Revista de Estudios Empresariales. Segunda época.
Número: 1 (2023). Páginas: 119-141 DOI: https://doi.org/10.17561/ree.n1.2023.7398

THE ROLE OF TECHNOLOGY CENTERS IN REGIONAL COMPETITIVENESS: A MULTICRITERIA APPROACH

EL PAPEL DE LOS CENTROS TECNOLÓGICOS EN LA COMPETITIVIDAD REGIONAL: UN ENFOQUE MULTICRITERIO

Cristina del Campo (Universidad Politécnica de Valencia)
Norat Roig-Tierno (Universidad Politécnica de Valencia)[1*]
Nuria Chaparro-Banegas (Universidad Politécnica de Valencia)[2]
Francisco Mas-Verdu (Universidad Politécnica de Valencia)[3]

Abstract

Countries adopt different policies and strategies to boost regional growth and competitiveness. R&D is one of the most important drivers of national competitiveness because of its ability to generate knowledge and convert that knowledge into useful information to improve people's lives and maintain economic prosperity. Innovation emerges within innovation systems. Such systems encourage collaboration among institutional and economic agents. One of the main groups of agents that foster such collaboration consists of innovation intermediaries. Technology centers (TCs) are a prime example of such intermediaries, which exert a positive impact on the business sector. Given the numerous factors influencing TC efficiency, this paper studies the key variables associated with this efficiency, providing a ranking of these variables based on the views of innovation system experts. To evaluate these variables, the Analytic Hierarchy Process (AHP) is used. Of the six areas identified as essential for TC activity, the impact of TCs and the types of actions they undertake are the most important aspects for improving TC and business efficiency, as well as regional competitiveness. This study highlights the role of TCs in helping companies respond to challenges with innovative solutions that foster a strong, competitive, and innovative regional business sector.

Keywords: Regional innovation system, national innovation system, innovation intermediary, technology center, AHP.

JEL Codes: O31; O38; I23; I25; I28.

Resumen

Los países adoptan diferentes políticas y estrategias para impulsar el crecimiento y la competitividad regional. La I+D es uno de los motores más importantes de la competitividad nacional por su capacidad de generar conocimientos y convertirlos en información útil para mejorar la vida de las personas y mantener la prosperidad económica. La innovación surge dentro de los sistemas de innovación. Estos sistemas fomentan la colaboración entre los agentes

* autor de correspondencia: norat.roig@upv.es
[1] ORCID: https://orcid.org/0000-0002-7980-3548
[2] ORCID: https://orcid.org/0000-0002-5907-5643
[3] ORCID: https://orcid.org/0000-0002-0902-9462

Fecha de envío: 08/09/2022. Fecha de aceptación: 23/11/2022

institucionales y económicos. Uno de los principales grupos de agentes que propician dicha colaboración son los intermediarios de la innovación. Los centros tecnológicos (CT) son un ejemplo excelente de estos intermediarios, que ejercen un impacto positivo en el sector empresarial. Dados los numerosos factores que influyen en la eficiencia de los CT, este artículo estudia las variables clave asociadas a esta eficiencia, proporcionando una clasificación de estas variables basada en las opiniones de los expertos en sistemas de innovación. Para evaluar estas variables, se utiliza el Proceso de Jerarquía Analítica (en inglés, *Analytic Hierarchy Process*, AHP). De las seis áreas identificadas como esenciales para la actividad de los CT, el impacto de los CT y los tipos de acciones que llevan a cabo son los aspectos más importantes para mejorar la eficiencia de los CT y las empresas, así como la competitividad regional. Este estudio destaca el papel de los CT para ayudar a las empresas a responder a retos con soluciones innovadoras que fomenten un sector empresarial regional fuerte, competitivo e innovador.

Palabras clave: Sistema regional de innovación, sistema nacional de innovación, intermediario de innovación, centro tecnológico, AHP.

Clasificación JEL: O31; O38; I23; I25; I28.

1. INTRODUCTION

The ability to generate and assimilate new knowledge while transforming it into something economically useful is essential for regional competitiveness. Hence, most developed regions and countries have placed research and development (R&D) near the top of their political agendas (Brandäo & Molero, 2013). In recent decades, the literature has paid increasing attention to innovation policies (Fagerberg & Verspagen, 2009; Martin, 2012; Shafique, 2013) to support and provide rigor to their design. Research has also attempted to evaluate their impact in different contexts (Borrás & Jordana, 2016; Flanagan & Uyarra, 2016; Uyarra & Ramlogan, 2012; Asheim & Moodysson, 2017; Coenen *et al*., 2017; Fagerberg, 2017; Isaksen, Normann & Spilling, 2017).

Within innovation systems, intermediaries play a fundamental role in fostering collaboration between researchers and non-academic organizations (D'Este *et al*., 2014; Mas-Verdú, 2021). This collaboration fosters science and technology for regions' economic development (Labra & Juan, 2017). Intermediaries encourage interaction between entities and actors and help exchange knowledge and experiences (Kanda *et al*., 2018). A notable example is that of technology centers (TCs), which foster the use of knowledge-intensive services in the productive sector (García-Quevedo & Mas-Verdú, 2008).

When implementing innovation policies to increase R&D and innovation activities, policymakers should consider the context where they are applied since similar policies and measures can result in different innovation and competitiveness performances (Edler & Fagerberg, 2017). These differences in performance arise from different national and regional characteristics, circumstances, needs, and barriers within the borders of innovation systems (Coenen *et al*., 2017). Many academics have studied innovation systems (Lundvall, 1992; Nelson, 1993; Freeman, 1994; Tödtling & Trippl, 2005), innovation intermediaries (Mas-Verdú, 2007; Bendis *et al*., 2008; Bakici *et al*., 2013; Ortega-Colomer, 2022), or competitiveness (Cantwell, 2004; Cho *et al*., 2008; Aiginger & Firgo, 2017). These three elements are undeniably connected: intermediaries are agents within the innovation systems, intermediaries provide services that facilitate the innovation process (Bakici *et al*., 2013), and innovation promotes competitiveness (Aiginger & Firgo, 2017). The paper's objective is to study the relationship between innovation systems, intermediaries (in particular, the role of TCs), and competitiveness

and how improvements in TCs efficiency could positively influence innovation development to increase regional competitiveness.

An improvement in TC efficiency triggers an increase in R&D and innovation activities which, in turn, lead to an increase in competitiveness. According to the literature and practical experience, several variables influence TC efficiency. These variables can be measured in terms of their contribution to enhancing innovation performance, as well as their impact on companies' sustainability and efficiency and, thus, their contribution to a region's competitive position. This paper tries to identify the key variables associated with TC efficiency and rank them in terms of their importance according to qualified experts of the regional innovation system. The Analytic Hierarchy Process (AHP) methodology is used for this purpose. This methodology allows to determine these relevant variables even when multiple criteria and attributes are involved.

The next section of this paper provides an overview of innovation systems and their intermediaries, highlights the role of TCs, and introduces the variables that potentially affect TC efficiency. The following section explains the data and method. The results are then presented. Finally, the last section details the conclusions, including recommendations and proposals for future avenues of research.

2. THEORETICAL FRAMEWORK

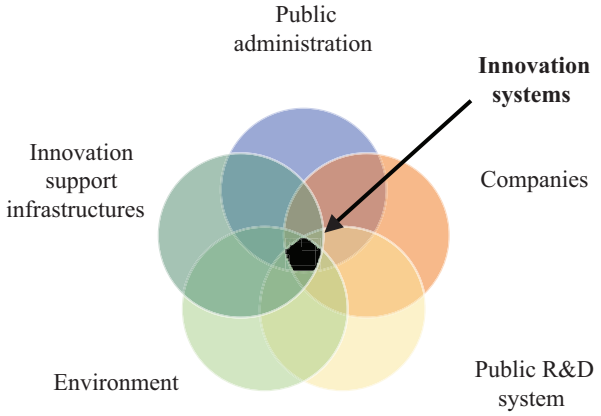
2.1. Innovation systems and innovation intermediaries

Organizations are open systems that feed on their external environment while also feeding back to this environment (Forrest, 1991). The interdependence of firms with their environment leads to innovation systems. These systems comprise a multitude of institutions, networks, and interrelationships. The corresponding set of interrelated economic and institutional agents affects both innovation performance and innovation behavior (Freeman, 1987; Lundvall, 1992; Nelson 1993; López-Rubio *et al*., 2021a). This interaction between firms and institutions plays a central role in the launch and marketing of new products, processes, and organizational forms for economic use (Mytelka, 2000).

