that collaborative networks play in relation to publication and new research projects outcomes.

On the other hand, the evaluation has shown no evidence that COP investments in research infrastructures succeeded in improving innovation and technological outputs such as new or improved products, methodologies, or technologies, results transferable to the economy, or patent applications. Our results are consistent with previous evaluations conducted at European level by CSIL, Prognos AG & Technopolis (2021), suggesting that the translation from positive effects in terms of scientific production to technological exploitation can last longer periods of time (Finardi, 2011). Moreover, in order for the investments in research infrastructures to determine positive wider economic and societal impacts, a long-term vison coupled with a stable support have to be provided. As stated by the European Strategy Forum on Research Infrastructures (2017), treating research infrastructures as long-term strategic investments will enable them to unfold their full potential in boosting economic growth and well-being.

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