

# Incidence of the quintuple helix model on social innovation generated in university extension projects from “impact” variable

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**Abstract:** Currently, University extension projects have taken a lot of relevance to solve the needs of contexts in which higher education institutions have influence due to the importance of getting social innovation. In this point, the relationship with external sector becomes more relevant, generating solutions that solve local needs and the own interests of actors involved, in the Quintuple Helix Model. Now, in an increasingly influenced context by sustainable projects, social innovation, and the need to generate an articulated work with the stakeholders has become fundamental. Whereby, the main objective was to evaluate the incidence that generates the joint work be among the government, academy, enterprises, communities, and the environment in the improvement of social conditions of the populations and regions, framed since the scope of university extension projects from “impact” variable. In this research, there was initially a systematic literature review, in which it was identified the effect of every Quintuple Helix actor, in the success of extension projects. Then, it was built a research instrument that was applied in a random representative sample, since a 303 higher education institutions population in Colombia. In this way, there were applied multivariate segmentation techniques and machine learning using the statistical software R. As a results, it was verified three kinds of higher educational institutions groups linked to the impact in the social innovation generated in university extension projects from “impact” variable, the structural equations were built for each group, and finally, the proposal model was developed.

**Keywords:** university extension, university extension models, social innovation, higher education institutions, quintuple helix, machine learning, project management

## Incidencia del modelo de la quintuple hélice en la generación de innovación social generada en proyectos de extensión universitaria a partir de la variable “impacto”

**Resumen:** Actualmente, los proyectos de extensión universitaria han cobrado gran relevancia para atender las necesidades de contextos en los cuales las instituciones de educación superior tienen influencia debido a la importancia de lograr la innovación social. Allí, la relación con el sector externo se vuelve más relevante, generando soluciones que satisfacen necesidades locales y los intereses propios de los actores que integran el Modelo de la Quintuple Hélice MQH. Ahora, en un contexto cada vez más influenciado por proyectos sostenibles, la innovación social y la necesidad de generar un trabajo articulado con las partes interesadas se ha vuelto fundamental. Por lo tanto, el objetivo principal fue evaluar la incidencia que genera el trabajo conjunto entre el gobierno, la academia, las empresas, las comunidades y el medio ambiente en la mejora de las condiciones sociales de las poblaciones y regiones, enmarcado en el alcance de los proyectos de extensión universitaria desde la variable "impacto". Se realizó una revisión sistemática de la literatura y se aplicó un instrumento de recolección de información en una muestra representativa aleatoria, de una población de 303 IES en Colombia. Para ello, se utilizaron técnicas de segmentación multivariante y aprendizaje automático utilizando el software estadístico R. Se identificaron 3 grupos diferentes de instituciones de educación superior respecto al impacto en la innovación social generada en los proyectos de extensión universitaria. Así mismo, se analizó la variable “impacto”, se

construyeron ecuaciones estructurales para cada grupo de instituciones de educación superior (1,2 y 3), logrando así el desarrollo del modelo propuesto.

**Palabras clave:** extensión universitaria; modelos de extensión universitaria; innovación social; instituciones de educación superior; quintuple hélice; aprendizaje automático; gestión de proyectos

## Introduction

Nowadays, University extension is taking on increasing importance and it is considered one of the 3 core functions alongside research and teaching. Moreover, in Colombia, for the evaluation of qualified registration conditions by the Ministry of National Education (MEN) and for high-quality accreditation by the National Accreditation Council (CNA), the execution of social projection activities is required, including the implementation of projects carried out with external sectors. However, this requirement goes beyond a mere obligation, representing primarily the real and mission-oriented role that academia plays in society. From the outset, universities have been a fundamental actor in achieving social innovation, evolving over time as a member of the triple, quadruple, and now the so-called quintuple helix (industry, academia, government, society, and environment). Therefore, under “the new paradigm called Society 5.0, where humans are at the center of innovation [1]”, it is important to understand the impact of the quintuple helix model on social innovation generated in university extension projects through the "impact" variable. This concept is valuable, because higher education institutions are immersed in extension dynamics and processes specific to their context and nature, influenced by social needs, institution's philosophy, educational projects, policies, development plans, and support for addressing global needs, such as those related to Sustainable Development Goals, particularly SDG 4 Quality Education, SDG 10 Reduced Inequalities, and SDG 17 Partnerships to achieve the goals. Additionally, lessons learned after the COVID-19 pandemic, aging populations, and recent climate changes must also be considered, as there have been evident changes in processes, including the development of activities and projects in universities, which are not exempt from adaptation. As expressed by Cabrera, "the actions taken on the fly have allowed the extension to continue developing in other ways and the usual face-to-face connection with the community is not a requirement [2]."