During the 2000s, studies increasingly focused on the relationships between the performance of innovation systems and the factors that influenced this performance (Liu & White, 2001; Edquist, 2004; Lundvall, 2007). These findings have become useful for detecting the innovative capacity of a geographical area. Although the concept of innovation systems was initially applied at the national level in the form of national innovation systems, or NISs, it has subsequently been applied at the regional level (Koschatzky 2002; Landabaso *et al*., 2001; Oughton *et al*., 2002; Asheim and Isaksen 2002; Cooke 2002; Asheim and Coenen 2005) in the form of regional innovation systems, or RISs. The literature reflects the growing importance of RISs (Freeman, 1995; Tödtling & Trippl, 2005; López-Rubio *et al*., 2020) by showing that these systems are more developed in regions where NISs are adopted as the model for innovation policy design. Prime examples are Scandinavian and Western European countries (Sharif, 2006; OECD, 2011), as well as countries with highly decentralized political management. Specifically, the UK, Germany, Spain, the United States, Canada, and Switzerland offer prominent examples (Acs, Anselin & Varga, 2002; Kramer *et al*., 2011; Borrás & Jordana, 2016; López-Rubio *et al*., 2021b, c).

An innovation system has five subsystems: public administration, companies, the public R&D system, the environment, and innovation support infrastructures (see Figure 1; Mas-Verdú, 2007). Innovation support infrastructures are innovation intermediaries. That is,

FIGURE 1. SUBSYSTEMS OF INNOVATION SYSTEMS



they are organizations that facilitate innovation. They do so either directly, by enabling such processes in one or several companies, or indirectly, by fostering the innovative capacity of regions, countries, or sectors. Innovation support infrastructures operate as intermediaries between organizations by generating and encouraging collaborative networks, implementing and supporting technological development, and connecting and reducing the gap between the business world and the research community (Dalziel, 2010). Innovation intermediaries also help address some of the major development challenges, promoting economic activity through entrepreneurship and technological development (Mazzoleni & Nelson, 2007).

Innovation intermediaries focus on organizations that are generally ignored by traditional studies of national (Lundvall, 1992; Nelson, 1993), regional (Cooke *et al*., 2004), or sector-based (Malerba, 2002) innovation systems and statistical institutes (Godin, 2005; Siegel, 2003). The study of innovation intermediaries can help develop useful theory given the lack of research on innovation intermediaries, which partly explains the fragmented nature of the scientific literature (Howells, 2006; Phan, Siegel & Wright, 2005).

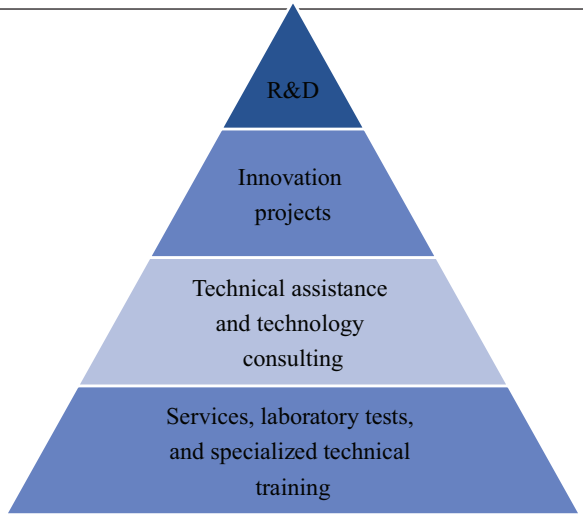
2.2. Technology centers (TCs) as intermediaries in the innovation system

Innovation intermediaries encompass a broad spectrum of organizations such as science parks, incubators, TCs, university transfer offices, public agencies that promote business activity, business associations, foundations, and chambers of commerce. TCs play a fundamental role in R&D and the transfer of technology to the productive sector. Such intermediaries help regions achieve greater development and strengthen their competitive and innovative capacity.

TCs differ from other intermediaries in their capacity to apply and transfer knowledge and their proximity to companies. Hence, in many cases, they play a central role as strategic agents in public policies to promote business innovation. In the largest European countries, the public sector supports TCs because of their crucial role in NISs as non-profit organizations whose income depends mainly on the market (i.e., projects with companies) but that have the capacity to conduct applied research thanks to their involvement in competitive public R&D support programs.

The activities undertaken by TCs aim to provide services and meet the technological demands of the business sector. Another objective of TCs is to implement a culture of innovation in companies through which they use technology to become more competitive (Mañas, 1999).

FIGURE 2. PYRAMID OF INNOVATION SERVICES



The range of solutions that TCs offer is wide (Ybarra, 2012; Ortega-Colomer, 2022). Solutions include laboratory tests and services, specialized technical training, technological consulting and diagnosis, and applied R&D projects. These services are usually represented as a pyramid, as shown in Figure 2 (Mañas, 1999; Izushi, 2003). Activities aimed at solving the intermediate problems of companies, such as technical services or consulting, form the base. Activities aimed at anticipating future problems, such as R&D and more complex and riskier customized services, appear at the top. Successfully delivering the activities located at the top requires frequent interactions and high levels of trust between parties.

Public support for the actions of innovation intermediaries can effectively increase innovation in companies (Dalziel, 2010). In some cases, public administrations establish a regulatory framework that specifies the requirements that TCs must meet to be considered as such and to receive subsidies to support innovation. For instance, the *Real Decreto 2093/2008* of December 19, 2008 regulates Technology Centers and Technological Innovation Support Centers in Spain and provides a register of these centers. This regulation specifies not only their legal basis and purposes but also a set of key indicators for registration.

These requirements include a minimum number of personnel under contract, a maximum percentage of non-competitive public funding, a minimum level of income from R&D (own or contracted), a minimum amount of income from companies as a percentage of total income, and a minimum number of private clients. Table 1 shows the details of the requirements at the time of registration and the changes to these requirements over time.

Key variables in relation to TC competitiveness were identified using the literature, practical experience, and the requirements to appear in the Spanish national register of TCs. The variables cover six indicators: (i) TC activity: R&D, innovation and technological support, laboratory testing, and training as a percentage of total income; (ii) impact on the business sector: number of client companies, private and public income from R&D and innovation, and the impact of the TC on companies (productivity or exports of client companies) and the regional economy (national and international public funding that the TC was able to bring to the region and creation of technology-based companies by the TC); (iii) scientific impact: number of scientific publications and instances of industrial property rights (IPR); (iv) economic and

TABLE 1. INDICATORS OF THE SPANISH OFFICIAL REGISTER OF TECHNOLOGY CENTERS (TCs)

Area	Criterion	Quantitative indicator	Requirement
Activity	Existence of an actual or potential group of client companies	Number of client companies by turnover in the last 3 years	Greater than or equal to 25
Activity	Existence of an actual or potential group of client companies	Number of different R&D clients in the last 3 years	Greater than or equal to 20
Activity	Quantity and quality of human resources available in the workforce	Number of permanent hires and graduates among technical and research personnel	Greater than or equal to 15
Activity	Quantity and quality of human resources available in the workforce	Percentage of doctors	Average greater than or equal to 7% (13% and 20% at 5 and 10 years of enrollment)
Economic viability	Private income	Annual income from member contributions	3-year average greater than 30%
Economic viability	Non-competitive financing	Annual income for operating expenses linked directly (or through public bodies or subsidies) to specific areas within the budgets of the local or national government or negotiated directly with administrations through performance measurement indicators, which should not exceed a certain percentage of total operating income	3-year average less than or equal to 30%
Economic viability		Percentage of income from R&D	3-year average less than or equal to 35%

