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Success variables in science and technology parks

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ABSTRACT

Science and technology parks are of great importance in the business context of the region in which they carry out their activity. They are the main mechanisms of public and private initiatives for the promotion of research, development and innovation, and technology transfer. The main goal of this type of institutions is not a purely economic benefit, but also social and cultural, which makes them an appropriate investment from the public institutions' viewpoint. They promote the creation of companies and agreements with universities and research centers, generate employment, and attract technology-based companies. Therefore, they require in-detail assessment to understand their operation to generate action plans and models that new parks or those who are still in their initial growth phase may follow. This study establishes a series of models—or operation strategies—to identify the strategies of successful parks; that is, parks that have overcome the initial stage and handle high revenue volumes, high rates of land occupation, and a large number of employees.

1. Introduction

No national or international agency questions the impact of research, development, and innovation (R + D + i) on the economy and the society of any country. After years of investment in these fields—primarily the efforts of institutions and public bodies (mainly universities)—advancing in the development of lines of work that allow a balance in R + D with a more active participation by private sector companies is a priority for the political, scientific, and business community. Within this context, science and technology parks (STP) play an essential role, because their existence represents an important factor in the competitiveness of the economy of a region or country, as well as a field for business investment. The Organization for Economic Cooperation and Development (OECD, 1987) defines STPs as zones of variable land areas that have the three following characteristics. Firstly, they concentrate high-tech industries and specialized service centers. Secondly, they have at least one university department or institute of technology with which hosted companies can communicate with each other in the material and intellectual sphere. Finally, they include an important component of research and development in the activities of the hosted entities.

The activity of STPs in Europe has nearly doubled in the last fifteen years. In 2013, 366 STPs exist in European Union member countries. These STPs have about 28 million square meters of buildings that host about 40,000 organizations of diverse nature, which, in turn, employ approximately 750,000 workers. Furthermore, many of these organizations carry out works of high added value. The capital investment in the STPs between 2000 and 2012 amounts to approximately 11.7 billion euros. In addition, during the same period, these institutions have invested about three billion euros in professional business support and innovation services for their hosted organizations and other technology-based firms in their locations or close to the parks (European Commission, 2014).

Previous studies analyze the problem in other continents like America, to study the possibility of exporting the case of Silicon Valley to other regions (Wonglimpiyara, 2010), or Asia: the detailed study of parks specializing in information technology in India (Vaidyanathan, 2008) and China with the park that the Tsinghua University promotes (Zou & Zhao, 2014).

The case of Spanish STPs is especially interesting because of their path to organizational development (Vásquez, Barge, & Modrego, 2016). The first Spanish STPs emerge in the mid-1980s as a strategy of regional development without any formal link with universities or the central government. The main goal of these early parks is to attract large high-technology firms, because they boost economic and industrial development of the regions surrounding STPs' location. After some years, the parks begin to represent an attraction for universities, which begin setting up smaller parks joined to their facilities dedicated especially to R + D activities and the creation of technology-based firms. The recognition of universities' key role in knowledge and technology transfer leads existing parks to increase their efforts to create links with them and other research institutions. With the support of the central and regional governments, the Spanish parks start a period of expansion since 1999. Thanks to this support, the number of STPs

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operating in Spain has increased, becoming the main political support initiative for R + D at present (Vásquez et al., 2016).

2. Theoretical framework

2.1. Importance of science and technology parks

Despite the widespread and considerable investments, the debate on the effectiveness of STPs as tools for the advancement of technology and the development of innovation policies remains open. On the one hand, a group of authors argue that STPs do not have any relevant effect on the outcomes of hosted companies, given that they are not successful in fostering collaborations and synergies that represent an added value for those companies (Macdonald, 1987). In addition, Massey, Quintas, and Wield (1992) criticize the model of STPs. Several empirical studies have not found a significant difference between the companies hosted in a STP and the others in terms of innovation outcomes, research productivity, or innovation processes (Colombo & Delmastro, 2002).