At the same time, in accordance with the historical mission of universities to contribute to society, it appears the concept of Corporate Social Responsibility (CSR). Universities “were conceived as managers of development and social welfare, and in relation to the concept of social responsibility, they should be mainly involved in outreach, research, management, and social projection activities, their main activity being the professional training of individuals and other functions that contribute to their strengthening [3]”. Therefore, that strengthening is very related to the variable "impact", which is defined as “the transformations that the components of the extension policy generate through university projects in people, groups, organizations, and regions. It could be said that impact involves understanding how the components and projects integrate into the daily lives of families, neighborhoods, communities, territories, and population groups. In the monitoring and evaluation system of university extension policy in Colombia, the impact variable consists of the subvariables of peace, equity, regional development, sustainable development goals, and sustainability [4]”. These aspects are key, as they address the influence of the quintuple helix in generating social innovation through the development of extension projects. In the current state of research field, there is a trend for models, systems, and procedures to be supported by the Quintuple Helix, "because this facilitates the rapid exchange of knowledge and resources essential for overcoming challenges and emerges as a strategic imperative for concerted action aimed at achieving eco-efficiency and eco-effectiveness [5].” The validity of the Quintuple Helix model is also noted "in representing the complex and articulated community of actors, as well as demonstrating the scalability of the model through dynamic and prospective approaches, for example, the opportunity to adopt Network Analysis to evaluate the centrality of stakeholder categories in alternative scenarios associated with public policies has been demonstrated [6]."

Other authors propose the Quintuple Helix Model as an analytical framework in which multiple stakeholders are part of an innovation ecosystem and exchange knowledge that contributes to the development of eco-innovations that facilitate both: circular economy and climate change mitigation [7]. Similarly, "advances have been made in exploratory models of circular economy, such as the 'Eco-Quintuple Helix Model (eco-5HM),' which can provide better information to decision-makers for CE operations and tactics in order to achieve the strategic objective of sustainability [8]."

The evolution of the social innovation model from helices has resulted from the optimization of the Triple Helix that initially included social innovation, based on the university-business-state relationship [9], to which the participation of the community or civil society was later added to form the Quadruple Helix [10], and currently "includes the environment as an additional actor to form the Quintuple Helix [11]." This is important because it reflects the consolidation of a model that has strengthened over the years and still allows for many developments surrounding it. However, the key concept, which is social innovation and that "is related to new products, services, and models aiming to improve human well-being and create social relationships and collaborations [12]" is not necessarily achieved with the mandatory participation of all actors in the Quintuple Helix QH, as this depends on the business model and the purposes of the organizations. "What is important for social BMI is the social mission, which needs to be defined in order to be able to move forward with the strategy, the value proposition, and the best practices of the business [12]." Therefore, is not always important that all members of QH participate into the projects to generate social innovation, because what is relevant is that the actors involved can get together "The two characteristics that are necessary to the social innovation process which are social action and social change. Social innovations are a type of a social change since they affect the future social development and balance the temporary trends [13]." Considering that this research was conducted within the framework of university extension projects, it is crucial to understand that "Social Innovation (SI) has become vital for addressing societal issues and uplifting community well-being. Universities are crucial in fostering SI through collaborative partnerships with communities. Universities, while communities, provide invaluable insights into localized challenges [14]."

