Analysis of the Dynamical Capabilities into the Public Research Institutes to Their Strategic Decision-Making

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Abstract: Academy–industry collaborations (AICs) play a crucial role in the creation of new knowledge, by transferring this knowledge to the society and bringing into line theory and practice. Although in the state-of-the-art exists a number of efforts to analyze different factors that influence these collaborations, little attention has been paid in the application of dynamic capabilities (DCs) as an emerging tool to identify strategic elements in public research institutes (PRIs). Aiming to fill this literature gap, in this study, DCs methodology was applied to the Mexican PRI in order to classify the research activities into these strategies. A second stage was carried out to determine the influence of each DC in the global productivity and knowledge integration or transfer. The relationship between the variables was statistically analyzed using one-way analysis of variance (ANOVA) and Pearson’s correlation coefficient. The main findings of this study showed that sensing and reconfiguration capabilities have a direct interaction on the global productivity and knowledge integration or transfer of the Mexican PRI, whereas the seizing capabilities present a weak impact on these items. The proper application of the DCs framework, as a substantial instrument for the PRI, opens up an alternative to identify that the main activities should receive special attention during the strategic planning process. These strategies can improve academic–industry collaborations by promoting the process of global knowledge and technology development.

Keywords: dynamic capabilities; strategic management; public research institutes; scientific productivity; collaboration networks

1. Introduction

The R&D projects between academic–industrial sectors have been recognized as a means for the acquisition or transfer of knowledge (technology) either for business leaders or latecomer firms [1]. For this reason, several studies have pointed out the challenges, benefits and focus on effective evaluations of academia–industry collaborations (AICs); however, most of them are based on subjective perceptions [2,3]. Particularly, for academic institutions, the needs of integrating or transferring new knowledge as well as solving the funding problems for the development of research projects are an incentive to seek collaborations with firms. An additional point to consider is that there is an enormous social pressure on academic institutions for their research projects to have an economic impact, modifying the traditional role (education and generation of knowledge) [4,5]. A direct impact in academic sectors is that the AICs can allow them to stay at the forefront...
in all the knowledge fields. Academy–industry collaborations also impact their global productivity, recognition, the quality of the offered academic programs and the strategic planning process of the research lines.

With regard to the firms, they can gain greater benefits from the academic collaborations because the experimental, problem solving approach emphasized in technological recombination facilitates the process of the translation of scientific discoveries into technological innovations [6]. Unfortunately, most firms in developing countries invest in enhancing their strategic management from different strategies to predict business environments, which is evidently not aligned with the academic vision.

The most common strategies that organizations use to analyze foresight scenarios can be divided into distinctive marketing competencies, central capabilities, corporate foresight, resource-based perspectives and dynamic capabilities (DCs), among others, [7–10]. From these schemes, it has recently been recognized that DCs create business values and a permanent competitive advantage according to the changes in the business market [10–14]. DCs are strategic elements that enable the constant renewal of competencies to reconfigure and redirect the resources to be consistent with a rapidly changing environment, as well as to achieve and maintain competitive advantage in different institutions [15–20]. DCs involve the processes’ identification (managerial and organizational) that are necessary during the implementation of strategies, innovation and adaptation to a changing context [11,15,17,21,22].

From an analytical point of view, the dynamic capabilities are classified in three dimensions. Sensing capabilities (threats and opportunities), through environment exploration, trend-searching, and the identification of customers’ needs by scanning, filtering, identifying, learning and interpreting relevant information. Seizing capabilities (opportunities), through the necessary resources’ understanding, relevant decision-making, and the implementation of necessary changes. Finally, the reconfiguration capabilities, through developing adaptation abilities to changing circumstances and to market needs, and by realigning resources so that their combinations increase the organization value [9,11].

A number of studies have analyzed the successes and barriers of AICs by identifying a multitude of factors alternating from market conditions to governance structures and the entrepreneurial orientation of universities and firms [23–27]. From this last point can be highlighted differences in the objectives, interpretations, administrative processes and vision of the partners [28–30]. However, up to now, the DCs analysis has been applied successfully in entrepreneurial and/or industrial sectors, but to our knowledge, there are few studies that apply these strategies in public research institutes (PRIs) [31–34]. Then, empirical works of DCs in universities or research institutes are rarely considered for strategic management, competitive advantage in research and development, as well as the innovation process [35–38].

On the other hand, the state-of-the-art of institutions dedicated to science and technology in Mexico are as follows: there are around 350 research institutes, belonging to different public and private institutions, where the National Council of Science and Technology (CONACyT) is the governing body of the research system. Approximately, there are 150 research public institutes dedicated to science and technology (in this number are not included those dedicated to health). As with other developing countries, Mexico needs to identify the strategic activities that ensure that all the development and knowledge areas in each public research center are aligned with social requirements, including industrial collaborations. Then, a systematic analysis can be essential to help transfer conceptual and empirical knowledge between public research institutes and industry [39,40].

For the aforementioned, the purpose of this study was to identify the research activities of the PRIs in Mexico through the context of the DCs framework, proposing them as an alternative to evaluate the main activities that impact the strategic planning processes. Thereafter, the identified DCs were used to evaluate their influence on scientific productivity and knowledge integration or transfer, identifying factors that help improve AICs for PRIs in Mexico. It is expected that this study will serve as a reference for the use of
DCs in the academic segment, and could be extrapolated to most developing countries. The main research questions considered in this study are: how can these activities be identified and classified into the DCs framework?; is this strategy as valid for academic institutions as it has been for other organizations?; what kind of activities mainly impact in the global productivity and knowledge integration or transfer?, and would this analysis help to overcome the barriers in the AICs? To overcome these objectives, the structure of this study considers a theoretical overview related to the educational institutions–industry collaboration and its effect on the productivity and academic level of the PRIs, a description of the methodology and strategy, results, discussion, implications, limitations, suggestions for future research and conclusions.

2. Theoretical Background

The knowledge absorption and production are in constant transformation in the academic sector [41]. As part of these activities, it has been recognized that AICs play a crucial role, but it is also a challenge to establish an effective inter-organizational relationship [42], especially when this interaction is carried out between different sectors (e.g., private and public sectors) [4]. Dissimilarities in policies, operational flexibility, speed of service, administrative control and autonomy cause divergent perceptions and goals. For example, academics usually base their scientific reputation on the number of publications (journal quality, impact factor, quartile, etc.) and graduate students prefer research with a long-term impact [28,43,44]. In consequence, AICs are undervalued by academics, affecting, most of the time, the credibility of the academic programs, the technological applications of the research, technology transfer and the overall productivity of the institutions. Conversely, firms are motivated by the interest of generating market values with short-term benefits and, therefore, they also show little interest in collaborating with the academy [29].