Conversely, another group of authors argue that STPs can create a supportive space for new companies based on knowledge and technology, in addition to facilitating technology transfer, attracting companies at the head of a technology sector, or promoting companies' growth. Some empirical studies show that the location in a park is beneficial to the companies for several reasons, including the creation of external collaborations—which might have a positive effect on the outcomes of the companies—the increase in the performance of research, and support when applying for patents (Albahari, Barge-Gil, Pérez-Cantó, & Modrego-Rico, 2013).

A number of authors propose a possible explanation to reconcile these two different points of view: the parks are heterogeneous. Some parks work properly and generate values for hosted companies, whereas others are not successful. Albahari et al. (2013) assess the effect of the heterogeneity of the parks on the innovation performance of the hosted companies, which represents a novel view in the literature on STPs.

2.2. Characteristics of science and technology parks

According to a report by the European Commission (2014), among all the characteristics of most STPs, those that clearly differentiate them from a technology park or another similar organization are the following. Firstly, they take into consideration careful policies for the selection of companies that the parks will host. Secondly, they prioritize the most innovative technology-based companies. Thirdly, they participate in the transmission of knowledge (mainly through universities and research or higher education centers). Fourthly, they also aim to cooperate and promote cooperation with other actors in the public and private sectors. Fifthly, they have and/or manage one or several incubators. Finally, they provide business support and services for innovation designed to increase the depth and the extent of innovation and knowledge and technology transfer within the region or locality and the park itself.

In order to check the efficiency of the parks assessed in the study, the European Commission uses the following indicators (European Commission, 2014):

a) Area of the parks and their built-up area.
b) Number of hosted companies and their number of employees. Other useful information concerns the type of employment resulting from parks' activity and the number of skilled workers, such as doctors or engineers.
c) Number of in-park companies and their number of employees.
d) Rent and services that STPs provide, either by month, year, or in general.
e) Type and range of services that the parks offer (broadband connection, videoconferencing, meeting rooms, events management, administrative support, etc.). Some of these services are free of charge, whereas others involve an extra charge or are part of the rental agreement of the company.
f) Type and range of professional services that either the park (directly) or companies (following the park's indications) offer (accounting, tutoring, access to funding risk, marketing, development of advertising campaigns, etc.). These services may be free of charge or involve an additional cost for the companies that request them.
g) Funding for capital and operating purposes.
h) Investment projects attracted to the region by the parks and/or in cooperation with other institutions, such as research centers and regional agencies.

On the other hand, another line of research (e.g., Fukugawa, 2015) assesses the effect of STPs on the innovation outcomes of the hosted companies. Most studies following this approach draw on comparisons among companies hosted inside and outside the STPs, as well as on the responses of companies' or parks' managers to surveys. Studies addressing variables, such as the number of years in which the companies have been operating in the STPs, expenditure on R + D + i, and number of employees or patents the company applies for, assess the level of impact of the parks on the hosted companies. Within this category, relevant studies are the assessments of parks from Japan (Fukugawa, 2015), United Kingdom (Siegel, Westhead, & Wrigth, 2003), and Finland (Squicciarini, 2009).

The difficulty of quantifying a STP's effect on a hosted company owes mainly to the lack of an established definition of success or a standard procedure to measure the effect of a company on the economy. Studies aiming to determine the success or failure of STPs tend to focus on two areas: (a) benefits that the park or the community obtains; and (b) benefits the hosted companies perceive. One even greater challenge is defining success in a manner that enables comparisons among STPs (Kharabsheh, 2012).

The current literature on STPs falls within two main fields of study. The institutional perspective focuses on analyzing whether STPs confer competitive advantages to hosted companies, while exerting positive indirect effects on companies located in their vicinity. The geographical and economic perspective considers a STP and its surroundings as an entity consisting of a set of specialized companies with a structure of connections and agreements between companies that has agglomerative effects (Koh, Koh, & Tschang, 2005).

2.3. Variables of parks that influence success

The identification of a set of variables that influence the success of a park and the hosted companies involves the creation of a table with the most relevant publications on the subject (Table 1a and b). This procedure provides a first list of the most common variables in the analysis of STPs and their effects, regardless of the perspective and the methodology used in the present study. (See Table 1b.)