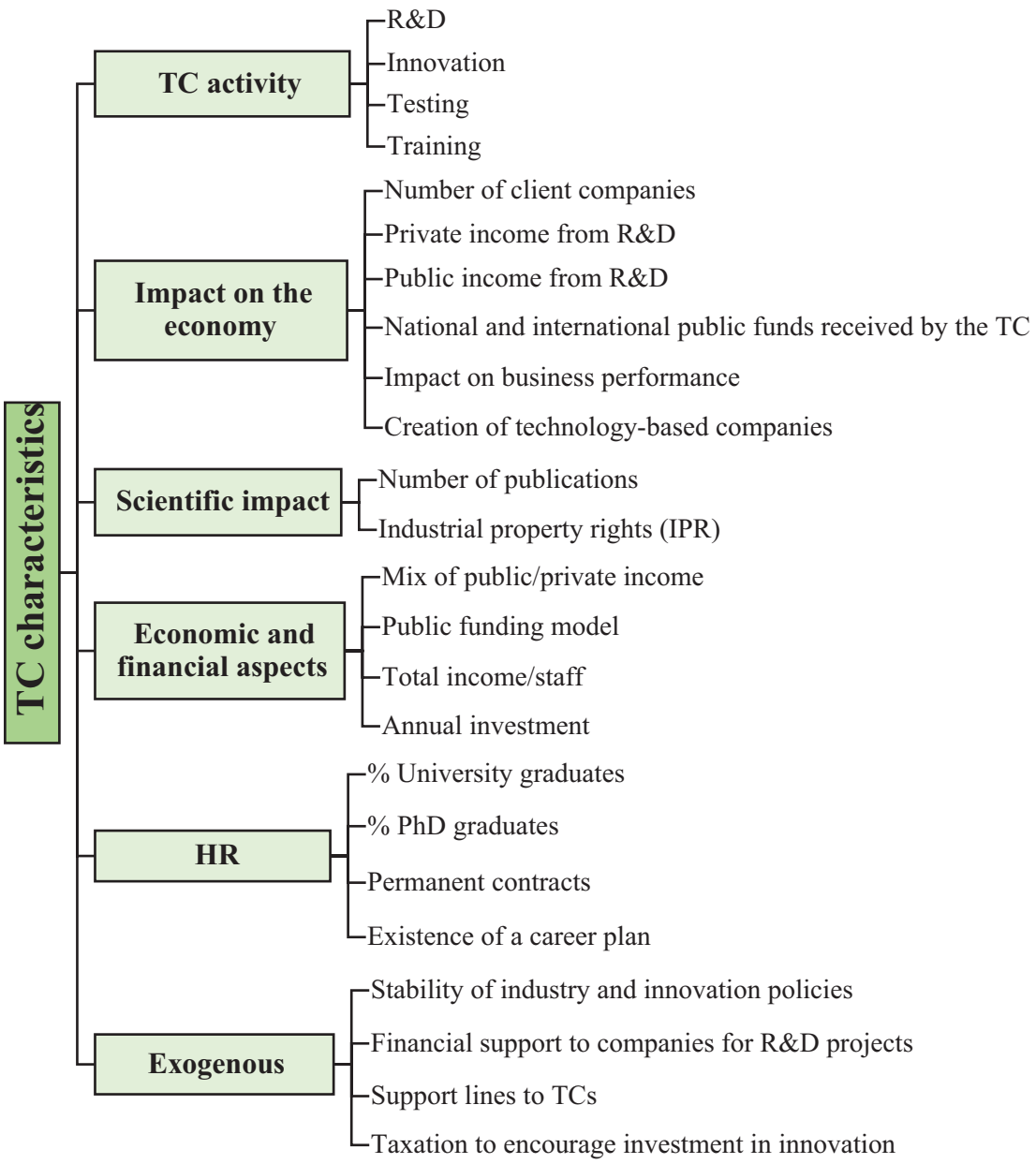
Source: Authors based on RD 2093/2008, December 19.

financial aspects: income mix by source of funding, public funding model, TC productivity, and annual investment; (v) human resources (HR) and talent management: percentage of university graduates, percentage of PhDs, permanent staff, existence of career plans, work-life balance, and worker equality; and (vi) exogenous factors: explicit policies to support business innovation and other elements of the political and social environment. Figure 3 illustrates these indicators and subindicators.

2.3. Regional competitiveness: the role of the intermediaries

Public administrations and international organizations have tried to encourage technology, science, and innovation advances through policies increasing competitiveness (Clark & Guy,

FIGURE 3. VARIABLES RELATED TO THE ACTIONS OF TCs



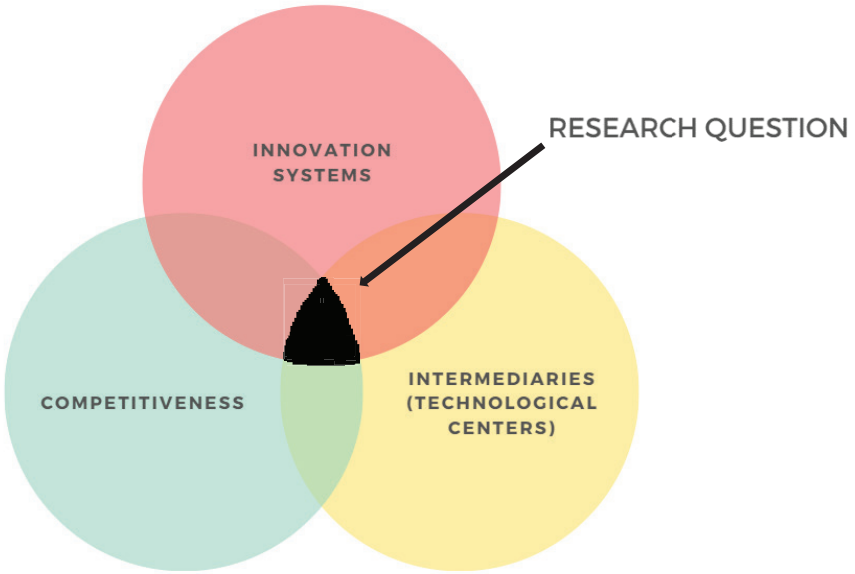
1998). High levels of innovation are achieved through innovation intermediaries who facilitate the creation of clusters and networks and the execution of projects (Bakici *et al*., 2013). These intermediaries are providers of national connectivity, cooperation, and trust among the different innovation agents contributing to the acceleration of innovation and technology development (Bendis *et al*., 2008). With this collaboration between different agents of the innovation system, competitiveness is therefore boosted (Bakici *et al*., 2013). Innovation systems offer a national infrastructure that encourages innovation and technology development by enhancing companies and other organizations to undertake R&D activities (Freeman, 1994). In this case, intermediaries can facilitate the companies' innovation process by supplying R&D support

services (Cho *et al*., 2016) since some intermediaries can alleviate R&D financing constraints (Xu, 2020).

R&D can push the development of business technologies encouraging further innovation activities due to the ease of technological adaptability (Carrillo-Hermosilla *et al*., 2009). Therefore, R&D becomes a support element for developing innovation projects, usually encouraged by universities and research institutions (de Jesus Pacheco *et al*., 2018). Universities and research institutions are considered providers of R&D resources. Given that financing availability is crucial for enhancing innovation (Johnson & Lybecker, 2012; Hojnik & Ruzzier, 2016), the literature focuses on studying the impact of public or private R&D investment on innovation. Tsai and Liao (2017) argue that companies can build technological knowledge and, hence, a competitive advantage by undertaking R&D activities grounded on innovation. Therefore, business and national competitiveness are increased. Private R&D investment improves companies' ability to acquire the knowledge and expertise needed to effectively develop innovations (Cainelli *et al*., 2012; Del Río *et al*., 2017). However, public administrations and universities are financing scientific research because of the related high levels of uncertainty. Private R&D investment contributions are usually minimal (Scarpellini *et al*., 2012).

Innovation systems, competitiveness, and intermediaries such as TCs are undeniably connected. The above suggests that intermediaries (which form part of the innovation systems) contribute to the competitiveness of a country through their support activities that encourage R&D and innovation. For this reason, the paper aims to analyze the crossroads among innovation systems, intermediaries, and competitiveness by determining and ranking the variables that lead to TCs' efficiency and, therefore, boosting competitiveness. Figure 4 illustrates the paper's objective.

FIGURE 4. TACKLING INNOVATION SYSTEMS, COMPETITIVENESS, AND TCs TOGETHER



3. DATA AND METHOD

Once the variables had been defined and structured, surveys were sent to 17 experts. Between June and September 2019, the experts answered the surveys in written form through email. These experts represented the triple helix of the R&D system (universities, intermediary innovation support organizations, companies, and public administrations). The aim was to prioritize the experts' judgments according to their importance. Given the limited resources of regions, this procedure enabled the identification of the most important factors for boosting regional innovation and competitiveness. The experts participating in the AHP were representatives from TCs, the academic community, public administration, and the business community. The TC experts were from the Network of Technology Institutes of the Region of Valencia (*Red de Institutos Tecnológicos de la Comunidad Valenciana*, REDIT) and the Spanish Federation of Technology Centers (*Federación Española de Centros Tecnológicos*, FEDIT). The academic experts were from several Spanish public universities. The public administration experts were from the Business Competitiveness Institute of the Region of Valencia (*Instituto Valenciano de Competitividad Empresarial*, IVACE) and the Valencian Innovation Agency (*Agencia Valenciana de Innovación*, AVI). The business experts were individual employers and representatives from the Business Confederation of the Region of Valencia (*Confederación Empresarial de la Comunidad Valenciana*, CEV) and the European Center for Innovative Business (*Centro Europeo de Empresas Innovadoras*, CEEI). This set of experts was selected because in-depth knowledge about the given geographical environment and regional characteristics is needed. With this in-depth knowledge, experts are able to answer specific questions about the region. The homogeneity in the set of experts is stated in the limitations of the paper since other regions or countries could highlight the importance of other factors in affecting TC's activity. A heterogeneous group of experts could hinder the drawing of conclusions since contexts with different national characteristics and situations would be mixed.

In addition to quantitative analysis, qualitative analysis was performed, with 12 experts participating in an interview consisting of three qualitative questions on the role of TCs in the innovation system and the main success factors and key barriers to achieving their mission within the innovation system. The qualitative survey was conducted through a personal interview, recorded, and later transcribed. Only some of them were answered in written form. The three questions helped contextualize the analysis. The results of the analysis are presented in the following section. The responses were collated and the data processed to prioritize the variables. This procedure is also explained in the following section.