Consequently, it has been well established that a successful AIC depends on the degree of commitment between the organizations to exchange different tangible and intangible resources, such as materials, equipment, technology, data and knowledge [44]. Relevant barriers that have been detected as important inhibitors of successful collaboration are associated with false mutual expectations, excessive bureaucratic structures to sign agreements, different interests and needs, lack of funding, disappointment or misunderstanding in the main objectives of the projects and credibility between the parties [45,46].

For example, academic institutions are expected to be well equipped to provide a means of stimulating business growth to the firms, new ideas for R&D projects and propitiate high impact innovations. However, in developing countries, this assumption is sometimes far from reality and each institution lacks enough infrastructure to properly attend innovative projects. Moreover, most scientists lack vision and motivation when deciding not to collaborate on industry projects, conduct investigations far from real applications, or take a long time to solve industrial problems, widening the gap for fruitful collaborative projects [47]. That is, the success of R&D collaborative projects depends on how one aligns common objectives and motivations [29,30,48–52].

For instance, the expectations of companies are usually related to solving a specific problem during their production process, while gaining expertise, new ideas, potential future employees and/or access to highly qualified people [1,28,53–55]. Companies are also motivated by the interest of acquiring external technology and procedures that enhance their innovation process to be competitive with other technological leaders, creating new products and solutions with a significant reduction in time [5,56]. Additionally, industrial organizations are incentivized to enhance their financial performance, open new business lines, solve complex problems, training collaborations, leverage the researchers’ expertise and explore benefits of the infrastructure. On the other hand, the academic component has the opportunity to acquire funds for the infrastructure, general maintenance and development of research projects. Furthermore, the personnel give the chance of absorbing and/or sharing their knowledge to the firm, promoting innovation with critical feedback [57–60]. Another important inflow is the participation of students in projects, who
may eventually be hired by the company, ensuring their participation in the production of knowledge [41,61].

In this context, different typologies or taxonomies of AICs have been proposed according to the interaction stage and duration of the relationship. One of the most complete classifications was foreseen by Santoro and Gopalakrishan, who projected different steps to reach effective AICs [62]. The first step is related to the endowment/trust fund (research support). The second level considers institutional agreements, institutional facilities, group arrangements and informal intentions (cooperative research). The next step is reached when the activities of the recruitment of recent graduates, personal interactions, institutional programs and cooperative education (knowledge integration or transfer) are involved. The last stage (strong interaction) is linked to the product development and commercialization activities through academic institutions (technology transfer → productivity → recognition). It can be noticed that each step is quite important to monitor the thrust between both sides.

As it is perceived, successful AICs propitiate a wide variety of benefits for both sites [47,63]. However, it is essential that academic institutions give an objective value to R&D projects, and at the same time, persuade their specialized personnel about the profits of establishing industrial collaborations. It is also indispensable that institutions identify their personnel skills, work styles, attitudes, and mental processes to create successful scenarios for AICs. To reach this objective, the academic institutions must also apply existing structures for a strategic management.

It is well-recognized that DCs have been used as a framework that allow the organizations to make strategic decisions in order to adapt them to the dynamic environment [64–66]. Besides, DCs contribute to the organizations to identify abilities to create, expand and modify their routines and resources base. Additionally, they promote new product development and market analysis, which implies changes to the current status-quo [17,67–71].

For this reason, in this document, it is proposed that DCs strategies can be used to detect the main activities that impact the strategic planning process of academic institutions and their effect on the scientific productivity and knowledge integration or transfer, taking into account factors that help improve AICs. Teece and coworkers established that the adaptation of any organization to a rapidly changing environment rests on the proper identification of their DCs [9]; i.e., the capability to build and reconfigure their internal–external competences [15]; in this perspective, the application of DCs can strongly help the academic institutions. In academic institutions, it is essential to create new knowledge from research, transfer knowledge to the society, innovate with a high social impact, seek new ways to find new means of acquiring technology, align theory and practice, expand the curriculum of researchers, and improve the academic level with an easier way for the insertion of postgraduate students into the industrial environment [72–78].

Particularly, this study is focused on the application of DCs to the Mexican PRIs in order to identify factors that influence scientific productivity and knowledge integration or transfer, which in turn help to reach successful AICs. The AICs in Mexico are established in two ways; a) interaction to solve specific problems of a firm, and b) formal contracts that seek innovations in their processes in a short period of time [79–81].

In the state-of-art, the analysis of strategic management of PRIs from dynamic concepts is unusual. In general, efforts are aimed to identify factors that promote successful R&D projects from a global context and/or statistical analysis [32,82]. However, it can be projected that academic institutions will shortly have to systematically apply these kind of strategies to ensure their short- and long-term competitiveness. This will impact on a positive perception of the institutions, the academic level of their graduates, the knowledge absorption and application with social and industrial influence, overall productivity and recognition. It is projected that the study may have important implications in the use of dynamic plans for the strategic design process and can be used as a reference in developing countries, where similar barriers to reaching successful AICs have been observed.
3. Methodology, Analytical Framework and Case Studies

3.1. Collecting Data, First Stage

The study was divided into two steps; at first stage, all public scientific and technological research institutes in Mexico were identified, through national science and technology databases, the National Council of Science and Technology (CONACyT), and official web portals of Mexican public institutions [83]. It was found that about 150 research public institutes are dedicated to science and technology (in this number are not included those dedicated to health). From these institutions, the means of contact for foresight experts, researchers and/or innovation and technology management staff were obtained. Thereafter, an initial questionnaire was elaborated from a framework based on previous fundamental works and studies of DCs. The scheme has been used to identify the strategic elements related to R&D collaborations [26,84]. Additionally, the main aspects established by the National Council of Science and Technology, through which it evaluates the research institutes for their inclusion into the National Register of Quality Postgraduate Programs in Mexico, were taken into account. The framework of DCs used by the PRIs in Mexico is shown in Figure 1, whereas the elaborated questionnaire can be observed in the Supplementary Materials (Table S1, Q1–Q31). It is important to highlight that the survey considers cumulative data from January 2014 to December 2019.

