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Linking the Performance of Entrepreneurial Universities to Technoparks and University Characteristics in Turkey

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Abstract. Universities' third mission of knowledge commercialization imposes them a core role towards becoming entrepreneurial universities in the triple helix interacting with the government and industry. Entrepreneurial universities have crucial functions of providing entrepreneurial support infrastructure for innovation and engaging in the regional economy. Technoparks, in that sense, form an essential channel for universities to disseminate and commercialize the knowledge considering their geographical proximity and facilitating mechanisms. Measuring the performances of entrepreneurial universities and technoparks in quantitative metrics have been initiated by different government agencies in Turkey, which resulted in two different indices. The Most Entrepreneurial and Innovative University Index and the Performance Index for Technoparks track performances annually. Using the data provided by the two indices, this study explores how the technoparks' performance can be linked to the universities' scores in entrepreneurship and innovation, along with some university-specific characteristics and their interactions. The geographical proximity provided by the technoparks contributes to the performance of entrepreneurial universities. While the increasing university size has a negative effect on university entrepreneurial scores, the socio-economic development factor of the region positively contributes to the scores. Young universities are also found to benefit more from the large share of the graduate students of their student composition on university entrepreneurship and innovation scores.

Key words: Entrepreneurial universities in Turkey, technoparks, knowledge commercialization, geographical proximity, regional innovation

1 Introduction

Universities play a fundamental role in regional innovation and economic growth (Gunaseka ra 2006, Power, Malmberg 2008, Rasmussen et al. 2006) beyond their traditional missions of teaching and research that they were identified with so long in the history. The third mission of universities, contributing to the knowledge society, has its roots seeded in the pioneering work of Clark (1983). In his conceptual tool of the triangle of coordination, Clark (1983) views the place of universities from a broader perspective within the interactions of academic oligarchy, state authority, and market. This notion of interactions was later developed into the notion of the triple helix by Etzkowitz, Leydesdorff (1995). Even the triple helix model has further been transformed into the quadruple and quintuple models to incorporate the society's and environment's role (Carayannis, Campbell 2010). The government plays a key role in the interaction of the university and industry where the linear model of innovation based on the long-term contribution of the knowledge disseminated from the university to the economy is no longer the only option. Universities contribute to knowledge-based economic development via a spiral model of innovation commercializing and capitalizing the knowledge in both short and long terms (Etzkowitz, Leydesdorff 1995, Leydesdorff, Etzkowitz 1996).

Studying the ten to fifteen years of transformative developments in the five European institutions, Clark (1998) argues that universities are forced to change by the enormous demand overload surpassing their capacities, which they respond to transforming themselves into entrepreneurial universities. The notion of the entrepreneurial university is closely linked to the universities' third mission of evolving with new perspectives on technology transfer and commercialization and expanding to undertake a more direct role in regional development and innovation (Rasmussen et al. 2006). Etzkowitz (2004) punctuates the new mission of the entrepreneurial university acting as an economic entity interacting with the users of knowledge in capitalizing the knowledge.

The acceptance of knowledge commercialization as a third mission first came onto the development agenda in the U.S. in the 1980s and later spread to European countries in the 1990s (Baycan, Stough 2013, Charles, Howells 1992, van Geenhuizen 2010). While the first wave of knowledge commercialization in the 1980s was recognized by the establishment of traditional science parks where collaboration with existing industry emerged, the second wave in the 1990s saw a stronger focus on patenting/licensing and spinoffs as well as an increased involvement by students in commercialization (Rasmussen et al. 2006).

The third mission of engaging with the community (Rubens, Spiragelli 2017) is essential in getting the most out of all the stakeholders in the interacting spheres of the university, industry, and government. The engagement with the industry could take different forms, such as formal contracting, sponsoring research, transferring key personnel into employment, or access to university facilities (Monck et al. 1988, Quintas et al. 1992). Science and technology parks form another significant mechanism in engaging businesses with the academic knowledge on-site, which could have important regional implications (Lindelöf, Löfsten 2002). The geographical proximity provided by science parks could facilitate the transfer of knowledge, interactive learning, and innovation (Albahari et al. 2017).

The emergence of science and technology parks initiated a debate on how property-based actions improve the economic and innovation performance of the university, industry, and the region (Link, Scott 2007). In the prior literature, scholars study how the science and technology park characteristics such as size, age, sectorial specialization, and geographical area affect the park tenants' innovation performance (Albahari et al. 2017, 2018, Liberati et al. 2016). Firms that are smaller in size benefit more from being located in science and technology parks on innovation performance (Huang et al. 2012). Besides, firms' innovation performance improves when the firms are located in less technologically developed areas or very new or longer established parks (Albahari et al. 2018).