The variables were prioritized using multicriteria analysis. In multicriteria analysis, the most relevant variables are identified based on expert judgments (Bogetoft & Prusan, 1997; Løken, 2007). These judgments are combined for both qualitative and quantitative variables. Some multicriteria analyses are Analytic Hierarchy Process (AHP), multiattribute utility (MAUT), and linear weighting (Roig-Tierno *et al*., 2013). In this study, the multicriteria analysis method was the AHP since it was intended to prioritize the variables according to the opinion of experts. There was no interest in weighting the variables or the experts' preferences in terms of a utility function. The AHP is designed for solving large-scale problems involving a multitude of criteria. It is a methodological framework for solving complex problems (Saaty, 1986) by using the judgments of several experts for the evaluation of alternatives with numerous attributes to optimize decision making. The methodology involves the consideration of subjective factors. It therefore offers an advanced technique when compared to other methods (Emrouznejad, 2017).

In the present study, the AHP was used to rank the variables that influence the ability of TCs to achieve their mission and the impact of TCs on regional competitiveness according to the importance of those variables. Given the method's flexibility and broad applicability, the AHP has been extensively studied and employed over the last 20 years in diverse contexts (Ho, 2018). The hierarchical model used with this methodology has three levels: objectives (the purpose of the process; what it intends to achieve), criteria (the standards used to validate whether the objective has been achieved), and alternatives (the aspects that form the basis of the criteria; Roig-Tierno *et al*., 2013).

Application of the AHP has three steps. First, the problem must be defined and any necessary information identified. The problem is assigned a hierarchical structure (Badi & Abdulshahed, 2019). At the top of the hierarchy is the general objective, followed by the subcriteria and alternatives at each descending level (Fong & Choi, 2000). This structure provides an overview highlighting the relevance of the variables, in this case those affecting TC efficiency and regional competitiveness.

Second, pairwise comparisons are performed at both the hierarchy and subcriteria levels. Scores or weights are assigned to the pairwise comparisons using a nine-item scale (Roig-Tierno *et al*., 2013) expressing the importance of the compared criteria. At each hierarchical level, items are compared pairwise according to their relevance in relation to a factor at a higher level (Fong & Choi, 2000). The basic comparison scale ranges from 1 to 9, as shown in Table 2.

Third, the results are given by the calculations of the weights (Badi & Abdulshahed, 2019). Individuals' preferences may be inconsistent, which can jeopardize the quality of the analysis (Marinoni, 2004). To resolve these inconsistencies, the consistency ratio (CR) of the expert judgments is calculated, as shown in Equation 1 (Saaty, 1980; Muralidhar et al., 1990; Partovi, 1994; Chen, 2006). The AHP thus includes a mechanism to measure the degree of consistency of the responses to reject responses with an unacceptable degree of inconsistency. However, it is practically impossible to achieve total consistency. The CR is obtained by dividing the consistency index (CI) by the random consistency index (RI). The CI directly considers experts' preferences, as shown in Equation 2 (Marinoni, 2004), whereas the RI is calculated by randomly creating a matrix of pairwise comparisons, as shown in Equation 3 (Chen, 2006). The CR is designed in such a way that values exceeding 0.1 are considered a sign of inconsistent judgment (Sevinc *et al*., 2018). Therefore, this study does not include the expert surveys with an inconsistency higher than 10% (consistency ratio)

TABLE 2. BASIC PAIRWISE COMPARISON SCALE IN AHP

Basic AHP pairwise comparison scale	
1	Both criteria are of equal importance
2	Intermediate importance between 1 and 3
3	The preferred criterion has a slightly higher importance than the other criterion
4	Intermediate importance between 3 and 5
5	The preferred criterion is moderately more important than the other criterion
6	Intermediate importance between 5 and 7
7	The preferred criterion has a much higher importance than the other criterion
8	Intermediate importance between 7 and 9
9	The preferred criterion has an absolute importance in relation to the other criterion

to maintain the analysis quality and robustness since these surveys were not considered coherent.

$$CR = \frac{CI}{RI} \tag{1}$$

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{2}$$

where λ_{max} is a reference index for validation of the AHP.

$$Aw = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ & & \vdots & \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \lambda_{max} w \tag{3}$$

where A is the pairwise comparison matrix and w is the weights matrix.

The process requires subjective evaluation by the respondents regarding the relative importance of each criterion, specifying its preference with respect to the other alternatives. This characteristic of the AHP highlights the importance of working with experts with a solid understanding of the topic of interest.

4. RESULTS

The AHP results provide a ranking of the six variables that affect regional competitiveness and TCs' achievement of their mission. All comparisons with a CR greater than 0.1 were discarded because of their high level of inconsistency. Therefore, the results were limited to 10 consistent responses.

Table 3 shows that the area of greatest importance for the experts is the impact of TCs' activity on the business sector (30.5 per cent of the weight). This result is consistent with the objectives of the TCs, which are defined not as an end in themselves but as a means to improve regional competitiveness. The gray literature includes numerous references to this issue. For example, AINIA, an agrofood TC, aims to "add value and cooperate with companies, leading to innovation and technological development in a sustainable manner."[4] AITEX, a textile TC, describes its mission by stating on its website that it "focuses on customers, adding value and increasing the competitiveness of member companies, highlighting the proximity service."[5]

This result is also consistent with the opinions expressed by several experts in the qualitative interviews. For instance, the TC experts reported that, "*the ultimate goal of a TC must always be the firms*," and that TCs are a "*scientific-technical support for firms, in areas that are very important for them, but which they cannot address individually because of their complexity, the need for specially qualified personnel or the requirement of adequate infrastructure*."

In addition, a business expert reported that "*a successful TC requires strong interaction with the regional innovation ecosystem*," confirming what a TC expert reported regarding the fact that one of the key success factors of TCs is their "*proximity to the industrial reality*." A

[4] https://www.ainia.es/
[5] https://www.aitex.es/

TABLE 3. PRIORITIZATION OF THE VARIABLES MEASURING TC EFFICIENCY

			Subweights	Final weights
Actions	21.9%	R&D	31.6%	**6.9%**
		Innovation	48.7%	**10.6%**
		Testing	9%	2%
		Training	10.8%	2.4%
IMPACT ON THE BUSINESS SECTOR	30.5%	Number of client firms	17.3%	**5.3%**
		Private income from R&D	28.9%	**8.8%**
		Public income from R&D	6%	1.8%
		National and international public funds received by TC	10.2%	3.1%
		Impact on business performance	28.3%	**8.6%**
		Creation of technology-based companies	9.3%	2.8%
SCIENTIFIC IMPACT	4.3%	Number of publications	14.6%	0.6%
		Industrial property rights (IPR)	85.4%	3.8%
ECONOMIC AND FINANCIAL ASPECTS	14.5%	Mix of public/private income	43.7%	**6.3%**
		Public funding model	18.6%	2.7%
		Total income/staff	19.6%	2.8%
		Annual investment	18.1%	2.6%
HR	13.8%	% university graduates	33.1%	4.6%
		% PhD graduates	35.7%	4.9%
		Permanent contracts	18.7%	2.6%
		Existence of a career plan	12.5%	1.7%
EXOGENOUS FACTORS	15%	Stability of industry and innovation policies	51.6%	**7.7%**
		Aid to companies for R&D projects	14.2%	2.1%
		Support lines to TCs	22.4%	3.4%
		Taxation to encourage investment in innovation	11.9%	1.8%

public administration expert insisted on the need for close collaboration between TCs and firms because a TC's ability to achieve its mission is normally hindered by its "*disconnection from the 'real' needs of the local regional business sector for which it was originally conceived as a priority actor, given the complexity of managing R&D services with a large sample of SMEs that are not innovation-sensitive*." A public administration expert also added that the TCs must be "*a driving force for the generation and transfer of knowledge and technology to the firms that they serve within the regional innovation system and with a constant projection towards excellence*." A business expert considered TCs to be "*the only institution that, to date, we know that is concerned about reaching small companies like ours and proposing strategies to us*."