According to the review of the state of the art observed in the previous tables, with the independent work of the European Commission (2014) and table articles cited in the Web of Science, the following variables stand out: funding received, expenditure on R + D + i, employees in the STP, years of operation of the STP, population of the park; number of hosted companies, linkages and agreements with universities, number of companies incubated in the park, services that the STP provides, patents that the hosted companies apply for, revenue of hosted companies, and presence of universities and research centers.

3. Method

The goal of the present study is to assess the importance of the main variables appearing in the literature concerning the advancement of STPs to group them according to their operating characteristics. To that end, the study assesses the STPs of the region of Andalusia, Spain. This is the largest Spanish region in extension and population,

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Table 1a
The most commonly used variables assessed in the studies on scientific and technology parks: part I.

Author(s)	Population (number of companies)	Land area (total, built-up)	Specialization level of the park	Employment in the companies	Linkage with universities	Collaboration between hosted companies	Companies incubated in the STP	Services provided by the STP	Number of patents and publications
Albahari et al. (2013)	X	X						X	X
European Commision (2014)	X	X		X				X	
Fukugawa (2015)				X	X				X
Kharabsheh (2012)				X	X	X		X	X
Koh et al. (2005)	X		X	X			X		
Phan, Siegel, & Wrigth (2005)	X	X	X	X				X	X
Ringlever (2012)					X	X	X	X	X
Siegel et al. (2003)				X					X
Squicciarini (2009)			X	X			X		X
Vásquez et al. (2016)						X			
Wallsten (2011)									

comparable to some member countries of the European Union such as Portugal. The study uses the information from the ten existing parks in Andalusia, which comprise the entire population. They have different characteristics and management strategy.

Table 2 illustrates the input variables for the model. The selection draws on the previous qualitative study and the available data in the questionnaire that the parks filled. These variables are: variability in years of operation; population of the companies; budget in thousands of euros; land areas in hectares; number of collaboration acts per year; annual internationalization events; specific use of R + D; (lack of) specialization of the park in any particular sector; number of incubated startups; percentage of incubators occupancy; and gross domestic product (GDP) per capita in thousands of euros. As output of the model—which will be the variable that measures the influence of the rest of the inputs on the behavior of the parks—two possibilities arise: (a) average revenue of the hosted companies measured in thousands of euros; and (b) the number employees in the companies.

The universe of this sample encompasses most of the possible types of parks, therefore, their analysis is worthy, given the generalization possibilities.

3.1. Calibration of variables

The QCA method constitutes an analytical approach and a set of research techniques that combine a detailed analysis of the cases under study and comparisons between such cases. Therefore, QCA builds on two fundamental principles: (a) causal complexity as underlying assumption, and (b) the combination of detailed assessment of the cases and the formal comparison between cases as modus operandi (Legewie, 2013). In the present study, the QCA type allows assessing the combinations of characteristics leading to an outcome rather than the net effects. In addition, the sample size is small, (i.e., only ten cases).

One of QCA strengths is the calibration of measures. For fuzzy-set Qualitative Comparative Analysis (fsQCA), the study transforms the measures into conditions assigning a membership within the interval from 0 to 1. Disclosing the membership criteria and providing arguments for them (according to the theory and case knowledge, preferably external to the data) are essential factors to understand the underlying assumptions, whose studies consider good practice (Schneider & Wagemann, 2012). The majority of QCA studies on business and management follow this recommendation.

The calibration of variables into conditions (equivalent to independent variables in fsQCA) and outcomes (equivalent to dependent variables in fsQCA) is a critical step in fsQCA, because the calibration determines the final fuzzy-set scores for conditions and outcomes. When using the fsQCA software, calibration requires assigning three membership thresholds: 0.95, 0.5 or cross-over point, and 0.05. The transformation of data into fuzzy sets is critical, because the results strongly depend on the calibration. Original variables do not require a calibration; therefore, their values are meaningful with respect to each other. Researchers must calibrate fuzzy sets according to the degree of membership that corresponds to theoretical constructs (Ragin, 2008).