The instrument was subjected to the review, criticism and validation of 7 experts, who were scientific and technological personnel from different research institutes and university academics. Subsequently, it was applied to 123 members of different research groups belonging to distinct Mexican public research institutes. The surveys represent 49 Mexican public research institutes, located in 21 of the 32 federal states. These public research institutes correspond to 75% of those belonging to the National Council of Science and Technology (CONACyT, Mexico), as well as 60% of those of the National Polytechnic Institute (IPN, Mexico), and 26% of the National Autonomous University of Mexico (UNAM, Mexico); which are the three main research public institutions in the country, where most of the scientific productivity resides. Therefore, it was considered that the obtained information is statistically reliable and representative to all Mexican public research institutes.

Data were collected from individual insights and experience of the respondents through an online survey, using the SurveyMonkey® platform (SurveyMonkey, San Mateo, CA, USA). All the questions were in an open-ended format in order to propitiate versatility during the evaluation of the indicators analyzing their social impact. As mentioned before, the first assessment instrument has the purpose of classifying and identifying the critical factors carried out during the research activities of the Mexican PRIs using DCs strategies.

3.1.1. Statistical Analysis

The collected data were initially analyzed by the simple constant comparative method which traditionally consists of data comparison, deduction, conclusions and verification [85]. Thereafter, the critical factors were categorized through statistical analyses using IBM statistics SPSS v.21 software (IBM Co., New York, NY, USA). A one-way analysis of variance (ANOVA) was considered for potential interactions using a $p \leq 0.05$ and examining Fisher’s test (F). The relevant relationships of the research activities were only analyzed in the second stage.

The effects of each variable were analyzed separately for each factor, determining the relationship between the type of research of PRIs and the sensing, seizing and reconfiguration variables from the framework of DCs. The one-way ANOVA is a simple but powerful statistical technique that can be used to analyze the variability in data and determine the interactions among population means. It can be considered as an extension of the t-test for two independent samples to more than two groups [86].
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Essentially, in this case, it was used to obtain information from the PRIs without manipulating variables and also to detect strengths and weaknesses in the academic environments.

3.1.2. DCs Framework for Mexican PRI

From the results of the simple constant comparative method and the complement with the statistical analysis, a dynamic capabilities framework was proposed that considered the main activities that were detected as essential in the Mexican public research institutes. This scheme was taken as a reference in the second step.

3.2. Collecting Data, Second Stage

In a second stage, a subsequent questionnaire was constructed, based on the framework for Mexican PRIs, to determine quantitatively their productivity and knowledge absorption or transfer, as well as to identify the research activities related to this information (See Supplementary Materials Table S2). Innovation and technology management staff were asked to answer this instrument. The information was requested from the research institutes through the National Institute of Transparency, Information Access and Personal Data Protection platform. The data were initially collected considering a period of time of January 2014 to December 2019.

Statistical Analysis

The statistical analysis for the second stage was carried out using the IBM statistics SPSS v.21 software (IBM Co., New York, NY, USA). The quantitative analysis consisted of one-way analysis of variance ($p \leq 0.05$) along with Pearson’s correlation. The Pearson’s correlation is usually well-accepted as a method to evaluate numerical variables [88]. Both
techniques were used to guarantee the interaction between the analyzed variables. In the case of Pearson’s correlation, it was considered a strong correlation when \( r \geq 0.50 \) and \( p \leq 0.05 \), a moderate correlation when \( 0.49 \leq r < 0.30 \) and \( p \leq 0.05 \), a weak correlation when \( 0.29 \leq r < 0.10 \) and \( p \leq 0.05 \), and null when \( r < 0.10 \) or with another \( r \)-value and \( p > 0.05 \). The analysis was realized comparing the research activities identified in the DCs framework that presented a strong influence during the first survey with each variable of the second survey.

From the interactions between both questionnaires, the critical factors that impact on the knowledge integration or transfer and scientific productivity were determined. The potential opportunity areas to generate successful AICs were also analyzed [32,89,90].

4. Results
4.1. Indicators Identification of DCs for Mexican Public Research Institutes
4.1.1. Initial Analysis by Constant Comparative Method

This study was carried out to classify the research activities into the DCs framework and determine the activities that predominantly influence the strategic planning process of the Mexican PRIs. Initially, an analysis of the criteria that PRI follow for updating their research lines was carried out, and foresight techniques to propose their research projects were applied. The analysis was realized by the constant comparative method, identifying the questions that correspond to the criteria used by Mexican PRIs for updating the research lines and also, the enquiries to determine the percentage of research activities that are supported by technology foresight or conventional methods.

The findings of the initial examination are shown in Figure 2a and indicate that the main activities carried out by the Mexican PRIs to update their research lines are: conducting research projects through calls from state or federal authorities (14.73%), experience of the researchers and collaboration in national–international networks (13.79%), updating through participation in academic events (12.85%), review of scientific publications (12.54%) and industry-related projects (12.23%). Conversely, the activities that have scarcely been realized to update the research lines are related to the association of market studies including SWOT analysis, benchmarking bibliometrics (4.07%) and specific or relevance studies of social changes (6.90%). The main activities seem to be consistent with a previous evaluation realized in the PRIs of Mexico in 2013 [32], confirming that systematic methods are required to promote a strategic decision during the academic planning process.

![Figure 2](image-url)

**Figure 2.** Criteria that PRIs in Mexico follow for (a) updating research lines and (b) percentage of research activities that are supported by technology foresight or conventional methods (survey 1, see Supplementary Materials Table S1).
On the other hand, in Figure 2b, the analysis to identify the percentage of research activities that are supported by technology foresight methods in comparison with traditional methods is shown. The bar charts show that most of the proposed projects in the PRIs of Mexico are based on literature review (18.70%), SWOT analysis (14.50%), environmental scanning (10.69%), brainstorming (9.54%) and expert panels (7.92%); i.e., without a process that implies a systematic strategic management of the research and emerging technologies with a social impact. The integration of forecasting and traditional methods in science has been identified as the best way to predict, understand and react to technological challenges. Then, the integration of foresight activities to the Mexican PRIs can catalyze the productive and social environment transformation; i.e., the application of quantitative and qualitative methods for future-oriented technology analysis [91].

Another important analysis obtained in the first survey is that the structure of Mexican PRIs is originally focused on the application of science and technology. However, it was found that most of the research activities correspond to basic science (39.45%), which are comparable to the efforts developed in applied research (38.42%); whereas R&D activities are far from being important in the Mexican PRIs (22.13%) (Figure 3a). It was also found that these activities are mainly projected in the short (39.45%) and medium term (35.04%); i.e., in a period between 2 and 5 years (Figure 3b). Consequently, the research activities are in consequence poorly structured in the long-term (below 26%). The results pointed out that the organizational objectives are more dependent on social pressure to generate high impact developments than align resources in the most strategic manner. It is important to highlight that these results may be influenced by other factors that are far from the goal of this work, such as available infrastructure, the specialties of the research groups and particularities of the industry in each region.