One of the experts described a broader vision of the concept of TCs' impact that also encompasses their impact on society. The view of the TC expert highlights the role of TCs in "*orienting their mission to maximize the impact of their activities. A TC is crucial as long as it is useful to society. This positive usefulness can be achieved through multiple mechanisms*

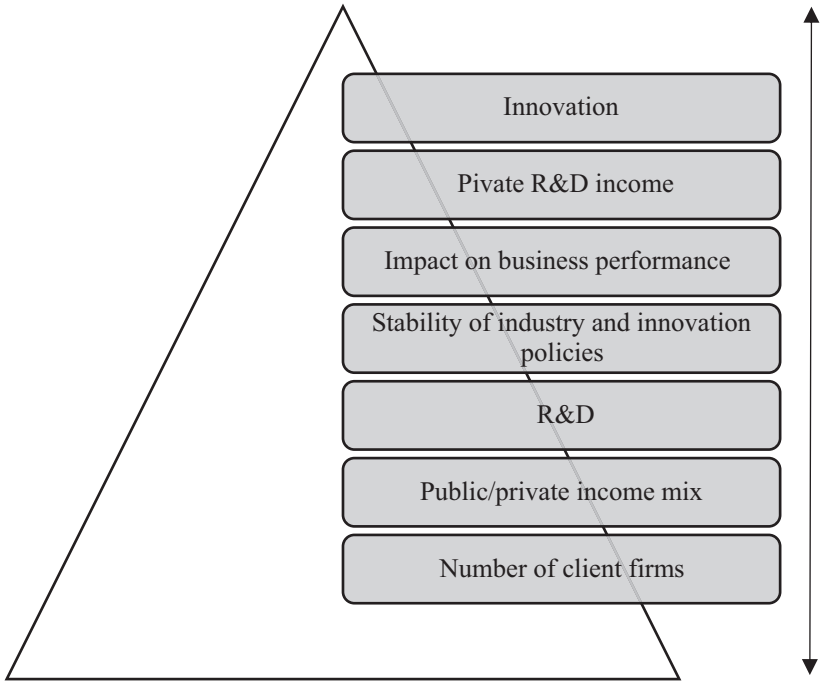
(influencing public policies or reaching the market, among others) but it must be an essential criterion of the TC." This view suggests that the impact of TCs is twofold, affecting not only the business sector but also society and the local region.

The second most important variable is the type of TC activity, with 21.9 per cent of the weight. The type of TC activity undertaken is closely related to its impact on the business sector. Understandably, this variable is relevant because it determines the value provided by the TC to its client firms and hence its impact on companies and society. In the AHP analysis, exogenous factors, the economic and financial aspects of TCs, and factors related to HR management also emerge as important, with 15 per cent, 14.5 per cent, and 13.8 per cent of the weight, respectively. The scientific impact of TC activity is much less important than the other areas, with 4.4 per cent of the weight.

This finding may be related to the role of TCs in the R&D system. TCs are in an intermediate position between companies, which seek to place their goods and services in the market, and universities and public research organizations, which generate basic knowledge but are not necessarily focused on the application of this knowledge in the productive sector. The essence of TCs lies in the generation of development and innovation for practical application in firms. Therefore, scientific impact is not always completely aligned with their main mission.

Table 3 shows seven subindicators with more than 5 per cent of importance, according to expert opinion. These subindicators are innovation actions, private R&D income, impact on business performance, stability of industry and innovation policies, R&D, public/private income mix, and number of client firms. The weights of these seven variables amount to 54.2 per cent in TC efficiency. Given the limited resources at the national, regional, and business levels, these results emphasize the relevance of focusing on the areas represented by these variables. Resources should be channeled toward the aspects with the greatest impact on TC efficiency. The effects of TC activity could then act as a catalyst for different sectors within the

FIGURE 5. VARIABLE IMPORTANCE HIERARCHY ACCORDING TO EXPERTS



region, and regional competitiveness could thus be improved. Figure 5 graphically illustrates the prioritization of the seven variables. The most relevant aspects are shown at the top, and the level of relevance decreases in descending order.

The method employed in this study enables prioritization of each set of variables in each of the six main areas, as shown in Table 3. Although the most important area in the overall analysis is the impact on business performance, the detailed analysis reveals that the experts considered innovation activities to be the most relevant factor in TC efficiency (10.6 per cent). This result confirms that the backbone of a TC's activity should be innovation that seeks to apply relevant knowledge to processes, products, and business models to improve business performance. This improvement in business performance would result in a positive impact on regional competitiveness. In this case, the experts emphasized a preference for innovation and R&D over laboratory services and training.

Other important variables are private income from R&D (8.8 per cent), followed by the impact on business performance (8.6 per cent), and the stability of industry and innovation policies (7.7 per cent). The stability of industry and innovation policies was highlighted by all experts in the qualitative interviews. A TC expert reported that one of the main obstacles is "*the lack of stability in public R&D policies and the uncertainty in the allocation of public funds to the different instruments that can enhance the activity of a TC and its relationship with other actors in the R&D system*." In this case, the expert referred to "*regional, national, or European policies. Stable policies, budgets, and programs are essential*."

According to a TC expert, TCs sometimes encounter "*fluctuations and uncertainty in the industrial and innovation policy of the public administration*," which negatively affect their ability to act and can therefore jeopardize regional competitiveness. A public administration expert indicated that "*dependence (just like many other key players on the political, social, and financial contexts), instabilities and increasing uncertainties, can lead to unfocused strategies or growth that is not sustainable over time*." According to a business expert, "*TCs require continuous and sustained commitment over time with stable, continuous, and credible policies. In this way, the centers can develop their potential in the medium and long term. This framework of stability for the centers and the innovation system is fundamental*."

The AHP method also enables the segmentation of responses by each group of experts. This segmentation facilitates detailed analysis of the differences in criteria applied by each group of experts (i.e., public administration, business experts, TCs, and academics). The results for each group of experts are shown in Tables 4 and 5. The tables show the six main areas evaluated and the details of the variables. In relation to type of activity, the national innovation system (NIS) actors (i.e., public administration, business experts, TCs, and academics) seem to agree that activities with a shorter cycle, such as technology consultancy and laboratory testing, which are useful for companies and constitute a first stage in the relationship with TCs, do not generate the greatest impact. This consideration is reasonable because these activities can generally be fulfilled by other private sector agents such as consulting firms and private laboratories.

Similarly, expert opinions suggest that TCs are efficient and competitive when they have a high impact on the regional business sector. Specifically, the TC efficiency translates into a significant volume of private income from R&D activities and the effect of such collaboration between TCs and private companies on the performance (e.g., productivity and exports) of collaborating companies. This vision is consistent with the instrumental view of TCs as vehicles for improving business and regional competitiveness.

The results also reveal substantial differences between the vision of TCs themselves and that of academics. These differences are in relation to the greater importance that TCs attach to their R&D activities and the greater importance that academics attach to indicators of scientific

impact and HR, with particular emphasis on the percentage of PhDs. According to TC experts, the type of activity (34.5 per cent) is the most relevant factor for boosting TC competitiveness. R&D activities (17 per cent) is another noteworthy factor. The impact on the business sector has a weight of 27.3 per cent. Public administration experts also reported that the impact on the business sector plays a crucial role in the performance of TCs' activities (36.3 per cent). These results confirm the view of TCs as a vehicle to improve regional competitiveness primarily through applied research and innovation.

Although the fact that TCs attach greater importance to R&D may seem contradictory, this potential contradiction could be explained by the academic approach to R&D. It is reasonable to assume that academics tend to conceive R&D from a basic research perspective. Therefore, academic experts would not consider R&D relevant for TCs, which tend to adopt a practical approach to R&D. In contrast, the TCs themselves perceive R&D as central to the fulfillment of their mission. An even greater contradiction emerges when considering the importance that academics attach to the percentage of PhDs working in the TC. A priori, this high percentage of PhDs should be expected to be related to greater R&D activity as opposed to innovation or other less complex activities.

The osmosis effect between the concepts of R&D and innovation is important. The close link between R&D and innovation may hinder the distinction between one type of activity and the other by experts. Any review of these concepts would be incomplete without considering the Frascati (OECD/FECYT, 2002) and Oslo (OECD, 2005) manuals, which are universally recognized as sources of reference in the fields of R&D and innovation, respectively.

Academic experts attach greater importance to scientific impact and HR indicators, with a notable weight assigned to the percentage of PhDs in TCs (13.9 per cent). Notably experts from TCs, firms, and public administration also emphasize the relevance of HR policy and talent management in TCs. However, the relevance of these factors is seen from the perspective of effective management. The following are identified as factors for successful TC performance: "*maintaining HR policies in constant evolution to encourage the generation of renewed knowledge and adaptation to future challenges by developing priority lines of research*" and the existence of "*HR that combine technical-scientific excellence with a focus on business results*" (PA expert). These factors are essential because "*people management is precisely one of the determining factors, an effective talent management*" (TC expert). Therefore, a TC must "*have an adequate recruitment and retention policy. The excellence and motivation of TC personnel is critical for the fulfillment of the mission*" (TC expert).

TABLE 4. ANALYSIS OF AREAS BY GROUP OF EXPERTS

	Final weights (%)			
	Public administration	**TCs**	**Business**	**Academia**
Type of activity	12.6%	34.5%	16.5%	19.5%
Impact on the business sector	36.3%	27.3%	28.7%	22%
Scientific impact	5%	2.4%	3%	11.4%
Economic and financial aspects	18.1%	7.9%	22.2%	10.3%
HR	18.1%	9%	8%	30.7%
Exogenous factors	9.9%	18.9%	21.6%	6.2%

Note: PA = public administration; TCs = technological centers.

TABLE 5. ANALYSIS OF VARIABLES BY GROUP OF EXPERTS.