First, according to Ragin, researchers should develop the anchor points, which divide the membership of the subject into the set considering full-membership (0.95), mid-membership or cross-over point (0.5), and non-membership (0.05). In this way, 1 represents full membership and 0 represents full exclusion—or non-membership—with all the values in between representing different degrees of membership. Two possibilities emerge for the conditions of the two datasets in this study: (a) data-dependent calibration; and (b) data-independent calibration. The first one uses the median of variables as cross-over

Table 1b
The most commonly used variables: part II.

Author(s)	Innovation outcome	Projection, internationalization	Revenue of the companies	Years of operation in the park	Level of land occupation	Universities and research centers	Expenditure on R + D + i (total or proportional)	Funding received	Employment in the management of the park
Albahari et al. (2013)	X	X	X	X			X		X
European Commision (2014)								X	
Fukugawa (2015)			X			X	X	X	
Kharabsheh (2012)						X		X	
Koh et al. (2005)			X			X			
Phan et al. (2005)		X	X	X		X	X	X	
Ringlever (2012)				X					
Siegel et al. (2003)							X		
Squicciarini (2009)				X		X			
Vásquez et al. (2016)	X						X		
Wallsten (2011)							X		

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Table 2
Distribution of the variables and their corresponding sets.

Variable	Coding	Original range	Original mean	Set mean
Years of operation	Y	3–21	10.90	5.66
Population	P	5–494	114.84	160.11
Budget	B	253–2576	1170.60	600.96
Land area	L	6.96–222.50	78.98	56.15
Collaboration	C	4–65	26.67	18.58
Internationalization	I	1–60	12.60	16.68
R + D + i workers	RDiw	5–4068	688	1204.90
Management workers	Mw	3–24.20	8.64	6.17
Specialization	S	0–1	0.35	0.45
Incubation	In	0–82	33.67	30.44
Incubators occupancy	Ino	0–87.67	44.17	30.37
GDP per capita	GDP	15.8–18.70	17.13	0.93
Revenue	R	253–1.86 exp6	4.65 exp5	6.70 exp5
Workers	W	33–14,716	3706.90	5572.59

point, approximately the lowest value of the top 5–10% as 0.95 and, conversely, the highest value of the lowest 5–10% as 0.05. This calibration leads to different values for each dataset.

Table 3 presents the truth table, which provides details on the calibrated scores for the relevant cases on the outcome and causal conditions. The truth table consists of 10 rows and all cases relevant for the outcome.

3.2. Fuzzy-set qualitative comparative analysis

This study performs a fsQCA of datasets and includes positive and negative versions of revenue and workers (indicating acceptance and refusal behaviors, respectively) as outcomes. This analysis highlights the variables that influence success of STPs, so that new parks can implement measures for sustainability. The study considers the data from 2010 to 2012 to assess parks' relative positions with other parks and their grouping.

The codification of cases in the truth table does not delete cases with no occurrences, because all parks completed the survey. Table 4 and 5 shows the intermediate solution of the fsQCA for the datasets and the results with revenue and workers as outcomes.

The consistency cutoff is 0.90. The results indicate that the parsimonious solution contains 4 combinations of conditions and the intermediate solution contains 3 combinations of conditions. Consistency levels of both solutions are higher than 0.86 and above the limit of 0.74 that Ragin (2008) proposes for a model to be informative (Woodside, 2013). Furthermore, all consistency levels for every condition are higher than 0.83.

4. Results

After the selection of the revenue as first output of the study, the results yield a complex solution with three groups of parks, each one constituting a different model.

Table 3
Truth table.

STP	Y	P	B	C	I	W	GDP	R
PITA	0	0	1	0	0	0	1	0
PCTAJ	0	0	0	0	0	0	0	0
TecnoBahía	0	1	0	0	1	1	0	1
Rabanales	1	0	0	0	0	0	0	0
PTS	1	1	1	1	1	1	0	1
PCTH	0	0	1	0	0	0	1	0
Geolit	1	0	0	1	0	0	0	0
PTA	1	1	1	1	1	1	0	1
PCT Cartuja	1	1	1	1	1	1	1	1
Aerópolis	0	1	0	0	1	1	1	1

Fig. 1 illustrates the three resulting groups of parks:

Table 6 shows the solution that considers workers as output. The groups of parks are the same, but the conditions change.