![Type of research activities](#) ![Research development deadlines](#)

**Figure 3.** Integration of research projects based on (a) type of research activities and (b) research development deadlines.

4.1.2. Statistical Analysis of the First Stage

Derived from this examination and considering that worldwide, evidence-based knowledge creation from the academic sectors is still essential, the statistical analysis was carried out comparing each variable in terms of research type, i.e., basic science (A), applied science (B) and R&D activities (C). The quantitative analyses were performed using the one-way ANOVA test based on p-value and F-value. The sample group size was of 49 (N) and a level of statistical significance was fixed $p \leq 0.05$.

Tables 1–3 show the descriptive statistical analysis of the first survey responses which was constructed from the framework of DCs. The analysis was separated by sensing (Table 1), seizing (Table 2) and reconfiguration (Table 3). The statistical analysis of sensing capabilities indicates that there is a strong correlation of basic science projects with the bibliometrics methods ($p = 0.04$) and the interaction with national–international collaborations ($p = 0.03$).
Table 1. Relationship between the type of research of PRIs and the sensing variables from framework of DCs.

<table>
<thead>
<tr>
<th>Q1. Researchers</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Q2. Technicians</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>54.5</td>
<td>Mean</td>
<td>33.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std Deviation</td>
<td>56.30</td>
<td>Std Deviation</td>
<td>43.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1.11</td>
<td>1.02</td>
<td>0.53</td>
<td>F</td>
<td>1.46</td>
<td>2.79</td>
<td>3.77</td>
</tr>
<tr>
<td>p</td>
<td>0.40</td>
<td>0.48</td>
<td>0.93</td>
<td>p</td>
<td>0.18</td>
<td>0.08*</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

Q3. Research Lines

| Mean | 12.5 | Mean | 0.75 |
| Std Deviation | 14.8 | Std Deviation | 0.40 |
| F | 1.46 | 4.95 | 7.76 | F | 1.08 | 0.72 | 1.13 |
| p | 0.178 | 0.05 * | 0.01 * | p | 0.43 | 0.79 | 0.08 |

Q4. Relevance Studies

| Mean | 0.41 | Mean | 0.20 |
| Std Deviation | 0.49 | Std Deviation | 0.40 |
| F | 1.01 | 1.21 | 1.91 | F | 0.53 | 1.37 | 1.49 |
| p | 0.48 | 0.33 | 0.06 | p | 0.94 | 0.23 | 0.16 |

Q5. SWOT Analysis

| Mean | 0.71 | Mean | 0.53 |
| Std Deviation | 0.46 | Std Deviation | 0.50 |
| F | 1.24 | 1.93 | 1.49 | F | 0.85 | 0.91 | 0.96 |
| p | 0.50 | 0.06 | 0.16 | p | 0.66 | 0.39 | 0.54 |

Q6. Benchmarking

| Mean | 0.28 | Mean | 0.24 |
| Std Deviation | 0.46 | Std Deviation | 0.43 |
| F | 0.91 | 1.69 | 2.61 | F | 2.02 | 0.73 | 0.75 |
| p | 0.59 | 0.11 | 0.01 * | p | 0.04 * | 0.78 | 0.74 |

Q7. Market Studies

| Mean | 0.41 | Mean | 0.20 |
| Std Deviation | 0.49 | Std Deviation | 0.40 |
| F | 1.01 | 1.21 | 1.91 | F | 0.53 | 1.37 | 1.49 |
| p | 0.48 | 0.33 | 0.06 | p | 0.94 | 0.23 | 0.16 |

Q8. Environmental Analysis

| Mean | 0.71 | Mean | 0.53 |
| Std Deviation | 0.46 | Std Deviation | 0.50 |
| F | 1.24 | 1.93 | 1.49 | F | 0.85 | 0.91 | 0.96 |
| p | 0.50 | 0.06 | 0.16 | p | 0.66 | 0.39 | 0.54 |

Q9. Academic Events

| Mean | 0.84 | Mean | 0.77 |
| Std Deviation | 0.37 | Std Deviation | 0.42 |
| F | 1.02 | 0.85 | 1.17 | F | 1.67 | 1.43 | 1.48 |
| p | 0.48 | 0.65 | 0.34 | p | 0.01 * | 0.19 | 0.17 |

Q10. National and International Networks

| Mean | 0.82 | Mean | 0.82 |
| Std Deviation | 0.39 | Std Deviation | 0.39 |
| F | 2.15 | 2.02 | 1.01 | F | 0.72 | 0.72 | 0.72 |
| p | 0.03 * | 0.05 * | 0.476 |

Q11. Bibliometrics

| Mean | 0.39 | Mean | 0.35 |
| Std Deviation | 0.22 | Std Deviation | 0.18 |
| F | 0.72 | 1.27 | 0.65 | F | 0.72 | 0.91 | 0.53 |
| p | 0.78 | 0.28 | 0.85 | p | 0.79 | 0.59 | 0.93 |

Q12. Experience of Researchers

| Mean | 0.84 | Mean | 0.77 |
| Std Deviation | 0.37 | Std Deviation | 0.42 |
| F | 1.02 | 0.85 | 1.17 | F | 1.67 | 1.43 | 1.48 |
| p | 0.48 | 0.65 | 0.34 | p | 0.01 * | 0.19 | 0.17 |

Q13. Short-Term

| Mean | 0.39 | Mean | 0.35 |
| Std Deviation | 0.22 | Std Deviation | 0.18 |
| F | 0.72 | 1.27 | 0.65 | F | 0.72 | 0.91 | 0.53 |
| p | 0.78 | 0.28 | 0.85 | p | 0.79 | 0.59 | 0.93 |

Q14. Medium-Term

| Mean | 0.39 | Mean | 0.35 |
| Std Deviation | 0.22 | Std Deviation | 0.18 |
| F | 0.72 | 1.27 | 0.65 | F | 0.72 | 0.91 | 0.53 |
| p | 0.78 | 0.28 | 0.85 | p | 0.79 | 0.59 | 0.93 |

Q15. Long-Term

| Mean | 0.25 | Mean | 0.25 |
| Std Deviation | 0.18 | Std Deviation | 0.18 |
| F | 1.91 | 0.87 | 1.15 | F | 0.72 | 0.91 | 0.53 |
| p | 0.04 * | 0.63 | 0.36 |

* Descriptive analysis using N_{obs} = 49, p ≤ 0.05.