		Final weights (%)			
		Public administration	**TCs**	**Business**	**Academia**
TYPE OF ACTIVITY	R&D	4	17	6.4	3.1
	Innovation	6.7	11.1	7.2	12.1
	Testing	0.6	2.4	2	1.8
	Training	1.3	4.1	1	2.5
IMPACT ON THE BUSINESS SECTOR	Number of client firms	4	4.7	3.9	2.9
	Private income from R&D	6.2	10.7	7.4	5.7
	Public income from R&D	3	1	2.8	1.4
	National and international public funds received by the TC	2.8	3.9	3.6	3.3
	Impact on business performance	16.2	4.6	9.8	6.1
	Creation of technology-based companies	4.1	2.5	1.1	2.6
SCIENTIFIC IMPACT	Number of publications	0.7	0. 3	0.4	2
	Industrial property rights (IPR)	4.3	2.1	2.6	9.5
ECONOMIC AND FINANCIAL ASPECTS	Mix of public/private income	10.3	2	12.4	2
	Public funding model	2.7	2.5	2.2	1.5
	Total income/staff	3.6	0.4	6.3	2.7
	Annual investment	1.5	2.9	1.4	4.1
HR	% university graduates	4.6	2.5	3.4	6.6
	% PhD graduates	6.2	1.9	3.5	13.9
	Permanent contracts	4	3.3	0.5	2.2
	Existence of a career plan	3.3	1.3	0.5	8
EXOGENOUS FACTORS	Stability of industry and innovation policies	6.3	9.4	12	2.1
	Aid to companies for R&D projects	0.8	2	4.6	1.3
	Support lines to TCs	1.2	6.3	4	1.8
	Taxation to encourage investment in innovation	1.5	1.2	1.1	1

Note: PA = public administration; TCs = technology centers.

The low importance that the academic experts attributed to the stability of public policies (2.1 per cent) is noteworthy because this factor was highlighted by firms (12 per cent), TCs (9.4 per cent), and public administration (6.3 per cent), albeit to a lesser extent.

Tables 4 and 5 provide an overview of the role of TCs for each group of experts. The public administration experts reported that the most important factor is the impact of TCs on the regional business sector, highlighting the "impact on business performance" subindicator. This group of experts also advocated the need for a public/private income mix to achieve high levels of TC efficiency. Likewise, business experts emphasized the relevance of business sector impact. However, the analysis of subindicators shows that the public/private income mix and the stability of industry and innovation policies are the most important variables. TC experts focused more on type of activity and, in particular, highlighted the role of innovative

activities. The volume of private R&D income is also relevant for TC experts. Finally, academic experts reported that HR is the key aspect for boosting regional competitiveness through TCs, specifically the role of the percentage of PhDs within the TC.

5. CONCLUSIONS

Based on the AHP methodology, this paper presents a multicriteria expert-based evaluation of TCs and regional competitiveness. These experts represent all agents of innovation systems. They prioritized the areas and variables with the greatest influence on the competitiveness and efficiency of TCs. The analysis was based on the responses of 10 of the 17 experts, corresponding to those with a CR lower than 10%. Applying this consistency threshold guarantees an acceptable level of consistency of judgments and ensures the robustness of the model.

First, the results of the AHP provide a ranking of the six areas identified as essential for TCs according to their importance. The analysis shows that the impact of TC actions on the business sector is the most relevant area, followed by the type of actions conducted by the TC. This finding is consistent with the mission of TCs to improve business competitiveness (Mañas, 1999), help the local region prosper (Mazzoleni & Nelson, 2007), and ensure the welfare of society. A TC fails to fulfill its mission when local companies do not improve their competitiveness through collaboration with the TC (Bakici *et al*., 2013). This enhanced competitiveness may be the result of developing products, improving processes (Mytelka, 2000), or attracting public funds for innovation (Dalziel, 2010), among others.

Second, the importance attached to the activity of TCs is consistent with their role in the innovation system as intermediaries between science or basic research (Cho *et al*., 2016) (predominantly performed in universities and public research organizations; de Jesus Pacheco et al., 2018) and market activity (generally performed by the private business sector). The relevance of applied R&D focused on knowledge absorption (Cainelli *et al*., 2012; Huang & Chen, 2020) by companies is intrinsic to the mission of TCs to improve industrial competitiveness. Both findings relate to the role of TCs as strategic partners of companies in innovation and technology (Bendis *et al*., 2008). This crucial role is explicitly stated in the publications of numerous TCs, from statutes to strategic plans, activity reports, websites, and social media accounts.

From the perspective of public policy, at the operational level, the results of the analysis indicate the value of actions aimed at providing stable, multiannual funding to TCs. This could be accomplished by (i) increasing the activity of TCs in European or national R&D projects, such as Horizon UE or Life projects at European level or "Misiones" or "Retos colaboración" projects at Spanish level or (ii) by implementing long term regional R&D public strategies, with multiannual programs and budgets.

The expert judgments indicate that society overlooks R&D, limiting the scope of policies and budgets and hence creating a barrier for TCs. This conclusion should be a warning to all public and private agents of the innovation system to raise society's awareness of the importance of investment in innovation. Such investment maintains the welfare state and people's quality of life (Erdin & Ozkaya, 2020). Intermediaries help companies and other organizations to overcome R&D investment constraints (Xu, 2020) which is a prominent element for increasing innovation (Johnson & Lybecker, 2012; Díaz-García *et al*., 2015; Hojnik & Ruzzier, 2016). Academics have broadly analyzed the relationship between public and private R&D investment and innovation. García-Álvarez-Coque *et al*. (2017) showed that innovation was equally enhanced through private and public R&D investment. In contrast, Scarpellini *et al*. (2012) argue that R&D is mainly financed by public administrations and universities, being private R&D contributions minimal. Our paper highlights the importance of private compared to public R&D investment when undertaking innovative activities for improving TC's efficiency and,

hence, regional competitiveness. This would provide insights to policymakers who would design and implement measures and policies that encourage the private sector to invest in R&D that considers principles of sustainable development, global well-being, and quality of life.

The findings can also be useful to help the internal management of TCs, given the ranking of variables for each agent in the system, and to encourage lines of action to improve certain indicators. The conclusions of this research can also be of strategic interest for the design of public policies to support innovation, specifically those aimed at supporting TCs. Public administrations can link aid for TCs to the achievement of certain levels of performance in specific indicators and variables to increase innovation in companies (Dalziel, 2010). Given that public resources are limited, this hierarchy of variables could be used when designing and implementing regional efficiency and competitiveness strategies to ensure that aid is granted in a highly targeted manner.

In driving business innovation, the intermediary role of TCs has become essential. They have a positive effect not only directly on the companies they work with (Cho *et al*., 2016) but also indirectly at the regional level (Labra & Juan, 2017). When the efficiency of TCs improves, they can help companies solve problems with more innovative solutions. The business sector evolves and has to face major competitive challenges. Regional competitiveness can thus be enhanced (Mas-Verdu, 2021). Building a solid, competitive, and innovative business sector that ensures sustainable development is one of the biggest problems facing all Spanish Autonomous Regions in the 21st century. To achieve sustainable development, the innovative actions of intermediaries such as TCs can act as a catalyst for regional efficiency and competitiveness (Gliedt *et al*., 2018), making TCs essential actors.

This article is not without limitations. Previous literature, experience, and the requirements for inclusion in the TC register provided the guidelines to identify the variables that affect TC activity. However, there may be many more aspects involved in TCs' technological and innovative processes. To identify these aspects, Spanish academic, business, public administration, and TC experts were consulted. Nevertheless, in other countries, other factors may be more relevant. Moreover, because regulations and regulatory enforcement differ in different contexts, other aspects may be necessary to boost regional competitiveness through TCs.

Given the aforementioned limitations, some future lines of research can be proposed. The same analysis could be conducted with additional experts from other countries to assess whether the same variables are considered important or whether other relevant factors emerge. Regions could thus be compared in terms of key variables and the efficiency of TCs in enhancing regional competitiveness.

AUTHORS CONTRIBUTION

Conceptualization: Cristina del Campo, Francisco Mas-Verdú and Norat Roig-Tierno; Methodology: Cristina del Campo and Norat Roig-Tierno; Data collection: Cristina del Campo; Data analysis: Cristina del Campo, Norat Roig-Tierno and Nuria Chaparro-Banegas; Drafting-Preparation of original: Cristina del Campo and Nuria Chaparro-Banegas; Drafting-Proof, reading and editing: Cristina del Campo and Nuria Chaparro-Banegas; Supervision: Francisco Mas-Verdu and Norat Roig-Tierno.

FUNDING

This research has not received external funding.

REFERENCES

Acs, Z. J., Anselin, L., & Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research policy, 31*(7), 1069-1085. http://dx.doi.org/10.1016/S0048-7333(01)00184-6

Aiginger, K., & Firgo, M. (2017). Regional competitiveness: connecting an old concept with new goals. In *Handbook of regions and competitiveness* (pp. 155-191). Edward Elgar Publishing.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research policy, 34*(8), 1173-1190. http://dx.doi.org/10.1016/j.respol.2005.03.013

Asheim, B. T., & Isaksen, A. (2002). Regional innovation systems: the integration of local 'sticky' and global 'ubiquitous' knowledge. *The Journal of Technology Transfer, 27*(1), 77-86. https://doi.org/10.1023/A:1013100704794

Asheim, B. T., & Moodysson, J. (2017). Innovation policy for economic resilience: The case of Sweden. *Papers in Innovation Studies*, (2017/5).