Also, "Universities have long been considered key players in regional innovation systems and innovation-driven regional development [15]." Therefore, if one wants to generate social innovation with the participation of Higher Education Institutions (HEIs), it is necessary to consider the three main activities they develop, which are identified as community outreach (extension), education, and research, and from which social innovation can be generated. At this point, there are universities whose core is more related to one of those activities, but that doesn't mean that all activities are not carried out to some extent, depending on the strengths of each institution. Regarding community outreach, different terms have been used to identify the actions of HEIs, such as, for example, civic universities [15], and Community University Engagement CUE [16]. For the education function, the importance of "educational innovation" is emphasized.[17]" and as for research activity, a direct relationship is evident with terms such as "innovation," "technology," "development," among others. [18]". Likewise, the importance of increasing productivity in universities has been identified when the substantive functions are related, even more so when they are involved in projects where the university, government, and industry participate [19]." In the literature, there are other concepts linked to social innovation from universities, such as sustainability, development, and social responsibility [20],[21];[22] and [23]. Similarly, in this significant role played by HEIs, the generation of social innovation and the contribution to the development of the regions they impact not only relate to the development, to a greater or lesser extent, of their own activities but also depend, as in any organization, on external factors beyond their control concerning "Higher Education Institutes are being called upon to integrate sustainable development into their organization, driven by national and international events, policies and environmental targets.[15]"

Studies indicate, that regulations and public policies noticeably affect the conditions for generating social innovation, for example: "The results show that the collaborations which lead the development of university-industry-government relations, as well as the scope of collaborations, change in response to reforms in

regulations[24]” and therefore, “academia executives and policymakers may derive policy indications for the enhancement of the university system and the development of policies that would facilitate HEIs embracing Education for Sustainable Development. [22]”. Additionally, in the development of projects integrated by the government and the university, some key factors are distinguished that are considered indispensable for achieving success and must be met at the same time: “government-university collaboration to illuminate four potential determinants of success in such projects: output, institutional, relationship, and framework factors [25]”. Meanwhile, the development of social extension projects must be aligned with the sustainable development goals [26], as evidence of the generation of social innovation and as a basis for improving the conditions of the quintuple helix actors.

The reviewed literature comes from different contexts, to have a broader view of the social innovation generated in university extension projects; therefore, references to studies conducted in Europe, Asia, and Latin America are included. In Europe, for instance, it is identified that universities can have a greater participation when perceived as civic universities, and their contribution also depends on internal and external factors [15]. In Asia and Latin America, the situation is more similar, regarding “the importance that the University take a more active role in the construction of the territories based on proposals for development of sustainable spaces [23]” and about “social responsibility and sustainability development is still far from being fully integrated into the core activities of the HEIs [21]”

## Methodology

In this research, initially a systematic literature review was carried out, in which the effect of each actor of the Quintuple Helix on social innovation was identified. Continuing with the sequential process, an instrument was developed and applied to a random representative sample from a population of 303 higher education institutions in Colombia, excluding sectional choices and including only the main departments of the mentioned universities. As part of the approach, the incidence of the actors of the quintuple helix in social innovation generation was compared through the “impact” variable, composed of subvariables such as peace, equity, regional development, Sustainable Development Goals, and sustainability. Respondents rated from 0 to 10 the level of incidence of academia, industry, government, society, and the environment in social innovation generation through the "impact" variable. The instrument was validated by a group of 10 experts in university social outreach and projection. The research is mixed, utilizing both quantitative and qualitative data to complement the analysis and interpretation of the results. Multivariate segmentation techniques and machine learning were applied using the statistical software R. Universities were segmented into 3 major groups (low, medium, and high impact) for generating structural equations based on correlation matrix; subsequently, principal component analysis was conducted separately for the 3 groups, followed by comparison of the results within and among groups to derive the model of quintuple helix incidence in social innovation generation from the impact variable.

## Results

Initially, a correlation analysis was conducted to identify the relationship between the academic, environmental, industry, societal, and governmental impacts. These relationships were consolidated in the following table.