Table 2. Relationship between the type of research of PRIs and the seizing variables from framework of DCs.

<table>
<thead>
<tr>
<th>Q17. Short-Term</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Q18. Medium-Term</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.39</td>
<td>Mean</td>
<td>0.35</td>
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<td></td>
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<td></td>
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</tr>
<tr>
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<td>1.27</td>
<td>0.65</td>
<td>F</td>
<td>0.72</td>
<td>0.91</td>
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</tr>
<tr>
<td>p</td>
<td>0.78</td>
<td>0.28</td>
<td>0.85</td>
<td>p</td>
<td>0.79</td>
<td>0.59</td>
<td>0.93</td>
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Q19. Long-Term

| Mean | 0.25 | Mean | 0.25 |
| Std Deviation | 0.18 | Std Deviation | 0.18 |
| F | 1.91 | 0.87 | 1.15 | F | 0.72 | 0.91 | 0.53 |
| p | 0.04 * | 0.63 | 0.36 |

* Descriptive analysis using N_{obs} = 49, p ≤ 0.05.
Table 3. Relationship between the type of research of PRIs and the reconfiguration variables from framework of DCs.

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<tr>
<td>Mean</td>
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<td>0.61</td>
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<td>Std Deviation</td>
<td>0.43</td>
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<td>F</td>
<td>1.90</td>
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<td>p</td>
<td>0.06</td>
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<tr>
<th>Q22. Projects Related to Calls from Federal/State Institutions</th>
<th>Q23. Relevance Trees Studies</th>
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<td>Mean</td>
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<th>Q30. Time series Analysis</th>
<th>Q31. Scenarios Building</th>
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* Descriptive analysis using $N_{obs} = 49$, $p \leq 0.05$.

In the case of applied science research, a significant correlation was found with the average number of service technicians ($p = 0.008$), the average number of research lines per institution ($p = 0.05$), and national–international networks collaboration ($p = 0.05$).

The sensing activities that present a significant correlation with R&D activities are correlated with the average number of service technicians ($p = 0.001$), the number of research lines per institution ($p = 0.01$), studies for updating research lines ($p = 0.006$) and benchmarking ($p = 0.01$).

Descriptive analysis of the Fisher test (F), also known as the least significant differences method, also confirmed the influence or interactions observed with the $p$ value between the analyzed groups.

Interestingly, the research activities of Mexican PRIs classified as seizing capabilities presents only an important correlation between basic science developments with the percentage of investigations that provided solutions in long-term ($p = 0.04$), Table 2.

The research activities, classified as reconfiguration capabilities, that influence the activities of applied science projects were: the application of analytics techniques, specifically,
relevance trees studies ($p = 0.03$) or surveys ($p = 0.03$) to strengthen and update the lines of research.

Finally, in the case of the R&D projects, these are predominantly influenced by the use of surveys ($p = 0.03$) and cross-impact analysis ($p = 0.04$) which are applied to reinforce and plan the updating of research lines (Table 3).

The statistical results showed that the research activities of Mexican PRIs that present a strong correlation with the type of investigation (basic, applied or R&D) are oriented to the sensing capabilities. A lower interaction was observed in the activities classified as re-configuration and seizing capabilities. The results highlighted that PRIs should pay special attention to research activities that are classified as sensing capabilities during their strategic planning process [37,38,92]. This also suggests that having an efficient process in place can promote new opportunities that arise from existing or emerging technologies. Thus, the proper analysis of DCs that present a strong interaction must help to coordinate the PRI activities in order to generate superior benefits, properly updating the research lines and impulse their participation in innovation-based competitive environments [93]. By definition, the DCs are analyzed to generate and exploit internal and external organizational-specific competences as well as adapt to the changing environment [9,11,15]; then, in this case, the DCs enable one to identify and develop opportunities and requirements to add value during the creation, adsorption and transfer of knowledge.

Figure 4 illustrates a proposal of the DCs framework for Mexican PRIs based on these findings. The scheme corresponded to the application of sensing, seizing and reconfiguration dynamic capabilities without considering the organizational evolution (history of each institute), tangible competitive advantage and external factors of each region (type of industry) [15]. An especial emphasis was paid to the type of research activities (basic, applied and R&D) that can influence the global productivity and knowledge integration or transfer of each academic group according to the market evolution studies [94–98]. Each activity was planned to originate other sub-divisions with a subsequent hierarchy. In this way, the scheme effectively validates the application of DCs as a strategic methodology to evaluate research activities that must be considered fundamentally for effective strategic decision making. When analyzing the proposal, it can be seen that the activities that impact the productivity and knowledge integration or transfer depend in turn on the kind of projects developed by the Mexican PRIs. To validate the robustness of the scheme, a second stage was realized and discussed below.

4.2. Identification of Aspects That Impact the Scientific Productivity (Phase II)

Derived from these initial findings, a second questionnaire was applied considering that the identified dynamic capabilities for PRIs must be valuable and suitable in dynamic environments to identify competitive advantages [99]. Specifically, this second instrument was focused on the proposed activities that could affect scientific productivity and knowledge integration or transfer of the Mexican PRI. In this evaluation, respondents were requested to provide specific data about different aspects of scientific production from 2014 to 2019. The data were analyzed by means of statistical descriptive analysis. In this case, the collected data were analyzed by the one-way ANOVA test followed by Pearson’s correlation. The group sample size was 49 (N) and a level of statistical significance $p \leq 0.05$. To validate a multicollinearity of the variables, it was considered a strong correlation when $r \geq 0.50$ and $p \leq 0.05$, a moderate correlation when $0.49 \leq r < 0.30$ and $p \leq 0.05$, a weak correlation when $0.29 \leq r < 0.10$ and $p \leq 0.05$ and null when $r < 0.10$ ($p > 0.05$) or with another $r$ value and $p > 0.05$. The comparative process was carried out between the DCs that present a strong interaction depending on the type of projects that PRIs realized vs. each answer obtained from the second survey (Table S2).
The results of the descriptive analysis used to evaluate the global productivity can be seen in the Supplementary Materials (Table S3). The results indicated strong and moderate correlation of the sensing capabilities with the global productivity. Principally, the number of technicians that support the research work are strongly correlated with the number of laboratories \((p = 0.001, r = 0.50)\) and the total number of published scientific articles \((p = 0.001, r = 0.50)\), whereas a moderate influence was observed with the productivity of book chapters \((p = 0.008, r = 0.38)\) and null in the other analyzed variables.