Badi, I., & Abdulshahed, A. (2019). Ranking the Libyan airlines by using full consistency method (FUCOM) and analytical hierarchy process (AHP). *Operational Research in Engineering Sciences: Theory and Applications*, *2*(1), 1-14. http://dx.doi.org/10.31181/oresta1901001b

Bakici, T., Almirall, E., & Wareham, J. (2013). The role of public open innovation intermediaries in local government and the public sector. *Technology Analysis & Strategic Management*, *25*(3), 311-327.

Bendis, R. A., Seline, R. S., & Byler, E. J. (2008). A new direction for technology-based economic development: The role of innovation intermediaries. *Industry and Higher Education*, *22*(2), 73-80.

Bogetoft, P., & Prusan, P. (1997). *Planning with multiple criteria-investigation, communication and choice*. Copenhagen: Copenhagen Business School Press.

Borrás, S., & Jordana, J. (2016). When regional innovation policies meet policy rationales and evidence: a plea for policy analysis. *European Planning Studies, 24*(12), 2133-2153. http://dx.doi.org/10.1080/09654313.2016.1236074

Brandäo Fischer, B., & Molero Zayas, J. (2013). A cross-country approach on the drivers of success in international R&D networks. *Revista de Estudios Empresariales. Segunda época*, (1), 112-132.

Cainelli, G., Mazzanti, M., & Montresor, S. (2012). Environmental innovations, local networks and internationalization. *Industry and Innovation*, *19*(8), 697-734.

Cantwell, J. (2004). Innovation and competitiveness. In Fagerberg, J., Mowery, D., Nelson, R. (Eds.), *Handbook of Innovation*. Oxford University Press.

Carrillo-Hermosilla, J., González, P. R. D., & Könnölä, T. (2009). Barriers to eco-innovation. In *Eco-Innovation* (pp. 28-50). Palgrave Macmillan, London.

Chen, C. F. (2006). Applying the analytical hierarchy process (AHP) approach to convention site selection. *Journal of Travel Research*, *45*(2), 167-174. http://dx.doi.org/10.1177/0047287506291593

Cho, C., Park, S. Y., Son, J. K., & Lee, S. (2016). R&D support services for small and medium-sized enterprises: The different perspectives of clients and service providers, and the roles of intermediaries. *Science and Public Policy*, *43*(6), 859-871.

Cho, Y. J., Leem, C. S., & Shin, K. T. (2008). The relationships among manufacturing innovation, competitiveness, and business performance in the manufacturing industries of Korea. *The International Journal of Advanced Manufacturing Technology*, *38*(7), 840-850.

Clark, J., & Guy, K. (1998). Innovation and competitiveness: a review: Practitioners' forum. *Technology Analysis & Strategic Management*, *10*(3), 363-395.

Coenen, L., Asheim, B., Bugge, M. M., & Herstad, S. J. (2017). Advancing regional innovation systems: What does evolutionary economic geography bring to the policy table?. *Environment and Planning C: Politics and Space, 35*(4), 600-620. http://dx.doi.org/10.1177/0263774X16646583

Cooke, P. (2002). Regional innovation systems: general findings and some new evidence from biotechnology clusters. *The Journal of Technology Transfer*, *27*(1), 133-145. https://dx.doi.org/10.1023/A:1013160923450

Cooke, P., Heidenreich, M. & Braczyk, H.-J. (2004). *Regional Innovation Systems*. London: Routledge.

D'Este, P., Garcia-Quevedo, J., & Mas-Verdú, F. (2014). Transferencia de conocimiento. Del modelo transaccional al relacional. *Mediterráneo Económico, 25,* 279-293. http://hdl.handle.net/2445/114871

Dalziel, M. (2010). Why do innovation intermediaries exist. In *DRUID Summer Conference*, p. 24.

de Jesus Pacheco, D. A., ten Caten, C. S., Jung, C. F., Navas, H. V. G., & Cruz-Machado, V. A. (2018). Eco-innovation determinants in manufacturing SMEs from emerging markets: Systematic literature review and challenges. *Journal of Engineering and Technology Management*, *48*, 44-63.

Del Río, P., Romero-Jordán, D., & Peñasco, C. (2017). Analysing firm-specific and type-specific determinants of eco-innovation. *Technological and Economic Development of Economy*, *23*(2), 270-295.

Díaz-García, C., González-Moreno, Á., & Sáez-Martínez, F. J. (2015). Eco-innovation: insights from a literature review. *Innovation*, *17*(1), 6–23. https://doi.org/10.1080/14479338.2015.1011060

Edler, J., & Fagerberg, J. (2017). Innovation policy: what, why, and how. *Oxford Review of Economic Policy*, *33*(1), 2-23.

Edquist, C. (2004). Reflections on the systems of innovation approach. *Science and public policy*, *31*(6), 485-489. http://dx.doi.org/10.3152/147154304781779741

Emrouznejad, A., & Marra, M. (2017). The state of the art development of AHP (1979–2017): a literature review with a social network analysis. *International Journal of Production Research*, *55*(22), 6653-6675. http://dx.doi.org/10.1080/00207543.2017.1334976

Erdin, C., & Ozkaya, G. (2020). R&D investments and quality of life in Turkey. *Heliyon*, *6*(5), e04006.

Fagerberg, J. (2017). Innovation policy: Rationales, lessons and challenges. *Journal of Economic Surveys, 31*(2), 497-512. http://dx.doi.org/10.1111/joes.12164

Fagerberg, J., & Verspagen, B. (2009). Innovation studies—The emerging structure of a new scientific field. *Research policy, 38*(2), 218-233. http://dx.doi.org/10.1016/j.respol.2008.12.006

Flanagan, K., & Uyarra, E. (2016). Four dangers in innovation policy studies–and how to avoid them. *Industry and Innovation, 23*(2), 177-188. http://dx.doi.org/10.1080/13662716.2016.1146126

Fong, P. S. W., & Choi, S. K. Y. (2000). Final contractor selection using the analytical hierarchy process. *Construction Management and Economics*, *18*(5), 547-557. http://dx.doi.org/10.1080/014461900407356

Forrest, J. F. (1991). Practitioners' forum: Models of the process technological innovation. *Technology Analysis & Strategic Management*, *3*(4), 439-453. http://dx.doi.org/10.1080/09537329108524070

Freeman, C. (1987). *Technology, policy, and economic performance: lessons from Japan*. Pinter Pub Ltd.

Freeman, C. (1994). The economics of technical change: a critical survey article. *Cambridge Journal of Economics*, *18*(5).

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of economics, 19*(1), 5-24. https://dx.doi.org/10.1093/oxfordjournals.cje.a035309

García-Álvarez-Coque, J. M., Mas-Verdú, F., & Roig-Tierno, N. (2017). Technological innovation versus non-technological innovation: different conditions in different regional contexts? *Quality and Quantity*, *51*(5), 1955–1967. https://doi.org/10.1007/S11135-016-0394-2/FIGURES/1

García-Quevedo, J., & Mas-Verdú, F. (2008). Does only size matter in the use of knowledge intensive services?. *Small Business Economics*, *31*(2), 137-146. http://dx.doi.org/10.1007/s11187-007-9090-x

Gliedt, T., Hoicka, C. E., & Jackson, N. (2018). Innovation intermediaries accelerating environmental sustainability transitions. *Journal of Cleaner Production*, *174*, 1247-1261.

Godin, B. (2005). *Measurement and statistics on science and technology: 1920 to the present*. London: Routledge.

Ho, W., & Ma, X. (2018). The state-of-the-art integrations and applications of the analytic hierarchy process. *European Journal of Operational Research*, *267*(2), 399-414. http://dx.doi.org/10.1016/j.ejor.2017.09.007

Hojnik, J., & Ruzzier, M. (2016). What drives eco-innovation? A review of an emerging literature. *Environmental Innovation and Societal Transitions*, *19*, 31-41.

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy, 35*(5), 715-728. http://dx.doi.org/10.1016/j.respol.2006.03.005

Huang, J., & Chen, X. (2020). Domestic R&D activities, technology absorption ability, and energy intensity in China. *Energy Policy*, *138*, 111184.

Isaksen, A., Normann, R. H., & Spilling, O. R. (2017). Do general innovation policy tools fit all? Analysis of the regional impact of the Norwegian Skattefunn scheme. *Journal of Innovation and Entrepreneurship, 6*(1), 6. http://dx.doi.org/10.1186/s13731-017-0068-x

Izushi, H. (2003). Impact of the length of relationships upon the use of research institutes by SMEs. *Research policy*, *32*(5), 771-788. http://dx.doi.org/10.1016/S0048-7333(02)00085-9

Johnson, D. K., & Lybecker, K. M. (2012). Paying for green: An economics literature review on the constraints to financing environmental innovation. *Electronic Green Journal*, *1*(33).