**Table 1.** Correlation matrix

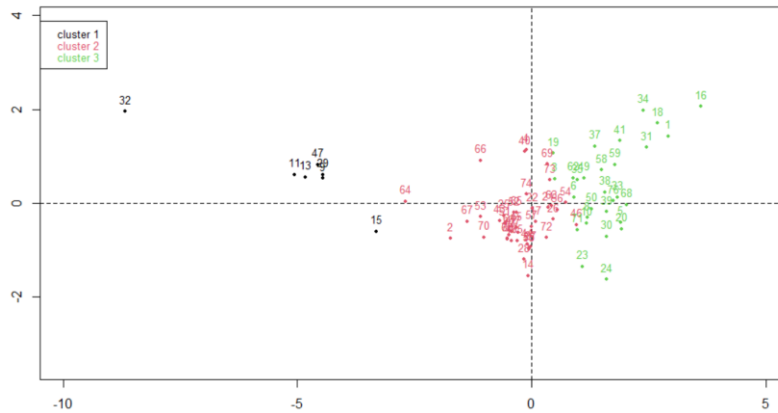
	Academy Impact	Environment Impact	Industry Impact	Society Impact	State Impact
Academy Impact	1.00000000	0.7683615	0.8054317	0.7600685	0.6462940
Environment Impact	0.7683615	1.0000000	0.7248150	0.6397910	0.5707830
Industry Impact	0.8054317	0.7248150	1.0000000	0.5839785	0.5822555

Society Impact	0.7600685	0.6397910	0.5839785	1.0000000	0.4708986
State Impact	0.6462940	0.5707830	0.5822555	0.4708986	1.0000000

Source: Own elaboration using the software R

It was identified that most correlations are high and significant, such as the one between industry and academia of 0.80, which is interesting considering the coordination in extension projects currently being developed between these two actors of the Quintuple Helix. Regarding the lowest correlation, it is observed between society and the government at 0.47, which is notable given the main function of the government to generate social development and innovation in communities. The contexts of higher education institutions in Colombia are very diverse, leading to specific impacts generated among the elements of the Quintuple Helix for each institution. This element can be confirmed, for example, when analyzing the number of academic programs in the higher education institutions sampled, where an average of 103 academic programs is found, but with a minimum of 7 and a maximum of 325. This indicates a wide range in the offering of academic programs, resulting in a coefficient of variation of 69.16%, a clear indication that higher education institutions in Colombia exhibit dissimilar behaviors. Considering the above, a stratified analysis was conducted, segmenting the sample base. As shown in Graph 1, three groups were identified.

Figure 1. Cluster



Source: Own elaboration using the software R

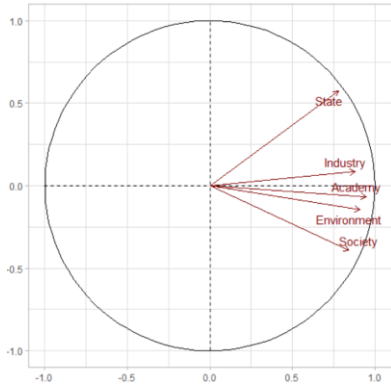
Table 2. Median Impacts by Groups.

Groups	Academy Impact	Environment Impact	Industry Impact	Society Impact	State Impact	Academic Programs
Group 1	8.513514	6.243243	5.837838	7.189189	6.189189	45.0000
Group 2	9.468750	7.812500	7.562500	8.406250	7.281250	131.8438
Group 3	10.000000	8.750000	8.875000	8.875000	7.875000	256.7500

Source: Own elaboration using the software R

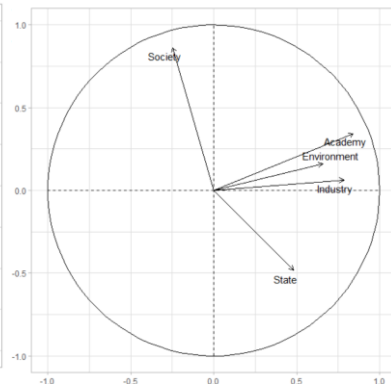
Group 1 shows low levels in most impacts and consisted of 32 higher education institutions. On the other hand, Group 2 shows a medium impact and was comprised of 37 universities, while Group 3 shows a high impact and was made up of 8 higher education institutions. It is also observed that Group 3 not only concentrates the majority of the academic program offerings but also a larger impact. This is important because it demonstrates the direct relationship between the number of programs and the impacts generated, as university extension in Colombia is carried out interdependent, and in the generation and participation of extension projects, faculty, students, and various academic actors can integrate the management of agreements, partnerships, formulation, and execution of these. Considering the stratification carried out, a principal component analysis was performed for each group, based on Figures 2, 3, and 4.