4.1. First group: TecnoBahía and Aerópolis

From the qualitative point of view, the grouping of these two parks obeys to the many qualities that they share. They appear in similar dates—one in December 2002 and the other in July 2003—and the two parks have a high degree of maturity. They are also two institutions with large land areas (66.67 and 116.49 ha), located in urban zones with good access and communication. In addition, the two parks present a high international profile and specialization in the aeronautical sector. The fsQCA indicates that the revenue receives significant influence from the number of hosted companies, the high level of internationalization, and employment figures. The GDP of the region has no influence and the negative variables are the years of operation, the funding received, and the acts of collaboration.

4.2. Second group: PTS, PTA, and PCT Cartuja

This group consists of the three older parks established between 1990 and 1997 and for this reason they present a high degree of maturity. They have a medium size occupying 62.66 and 69.23 ha. In addition, two of these parks are the only urban parks of the sample. Two of the parks present a general character, whereas the other specializes in the health sector, with a large number of hosted companies focusing on the fields of medicine and health. The influence of the universities stands out in the three parks, with a large number of contracts, agreements, and collaborations. In addition, the three parks have a great international projection, according to the large number of acts of internationalization they perform during the three-year period from 2010 to 2012. The variable GDP per capita does not influence the revenue and employment.

4.3. Third group: Geolit

In this third group, the fsQCA yields a specific park because of its importance with respect to its outcome, revenue, workers, and its differences with the other two groups. The importance of this park lies in the years of operation and the acts of collaboration, because the other variables do not influence the final achievement. For this reason, for parks with great operation periods, the number of acts of collaboration is essential to ensure their sustainability.

5. Discussion

During the period between the creation of a STP until that STP reaches a critical number of hosted companies that grant financial independence, the advancement and growth of the park are slow and complex. To overcome this situation, thus becoming a sustainable success case and a model for other parks, the manager should decide which strategy to follow, which is a complex task. The QCA method allows defining groups of parks, identifying (a) the variables that positively influence their behavior, (b) variables that have a lower value than the average value—which therefore have no relevant importance in the final configuration—and (c) non-existent variables, which do not appear in the model.

The fsQCA does not group some of the parks in these three clusters. This result owes to the lack of significance of the characteristics of these parks, which have a short operation period, a small size, and lower turnover and employment than the other parks. However, the results are very useful for those parks, because according to their environment (they are close to a significant population), their degree of specialization, their percentage of occupation, and number of skilled jobs, they can consider one of the groups identified in this study as their ultimate goal, identifying the inputs that they should enhance to achieve a sustainable state in the future.

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Table 4
Results of the analysis of revenue output.

Revenue				
Parsimonious solution				
Outcome	Conditions	Raw cov.	Unique cov.	Cons.
Revenue	Collaboration	0.82	0.01	0.83
Revenue	Population	0.86	0.00	0.99
Revenue	Internationalization	0.83	0.00	0.95
Revenue	Workers	0.90	0.03	0.98
Sol. coverage	Sol. consistency	Freq. cutoff	Consistency cutoff	
0.98	0.84	1.00	0.90	
Intermediate solution				
Outcome	Conditions	Raw cov.	Unique cov.	Cons.
revenue	W*I*~C*~B*P*~Y	0.29	0.08	1.00
revenue	W*I*~C*~B*P*~Y	0.53	0.35	1.00
revenue	~GDP*~W*~I*CP*~B*~P*Y	0.24	0.08	0.90
Sol. coverage	Sol. consistency	Freq. cutoff	Consistency cutoff	
0.73	0.86	1.00	0.90	

The STPs that do not appear in any of the previous groups have a lower output than the average (i.e., their turnover and employment is not high with respect to the cases under study). Therefore, the four parks that do not appear in any of the identified groups have three options to improve their outcomes:

- Option 1: The park should specialize in a particular sector, giving priority to the population, internationalization, and employment parameters. The park should obtain a large number of hosted companies and organize acts of internationalization, such as conferences, meetings, or visits.
- Option 2: The managers should analyze the possibilities of achieving a high degree of maturity. The number of hosted companies and the acts of collaboration and internationalization performed in the park constitute a successful case, guaranteeing turnover and employment generation.
- Option 3: A path for intermediate moments in the life of a park. At those moments, the park should focus on the organization of a large number of acts of collaboration between hosted companies, as well as achieving a high level of maturity.