Kanda, W., Hjelm, O., Clausen, J., & Bienkowska, D. (2018). Roles of intermediaries in supporting eco-innovation. *Journal of Cleaner Production*, *205*, 1006-1016. http://dx.doi.org/10.1016/j.jclepro.2018.09.132

Koschatzky, K. (2002). Networking and knowledge transfer between research and industry in transition countries: empirical evidence from the Slovenian innovation system. *The Journal of Technology Transfer*, *27*(1), 27-38. https://dx.doi.org/10.1023/A:1013192402977

Kramer, J. P., Marinelli, E., Iammarino, S., & Diez, J. R. (2011). Intangible assets as drivers of innovation: Empirical evidence on multinational enterprises in German and UK regional systems of innovation. *Technovation*, *31*(9), 447-458. http://dx.doi.org/10.1016/j.technovation.2011.06.005

Labra Lillo, R. & Myrna, J. (2017). El sistema de ciencia y tecnología de corea del sur:¿ un ejemplo de colaboración internacional para Europa?. *Revista de Estudios Empresariales. Segunda Época*, (2).

Landabaso, M., Oughton, C., & Morgan, K. (2001). Innovation networks and regional policy in Europe. In *Innovation Networks* (pp. 243-273). Heidelberg: Physica.

Liu, X., & White, S. (2001). Comparing innovation systems: a framework and application to China's transitional context. *Research policy, 30*(7), 1091-1114. http://dx.doi.org/10.1016/S0048-7333(00)00132-3

Løken, E. (2007). Use of multicriteria decision analysis methods for energy planning problems. *Renewable and sustainable energy reviews*, *11*(7), 1584-1595. http://dx.doi.org/10.1016/j.rser.2005.11.005

López-Rubio, P., Mas-Tur, A., Merigó, J. M., & Roig-Tierno, N. (2021a). Leading trends in technology transfer. In *Technology Transfer and Entrepreneurial Innovations* (pp. 21-41). Cham: Springer.

López-Rubio, P., Roig-Tierno, N., & Mas-Tur, A. (2020). Regional innovation system research trends: toward knowledge management and entrepreneurial ecosystems. *International Journal of Quality Innovation*, *6*(1), 1-16. http://dx.doi.org/10.1186/s40887-020-00038-x

López-Rubio, P., Roig-Tierno, N., & Mas-Tur, A. (2021b). Which regions produce the most innovation policy research?. *Policy Studies*, 1-23. http://dx.doi.org/10.1080/01442872.2021.1937595

López-Rubio, P., Roig-Tierno, N., & Mas-Verdú, F. (2021c). Assessing the origins, evolution and prospects of national innovation systems. *Journal of the Knowledge Economy*, 1-24. http://dx.doi.org/10.1007/s13132-020-00712-7

Lundvall, B. A. (1992). *National systems of innovation: towards a theory of innovation and interactive learning*. New York: Anthem Press. http://www.jstor.org/stable/j.ctt1gxp7cs

Lundvall, B. Å. (2007). National innovation systems—analytical concept and development tool. *Industry and innovation, 14*(1), 95-119. http://dx.doi.org/10.1080/13662710601130863

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy, 31*(2), 247-264. http://dx.doi.org/10.1016/S0048-7333(01)00139-1

Mañas, J. M. G. (1999). Los centros tecnológicos: modelo y financiación. *Economía industrial*, (327), 87-94.

Marinoni, O. (2004). Implementation of the analytical hierarchy process with VBA in ArcGIS. *Computers & Geosciences*, *30*(6), 637-646. http://dx.doi.org/10.1016/j.cageo.2004.03.010

Martin, B. R. (2012). The evolution of science policy and innovation studies. *Research policy, 41*(7), 1219-1239. http://dx.doi.org/10.1016/j.respol.2012.03.012

Mas-Verdú, F. (2007). Services and innovation systems: European models of technology centres. *Service Business*, *1*(1), 7-23. http://dx.doi.org/10.1007/s11628-006-0002-y

Mas-Verdú, F. (2021). Transferencia de conocimiento e intermediarios de innovación. *Papeles de Economía Española*, (169), 104-118.

Mazzoleni, R. & Nelson, R.R. (2007). Public research institutions and economic catch up. *Research Policy, 36*(10), 1512-1528. http://dx.doi.org/10.1016/j.respol.2007.06.007

Muralidhar, K., Santhanam, R., & Wilson, R. L. (1990). Using the analytic hierarchy process for information system project selection. *Information & Management*, *18*(2), 87-95. http://dx.doi.org/10.1016/0378-7206(90)90055-M

Mytelka, L. K. (2000). Local systems of innovation in a globalized world economy. *Industry and innovation, 7*(1), 15-32. http://dx.doi.org/10.1080/713670244

Nelson, R. R. (Ed.). (1993). *National innovation systems: a comparative analysis*. New York: Oxford University Press on Demand.

OECD (2005). *Oslo Manual. Guidelines for collecting and interpreting innovation data*. Paris: OECD/EUROSTAT. https://dx.doi.org/10.1787/9789264013100-en

OECD (2011). *Regions and Innovation Policy*. Paris: OECD Publishing. https://dx.doi.org/10.1787/9789264097803-en

OECD/FECYT (2002). *Manual de Frascati. Propuesta de norma práctica para encuestas de investigación y desarrollo experimental*. Paris: OECD.

Ortega-Colomer, F. J. (2022). Principales oportunidades ambientales en el distrito industrial textil valenciano. *Revista de Estudios Empresariales. Segunda Época*, 72-93. https://dx.doi.org/10.17561/ree.n2.2022.7048

Oughton, C., Landabaso, M., & Morgan, K. (2002). The regional innovation paradox: innovation policy and industrial policy. *The Journal of Technology Transfer*, *27*(1), 97-110. https://dx.doi.org/10.1023/A:1013104805703

Partovi, F. Y. (1994). Determining what to benchmark: an analytic hierarchy process approach. *International Journal of Operations & Production Management*, *14*(6), 25-39. http://dx.doi.org/10.1108/01443579410062068

Phan, P.H., Siegel, D.S. & Wright, M. (2005). Science parks and incubators: Observations, synthesis and future research. *Journal of Business Venturing, 20*(2), 165-182. http://dx.doi.org/10.1016/j.jbusvent.2003.12.001

Roig-Tierno, N., Baviera-Puig, A., Buitrago-Vera, J., & Mas-Verdu, F. (2013). The retail site location decision process using GIS and the analytical hierarchy process. *Applied Geography*, *40*, 191-198. http://dx.doi.org/10.1016/j.apgeog.2013.03.005

Saaty, T. L. (1980). *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. New York: McGraw-Hill.

Saaty, T. L. (1986). Absolute and relative measurement with the AHP. The most livable cities in the United States. *Socio-Economic Planning Sciences*, *20*(6), 327-331. http://dx.doi.org/10.1016/0038-0121(86)90043-1

Scarpellini, S., Aranda, A., Aranda, J., Llera, E., & Marco, M. (2012). R&D and eco-innovation: opportunities for closer collaboration between universities and companies through technology centers. *Clean Technologies and Environmental Policy*, *14*(6), 1047-1058.

Sevinc, A., Gür, Ş., & Eren, T. (2018). Analysis of the difficulties of SMEs in industry 4.0 applications by analytical hierarchy process and analytical network process. *Processes*, *6*(12), 264. http://dx.doi.org/10.3390/pr6120264

Shafique, M. (2013). Thinking inside the box? Intellectual structure of the knowledge base of innovation research (1988–2008). *Strategic Management Journal, 34*(1), 62-93. http://dx.doi.org/10.1002/smj.2002

Sharif, N. (2006). Emergence and development of the National Innovation Systems concept. *Research policy, 35*(5), 745-766. http://dx.doi.org/10.1016/j.respol.2006.04.001

Siegel, D.S. (2003). Data requirements for assessing the private and social returns to Strategic research partnerships: Analysis and recommendations. *Technology Analysis & Strategic Management, 15*(2), 207-225. http://dx.doi.org/10.1080/0953732032000051118

Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. *Research policy, 34*(8), 1203-1219. https://dx.doi.org/10.1016/j.respol.2005.01.018

Tsai, K. H., & Liao, Y. C. (2017). Innovation capacity and the implementation of eco-innovation: Toward a contingency perspective. *Business Strategy and the Environment*, *26*(7), 1000-1013.

Uyarra, E., & Ramlogan, R. (2012). *The effects of cluster policy on innovation. London: Nesta*.

Xu, K., Geng, C., Wei, X., & Jiang, H. (2020). Financing development, financing constraint and R&D investment of strategic emerging industries in China. *Journal of Business Economics and Management*, *21*(4), 1010-1034.

Ybarra Pérez, J. A. (2012). La política industrial y la Pyme en España: La relevancia del territorio. *Revista de Estudios Empresariales. Segunda Época*, (1), 27-39