**Figure 2.** Group 1 components



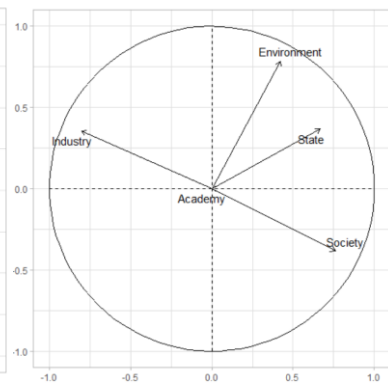
**Source:** Own elaboration

**Figure 3.** Group 2 components



**Source:** Own elaboration

**Figure 4.** Group 3 components



**Source:** Own elaboration

In figure 2, it is shown that the impacts generated by academia have a high relationship with those generated by industry and the environment. It is also evident that the social impact tends to be independent of the governmental impact. This indicates that the social innovation generated in group 1 is closely related to the coordination between academia, industry, and the environment, and that the impacts generated by the government and society require greater cohesion, for which it is necessary to strengthen the implementation of public policies that channel public resources towards the generation of social impacts. The structural equation for the total impact of group 1 is as follows:

$$G1 \text{ Impact} = \text{Academy} * 23.6 + \text{Industry} * 20.3 + \text{State} * 15.9 + \text{Society} * 18.5 + \text{Environment} * 21.7$$

In figure 3, it is identified that the relationship between society and the state tends to be inverse. The academia is much more related to the impacts and social innovation generated with the environment than what happened in group 1, and although the industry moves away a bit, it still maintains a high and direct correlation with academia and the environment. The structural equation for the total impact of group 2 is as follows:

$$G2 \text{ Impact} = \text{Academy} * 34.6 + \text{Industry} * 30.1 + \text{State} * 11.3 + \text{Society} * 2.9 + \text{Environment} * 21.1$$

In figure 4, related to group 3, it is found that industry and society are inversely related, which means that when there are high industrial impacts, impacts on society tend to be low and vice versa. Additionally, the impact generated in academia is zero because the average academic impact of the higher education institutions in this group is 10 (see table 2). It is assumed that belonging to group 3 implies the maximum impact on social innovation through academia. Consequently, this affects the structural equation and causes academia to show zero. The structural equation for group 3 is as follows:

$$G3 \text{ Impact} = \text{Academy} * 0 + \text{Industry} * 34.7 + \text{State} * 24.1 + \text{Society} * 31.5 + \text{Environment} * 9.7$$

As there are 3 equations, one for each group, they were compared in Table 3.

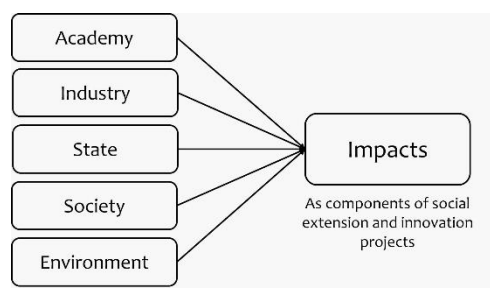
**Table 3.** Structural equations comparison

Group	Academy	Industry	State	Society	Environment
Group_1	23,6	20,3	15,9	18,5	21,7
Group_2	34,6	30,1	11,3	2,9	21,1
Group_3	0	34,7	24,1	31,5	9,7

**Source:** Own elaboration using the software R

It is evident that the group generates a greater impact on social innovation through university extension projects linked to industry, the government, and society. The academia does not carry weight in this group because its impact is fixed for this group, meaning it always exists. Regarding Group 2, it holds the most significant weight in academic impact, followed by industrial and environmental impacts, with a lesser influence from the government and very little from society. As for Group 1, although it represents the lowest levels of impacts fostering social innovation, it shows more similar results in terms of the weight of the variables in the equation. In this group, the primary impact is from academia, followed by the environment, industry, society, and lastly the government. Finally, as a product of the research, a model is proposed to assess impacts generated in social innovation through academia, industry, government, society, and the environment in university extension projects in Colombia.