6. Conclusions

This study responds to the need for more sophisticated techniques in the research on the science and technology parks, for the promotion of research, development, and innovation. This study analyzes different parks and selects operation strategies. Future studies should consider the evolution of the variables with the passage of time. This study assesses the average values of the year-period from 2010 to 2012. Future studies should also focus on obtaining further information such as entrepreneurship, projects for technology transfer in international consortia, or the number of patents and, from them, those ending as new products, processes or services arising from that knowledge. Regarding entrepreneurship, the influence of incubation of new startups on the long-term sustainability of STPs is a relevant line of research. To that end, studies must consider not only whether the parks have incubators in their areas, but variables such as the number of incubated initiatives, their success rate after 3/5 years of operation, turnover, and the number of jobs they generate.

Regarding international projects, they are relevant in raising funds through consortia of companies with high component of R + D + i, technological centers, and universities. These projects allow developing new products or services in sectors with future potential.

In terms of intellectual property, parks should not only focus on the number of patent registrations, but the number of countries in which companies register such inventions and whether the patent has single or shared ownership. Given the difficulty of identifying patents' influence in the final revenue, studies should consider the royalties that sales generate or the startups that emerge from this knowledge.

Given the special characteristics of STPs, if all this information is available in the future, new influential variables may emerge. Therefore,

Table 5
Combinations of sufficiency conditions for output revenue.

	Revenue		
Configuration	Group 1	Group 2	Group 3
Years of operation	○	●	●
Population	●	●	○
Collaboration	○	●	●
Budget	○	●	○
Internationalization	●	●	○
Workers	●	●	○
GDP			○
Consistency	1.0000	1.0000	0.9041
Raw coverage	0.2962	0.5296	0.2370
Unique coverage	0.0876	0.3482	0.0720
overall solution consistency 0.9361			
overall solution coverage 0.9670			

● indicates the presence of a causal condition; ○ indicates core conditions; blank indicates absence.

Table 6
Combinations of sufficiency conditions for output workers.

	Workers		
Configuration	Group 1	Group 2	Group 3
Years of operation	○	●	●
Population	●	●	○
Collaboration	●	●	●
Budget	●	●	○
Incubation	●	●	●
Revenue	●	●	○
GDP	○		○
Consistency	1.0000	1.0000	0.9119
Raw coverage	0.3680	0.3159	0.2765
Unique coverage	0.280	0.1239	0.0808
overall solution consistency 0.9611			
overall solution coverage 0.7540			

● indicates the presence of a causal condition; ○ indicates core conditions; blank indicates absence.

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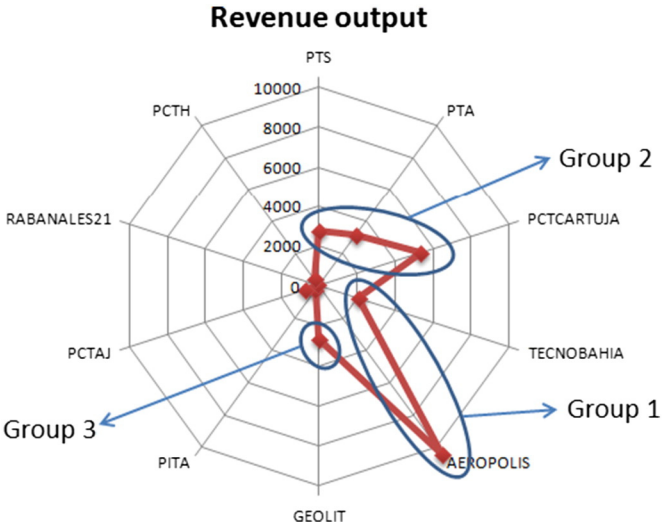

Fig. 1. Variable output of the model, revenue with groups of selected parks.

scholars should perform a special follow-up to detect new important variables in the environment that may be significant for future success.

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