The total number of research lines is strongly correlated with the number of laboratories \((p = 0.001, r = 0.73)\). A moderate influence exists in this group with the published
number of book chapters \((p = 0.006, r = 0.39)\), the total number of scientific articles \((p = 0.001, r = 0.47)\) and the total academic programs classified as quality-standard postgraduate programs \((p = 0.05, r = 0.40)\). The realization of benchmarking \((p = 0.020, r = 0.33)\) and the application of bibliometrics methods \((p = 0.001, r = 0.46)\) are moderately correlated with the total academic programs classified as quality-standard postgraduate programs.

In relation to seizing capabilities, a direct influence with the global productivity of PRIs was not found. The reconfiguration capabilities that influence the global productivity in a moderate manner is the usage of relevance trees studies to strengthen and direct the lines of research towards the future, which in turn influences the total academic programs classified as quality-standard postgraduate programs \((p = 0.003, r = 0.42)\). The application of cross-impact analysis presents interaction with the total number of published books \((p = 0.002, r = 0.44)\), the total number of published papers \((p = 0.019, r = 0.33)\), the number of graduate students \((p = 0.042, r = 0.30)\) and academic programs classified as quality-standard postgraduate studies \((p = 0.014, r = 0.35)\).

4.3. Activities That Influence Knowledge Integration or Transfer

Table S4 shows the effect of the identified DCs on the knowledge integration or transfer of the Mexican PRIs. According to the descriptive analysis, the activities related to sensing capabilities that directly affect the knowledge integration or transfer are as follows:

(a) The average number of technicians supporting research activities showed a moderate correlation with the quantity of national or international patent applications \((p = 0.008, r = 0.38)\), the total number of technological transfers \((p = 0.005, r = 0.40)\), the total number of research groups in each institution \((p = 0.021, r = 0.33)\), the number of projects related to the industry \((p = 0.001, r = 0.48)\) and the projects that Mexican PRIs realized with federal or state institutions \((p = 0.004, r = 0.41)\).

(b) The quantity of research lines present a direct correlation with the technological transfers that are in progress \((p = 0.001, r = 0.54)\). A moderate correlation exists with the technological transfers \((p = 0.015, r = 0.35)\), the number of projects related to the industry \((p = 0.031, r = 0.31)\) and the realization of projects with the federal or state institutions \((p = 0.010, r = 0.37)\). Additionally, a weak correlation with the quantity of the research groups was observed \((p = 0.047, r = 0.29)\).

(c) The relevance studies \((p = 0.024, r = 0.32)\) and benchmarking \((p = 0.016, r = 0.34)\) for new research or developments also have a moderate impact on the application of technology foresight.

(d) The national–international collaboration networks have a weak correlation with the research groups of each PRI \((p = 0.043, r = 0.29)\).

Once more, seizing capabilities do not influence the knowledge absorption or transfer. On the other hand, the reconfiguration capabilities that influence the absorption or transfer knowledge of PRI are:

(e) The activities of relevance trees studies, which are moderately related to the total number of granted utility models \((p = 0.020, r = 0.44)\). A similar trend was found with the amount of national or international patents granted \((p = 0.044, r = 0.30)\).

(f) The application of surveys to strengthen the research lines have a moderate influence on the application of technological foresight \((p = 0.042, r = 0.30)\).

(g) Finally, the cross-impact analysis to strengthen the research lines present a positive moderate correlation with the total amount of granted patents (national or international) \((p = 0.004, r = 0.41)\) and the projects realized with the public services \((p = 0.036, r = 0.31)\).

The results confirm that the research activities identified as sensing capabilities have the most direct correlation with global productivity and knowledge integration or transfer of the Mexican PRIs. Other activities categorized into the reconfiguration capabilities present a moderate or weak influence.
5. Discussion

The findings of this work can be divided in two parts: firstly, the analysis of the main criteria followed by the PRIs for updating their research lines and the application of foresight techniques; and, the categorization of the research activities of PRIs through DCs and the proposal of the DCs framework as an instrument for academic institutions in Mexico. In the second step, the influence of the main DCs that had a strong influence in the first step and that impact in the productivity and knowledge integration or transfer of academic institutions were analyzed. Consequently, the discussion was divided into two stages.

First stage. The criteria for updating the research lines in the PRIs in Mexico are based on the following activities: projects through calls from state or federal authorities, the expertise with other research groups (collaboration), attendance at academic events, scientific literature review and industry-related projects. Unfortunately, these activities are carried out without methodologies to apply strategic analysis. Additionally, the projects are preferably planned in the short-term but mainly for basic and applied science. It has been recognized that there is an important societal pressure on the academic institutions to promote economic growth, which is in detriment of the quality of the graduate students and knowledge generation or absorption. This may be the reason that most PRIs in Mexico base their research in the short-term [100,101].

The analysis of the DCs framework, as an instrument of the PRIs, showed that the main research activities are related with sensing capabilities, followed by the reconfiguration capabilities. Seizing capabilities only contribute with an influence in the development at long-term and it is not very relevant in the decision-making process for academic forecasting.

Sensing capabilities that must be carefully analyzed in relation to the type of research (basic science, applied science and R&D) are the number of technicians that support the research works, the number of research lines, the realization of benchmarking and bibliometrics studies to update research lines, attendance to academic events and the national and international collaborations networks. In the case of reconfiguration capabilities, activities that require a detailed analysis during the strategic planning process are the application of relevance trees studies, surveys, and cross-impact studies to strengthen and direct the research projects.

As a fact, the responses to the first survey pointed out that R&D activities of PRIs are far from a real-time innovation. The reason may be related to the statement that most research activities of PRIs are poorly based on systematic strategies (methodologies) and, as a consequence, the development of inadequate forecasting or planning. It was also inferred that the actual research activities of PRIs are inconsistent with the dynamics of social changes and do not take into account the skills, expectations and experience of their personnel. According to previous reports, analysis for the identification of DCs (sensing, seizing and reconfiguration capabilities) in organizations must be based on skills and willingness to do things, in order to introduce them into the groups and promote adaptation to social change, knowledge integration or transfer and innovation [102,103]. Thus, it is highly desirable that DCs as an instrument of Mexican PRIs be accompanied by a skills analysis of the personnel. This combination will allow one to identify research experience, collaborative work style (research groups), forms of knowledge absorption, learning, current forms of knowledge creation -basic vs. applied- and forms of knowledge transfer, which in turn are essential to create a strategic planning process that increases R&D activities focused on reaching real innovation.