**Figure 5.** Model



**Source:** Own elaboration

## Conclusions

The organization of university extension and social outreach in higher education institutions in Colombia is heterogeneous and follows the organizational structure of each institution. This results in some cases where the terms social outreach and extension are approached from the same perspective, while in others, they are clearly separated. It was identified that higher education institutions in Colombia have very different behaviors and impacts regarding the effects generated in university extension projects and social outreach promoted through the quintuple helix. In this context, higher education institutions in Colombia were classified into 3 groups based on the impacts generated in extension projects regarding their relationship with academia, the government, industry, the environment, and civil society. Group 1 was identified as institutions that generate low impacts, Group 2 moderate impacts, and Group 3 high impacts. Additionally, it was found that there is a direct relationship to generate greater impacts in higher education institutions that offer more academic programs. This is because universities carry out extension and social outreach in conjunction with their academic programs and due to the relationship between substantive functions. Furthermore, the creation of 3 different models of structural equations, one for each of the mentioned groups, is due to the diversity and heterogeneity of universities and the absence of clear and rigorous public policies, as well as the lack of an educational superintendent to establish clear parameters in university extension. In consequence, there is not a single organizational structure in Colombia that institutions of higher education must follow to separate and distinguish social outreach and extension activities, taking into account the autonomy of each university as an organization, as well as its institutional philosophy and strategic relationships. This significantly affects the stakeholders that each university has in the development of their projects and in the creation of social innovation. Furthermore, the impact of the actors of the quintuple helix in the development of extension projects that generate social innovation depends on the group to which they belong and is influenced by the following considerations:

- The generation of social innovation cannot be understood as a synonym for the exact coordination of all the actors of the quintuple helix because, in fact, social innovation can be generated in different combinations and relationships of the helices, and not always do the results of the collaboration of the

five actors of the quintuple helix in university social extension projects generate social innovation, much less the achievement of project success measured by scope, time, and budget.

- The impact variable, analyzed through the sub variables of peace, equity, regional development, Sustainable Development Goals, and sustainability, enabled the identification of 3 main groups regarding the influence of the actors of the quintuple helix in generating social innovation through extension projects.
- Group 1 has the least impact on the generation of social innovation. In this group, there is more evident collaboration between industry and academia, with less influence from the environment. However, society and the state tend to have an inverse relationship, meaning the influence of one or the other may occur, but simultaneous impact is more challenging.
- Group 2 better integrates the influence of academia and the environment, with a lesser involvement of the industry. Nevertheless, the impact made by the state and society is reversed.
- Group 3 assumes the influence of academia, as it is an excellent coordinator. It includes both private and public universities with large budgets, recognized expertise, and excellent infrastructure and organizational structure, allowing them to consistently impact the generation of social innovation through the execution of social extension projects. Additionally, in this group, the environment, state, and society play a role. Here, the impact of society and industry is inverse.
- The literature supports the difficulty of integrating projects involving participation of all 5 actors of the helix, which is ideal but not always achievable. Regarding university extension projects in Colombia, the impacts identified in this research stem from relationships that are more feasible than others, considering the contexts and the group they belong to (1, 2, or 3) as found in this study.
- Social innovation in university extension projects is more likely when the group to which the HEIs belong (1, 2, or 3) and their potential for collaboration with the other helix members are clearly identified, recognizing that each project is unique and heavily influenced by its context.
- There is a need for public policies and mechanisms to ensure the allocation of resources from the state to society and an increased social investment to enable better coordination and collaboration among the actors of the quintuple helix in developing new products, services, and models to address social needs.

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