This first methodological instrument was also applied to several public research institutes in Spain, but we only obtained the response of 14 (See Supplementary Materials Table S5). It was considered that this number was adequate as an initial comparison of the research activities in Mexico. The PRIs of Spain are located in cities such as Madrid, Santander, San Sebastian and Barcelona. The results show a certain similarity with the Mexican PRIs, since the type of research that is mainly carried out is basic science, while R&D activities are realized in a low percentage. Additionally, the results related to the time
in which the investigations are oriented to provide solutions are alike, since the short and medium term is where these institutes mainly focus. Likewise, it was found that all of them use collaboration in networks as a means of updating their lines of research, followed by research projects by government calls, which fully coincides with the practice of most of the studied Mexican PRIs. Other elements used by the majority of these Spanish research institutes, also consistent with the Mexicans, are projects related to industry and the review of scientific literature. To the same extent as the previous ones, Spanish institutes also use expert panels for the aforementioned purpose, which differs from Mexican PRIs, since only a low percentage practice them. Other activities that are also important for updating research lines, for both the surveyed Spanish public research institutes and the Mexican PRIs, are participation in academic events, bibliometric studies and the experience of researchers. Despite the fact that the sample of Spanish public research institutes surveyed is not representative of all of them, it can be observed that there are very few differences in their DC practices compared to the Mexican PRI studied in this research.

In summary, DCs are an adequate instrument to assist Mexican academic institutions in the identification of research activities that mainly influence the updating of research lines and investigations with strategic planning.

Second stage. In reference to the activities that influence academic productivity and knowledge integration or transfer of the PRIs in Mexico, it was found that previous sensing and reconfiguration capabilities have an important impact on the publication of papers, publication of books, chapters books, graduated students, recognition of the institutions, utility models and patents (applications or granted), technological transfers, conformation of research groups, projects related to the industry or public services (AICs), projects carried out with federal or state institutions and the application of technology foresight. These activities can be used as main indicators to improve overall productivity and knowledge integration or transfer.

The most important interaction in the productivity can be ascribed to the sensing capabilities, where a strong correlation between number of technicians who support the research work with the available infrastructure and published papers was found. As expected, the numbers of research lines are highly dependent on the available infrastructure. Other moderate interactions that influence the global productivity were observed for benchmarking and bibliometrics studies to update research lines, the national and international collaboration networks, the application of the relevance trees studies, surveys and cross-impact studies to strengthen and guide the research projects.

Analyzing the data for the knowledge absorption or transfer, the trends seem to be similar. A strong correlation was obtained between the number of research lines and the technology transfer. AICs, as a particular subject of knowledge absorption or transfer, are reliant on the number of technicians to support research activities, the number of research lines, relevance studies, benchmarking and the cross-impact analysis to strengthen the research lines, but all of them presented a moderate correlation. This suggested that to improve the number of AICs, all these activities should be analyzed as a group.

The findings in the second stage suggest some practical implications: firstly, PRIs can apply the strategies of DCs to identify research activities that can be crucial to potentiate their global productivity and the knowledge absorption or transfer. Second, the acknowledged interactions suggest that DCs can also be used to overcome the barriers that commonly occur in cross boundary relationships (AICs) and adapt them to the constantly changing environment.

It is well-recognized that global productivity, as well as knowledge integration or transfer, are challenges in academic institutions and the path to improve and/or assimilate depends on social impact, including transformations within the research projects and social requirements [104]. Considering that not all knowledge can be created by the organizations themselves, the PRIs should use different existing technologies or instruments, as the projected in this work (DCs), in order to acquire, assimilate and disseminate the prevailing knowledge. An adequate analysis will help support research projects and provide oppor-
tunities that allow the exploration or exploitation of new information from sustainable strategic management.

Different researchers agree that scientific cooperation from different disciplines is essential to provide a path that facilitates the decision-making process of the organizations, which could undoubtedly be extrapolated to the Mexican PRIs [94,105,106]. As is the case with universities, PRIs should respond to the society challenges and modify their projects from multidisciplinary or interdisciplinary to transdisciplinary to ensure the generation of new knowledge with application in a short and long period of time [107].

For this scenario, PRIs must be prepared to absorb knowledge and skills through new topics incorporation and the updating of research programs, as well as sharing technology, making structural adjustments and changes in their operational processes. It is also evident that like other organizations [84,108], PRIs should guarantee linkages and collaborations with other academic institutions through co-workers, students and/or industry and government organizations, since the knowledge integration and its transfer require both academic and non-academic actors (technicians, project leaders, etc.). In this context, national or international collaboration networks promote the co-generation of value-added knowledge, which helps the strategic planning of each institution [8,109,110]. Evidently, the PRIs must be dynamic in the acquisition of new knowledge, skills and capabilities to propitiate adjustments in the operational process as well as a positive impact on the scientific productivity with technological application.

Another aspect to overcome is that in Mexico, like other developing countries, there may be opposition to adopting new strategies such as DCs, specifically in research areas; even if resistance adversely influences their global productivity. Diverse alternatives have been proposed to enhance the interest of researchers involved in AICs such as: policies to promote activities at a personal level, a broader range of incentives and acknowledgements [73].

As a final point, to achieve tangible objectives during AICs, the PRIs must be aligned with the stakeholders and reduce the bureaucratic procedures. The level of stakeholder engagement has been recognized as a critical factor for the success of projects [51]. Additionally, communication between PRIs and firms is essential, ensuring common objectives and funds. Determining the DCs for specific projects can also help to identify the needs of each client, increasing their satisfaction and cooperative relationship, which will impact immediately, or in the future, constructive collaborations. This study contributes to the literature on planned forecasting of academic institutions using DCs frameworks as instruments combined with a simple statistical analysis.

6. Limitations and Suggestions for Future Researches

This study can be added to the existing literature as a reference to the importance of the applied DCs to academic institutions in developing countries to reach proper strategic decision making. Particularly, to determine those activities related to the improvement of productivity and knowledge integration or transfer, which also can contribute to external recognition and the academic level of the postgraduate programs.

The main limitations of this work and that could be a guide for future works are: for instance, the surveys of this study were only constructed and applied based on research activities of PRIs in Mexico. Although there are similarities with most developing countries and some DCs should match, the situation with the industry, the experience of the researchers, and the academic level of each country, can modify the priority of the activities for the organizational strategic planning process. Thus, the results of this study can only be valid in Mexico.

Additionally, we considered the academic productivity (JCR, papers, patent application, patent granted, book chapters, books) in a general way, i.e., we did not separate main authors (first author, corresponding author), the position of the co-authors, and papers derived from national or international collaborations. Similar treatment was realized to intellectual property protection, technology transfer completed, postgraduate programs,
and R&D projects. Then, a detailed study separating these subjects must be realized to complete this research.

Another limitation to consider is that the R&D collaborations were only assessed from an academic point of view, but a detailed longitudinal study would help to complete the investigation and consider additional activities that impact the knowledge integration and transfer. As industrial organizations also acquire benefits such as innovations, transfer technology, patent participation, and student integration, the study must be completed with the industrial criteria of performance and general experience to establish real possibilities of future research projects. It may be relevant to analyze the knowledge generated in each PRI and how it can contribute to the establishment of new developments in the industry.

7. Conclusions

Worldwide, the number of companies that collaborate with academic institutions and that play a critical role in the knowledge-based economy is increasing. Additionally, the recognition of academic institutions depends on their academic level, which is generally accompanied by the overall productivity and efficiency in the integration or transfer of knowledge. This study applies the DCs strategies to public research institutes to identify the main activities that must be considered in the strategic planning process and that impact in the global productivity and the integration or transfer of knowledge. Derived from the findings of the study, the following conclusions can be drawn:

First stage. The activities commonly carried out by the PRI in Mexico to update research lines are correlated with the proposals of research projects through calls from state or federal authorities, the experience of the researchers and their collaboration in national–international networks, participation in academic events, the review of scientific publications and industry-related projects. At a global level, the innovation process forces to restructure the technological knowledge development, but in the case of PRIs, little relevance is given to market studies, including SWOT analysis, benchmarking and bibliometrics.

The descriptive analysis in the first stage, confronting each variable with the type of research (basic, applied or R&D), indicated that there is a strong correlation in the sensing capabilities with the use of bibliometrics and the national–international collaboration, number of technicians per research line and number of national–international networks, studies for updating research lines and benchmarking. In the case of seizing capabilities, it was only correlated with the application of basic science with solutions in the long-term, whereas the reconfiguration capabilities observed in this stage were the realization of relevance trees studies, surveys and cross-impact analysis to strengthen and direct the lines of research towards the future. Then, it was identified that sensing and reconfiguration capabilities can influence the activities that determine the kind of research in the PRIs in Mexico, whereas less influence was observed in the seizing dimensions.

From initial exploration, a DCs framework was constructed that validated the application of DCs as a strategic methodology to assist Mexican academic institutions in the identification of research activities that mainly influence the updating of research lines and investigations with a strategic planning.

Second stage. From the statistical analysis (second instrument) carried out to determine the variables that can help improve global productivity and knowledge integration of transfer, it was found that DCs are correlated with the publication of scientific papers, the publication of book chapters and books, graduated students, recognition of the institutions, utility models and patents (applications or granted), technological transfers, the conformation of research groups, projects related to industry or public services, projects carried out by calls from federal or state institutions and the application of technology foresight.

It was found that Mexican academic institutions should use the strategies of DCs to identify research activities that can potentiate their global productivity and the knowledge absorption or transfer. These interactions suggest that DCs can also be used to overcome the barriers that commonly occur in cross boundary relationship (AICs) and adapt them to the constantly changing environment. From the findings and literature review, it can
be inferred that success in public research institutes largely depends on the linkages and collaborations with other national or international researchers, their interaction with other non-academic actors and the knowledge transferred to other non-academic actors.

Then, this work shows that the proper application of the DCs framework as a substantial instrument for public research institutes opens up an alternative to promote the global knowledge process and the technology development, which in turn have a positive impact on the overall productivity and the knowledge integration or transfer of the institutions.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13126672/s1, Table S1: Questionnaire elaborated in the first stage from framework of DCs for Mexican public research institutes, considering the period of time of January 2014 to December 2019, Table S2: Second survey proposed to identify factors that impact in the global productivity and knowledge integration or transfer; considering the period of time of January 2014 to December 2019, Table S3: Anova test and Pearson’s correlation results carried out to evaluate the factors that impact the global productivity of PRI. The descriptive statistics were analyzed between the groups that presented a strong interaction in the first stage and the variables of the survey 2, Table S4: Anova test and Pearson’s correlation results carried out to evaluate the factors that impact the knowledge integration or transfer of PRI. The descriptive statistic was analyzed between the groups that presented a strong interaction in the first stage and the variables of the survey 2, Table S5: Analysis of the responses of the first stage from framework of DCs for Spain public research institutes.


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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

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Conflicts of Interest: The authors declare no conflict of interest.

References


30. Craig Boardman, P.; Pomomariov, B.L. University researchers working with private companies. *Technovation* **2009**, *29*, 142–153. [CrossRef]


38. Li, Y.; Tang, Y. A dynamic capabilities perspective on pro-market reforms and university technology transfer in a transition economy. *Technovation* 2021, 103, 102224. [CrossRef]
61. Towery, P. Dietetic Students’ Participation in Interprofessional Education Project at Southeastern University. *J. Acad. Nutr. Diet.* 2014, 114, A75. [CrossRef]
68. Yuan, C.; Xue, D.; He, X. A balancing strategy for ambidextrous learning, dynamic capabilities, and business model design, the opposite moderating effects of environmental dynamism. Technovation 2021, 103, 102225. [CrossRef]
78. Lundberg, J.; Tomson, G.; Lundkvist, I.; Skår, J.; Brommels, M. Collaboration uncovered: Exploring the adequacy of measuring university-industry collaboration through co-authorship and funding. Scientometrics 2006, 69, 575–589. [CrossRef]
79. Sun, H.; Wing, W.C. Critical success factors for new product development in the Hong Kong toy industry. Technovation 2005, 25, 293–303. [CrossRef]
87. Marazato, F.P.; Salerno, M.S. Integration between research and development: dynamic capabilities perspective. Revista de Administração de Empresas 2018, 58, 460–474. [CrossRef]
89. Ávila-Robinson, A.; Sengoku, S. Multilevel exploration of the realities of interdisciplinary research centers for the management of knowledge integration. Technovation 2017, 62–63, 22–41. [CrossRef]


98. Castelein, B.; Geerlings, H.; Van Duin, R. The reefer container market and academic research: A review study. *J. Clean. Prod.* 2020, 256, 120654. [CrossRef]