Different terminology is used for technology parks in the literature. It is more common to use the term science park in Europe, the research park in the U.S., and the technology park (i.e., technopark) in Asia (Eckhardt, Shane 2003, Link, Scott 2007). While science, research, and technology parks are used interchangeably in the literature, we choose to use the term technopark within the context of our study. According to the legislation passed in 2001 in Turkey, technoparks are referred to as technology development zones representing the sites where academic, economic, and social structures are integrated and established within the close vicinity of the university, high-technology institute, or R&D center for which they operate (General Directorate of Legislation Development 2001). Technoparks maintain companies that develop technology or software, carry out activities to transform a technological invention into commercial products, and use high or new technologies benefiting from the resources of the university or high-technology institute that they operate for.

On the other hand, entrepreneurial universities have come onto the agenda of the Higher Education Council of Turkey as well, and several programs, including regional development-oriented mission differentiation and specialization of Turkish universities, have been initiated recently. Two indices have been developed by the government agencies to track the performance of the entrepreneurial universities and the technoparks: the Most Entrepreneurial and Innovative University Index and the Performance Index for Technoparks. Universities that are smaller in size embrace the third mission differently in contributing to the regional economy and innovation (Rubens, Spiragelli 2017). Not all the universities get the expected benefits of the close geographical proximity of the technoparks. This study aims to understand how technoparks can be linked to the success of entrepreneurial universities from a regional perspective using the most recent data of the two indices. In understanding the link between the two, we also consider the effects of specific characteristics such as technopark age, university age, university size, the graduate program composition, and the socio-economic development index of the region.

In analyzing the third role of universities, Gunaseka ra (2006) highlights the variation in universities' performance of fulfilling the third mission in different regions. From the perspective of the Turkish regional innovation system, this study offers insights to regional policymakers, universities, and firms. Technoparks, with their proximity to universities, can help them to build entrepreneurial capacities and contribute to their innovation performances. However, other factors also promote entrepreneurial university performance a great deal. Young universities can benefit more from being research-oriented via investing in advanced degrees for more graduate-level students.

The rest of the paper is organized as follows. Section 2 investigates the geographical embeddedness of entrepreneurial universities, explicitly referring to the literature to understand how entrepreneurial universities commercialize knowledge and contribute to regional development via its linkages to technoparks. Section 3 describes the data and presents the empirical analyses of the research model. Section 4 offers a general discussion of the critical factors of the most entrepreneurial and innovative universities with concluding remarks and recommendations for future researches.

2 Linking Entrepreneurial Universities to Technoparks

The need for universities to transform themselves into a more entrepreneurial structure leads to the development of new kinds of relationships, governance systems, and a university-industry-public relations model. The model referred to as the triple helix (Etzkowitz, Leydesdorff 1995) indeed goes back to the pioneering study of Clark (1983) and visualizes the university as one of the main actors of the three – university, state, and the market – interacting with each other. Having high interactions with industry and government, entrepreneurial universities play an essential role in the process of knowledge commercialization and can contribute significantly to regional development.

The university dedicated to achieving the primary missions of teaching and research is needed to handle the new mission via the triple-helix or so-called partnership model carrying out the academic capabilities and resources outside the academic environment (Rubens, Spiragelli 2017). The universities undertaking the new mission are referred to as entrepreneurial universities resulting in an academic revolution in the field of higher education (Clark 1998, Etzkowitz 1983).

In fulfilling the third mission, entrepreneurial universities undertake new roles as

1. trainer (supply of skilled young graduates);
2. innovator (commercialization of academic knowledge);
3. partner (provision of technical know-how);
4. regional talent magnet (attractiveness of the region to talented academics and entrepreneurs);
5. facilitator (between private and public sectors) (Betts, Lee 2004).

In dealing with the new roles to become more entrepreneurial, universities face many challenges, from the perception of entrepreneurship and developing a shared institutional vision and consensus, to an organizational transformation or strong links with commercialization and income generation rather than education (Hannon 2013). However, the greatest challenge is how universities create effective environments for developing entrepreneurial capacities. Technoparks form a key channel in creating and enhancing the entrepreneurial capacities of the universities, in which there is a need to understand further how entrepreneurial universities are linked to technoparks.

2.1 Entrepreneurial Universities and Knowledge Commercialization

Three steps are defined towards an entrepreneurial university:

1. "the ability to set a strategic direction";
2. "a commitment to seeing that the knowledge developed within the university is put to use";
3. "the encouragement of start-ups based upon technologies that do not find a fit within existing firms" (Clark 1998, Etzkowitz 2016).

Therefore, universities develop their organizational capacities to work with firms, to transfer technologies, and to respond to societal changes. This proactive role that the universities take over leads to enhancing the innovation capabilities of the region where they are located. As a provider of human talent, entrepreneurial universities function as a seed-bed of new firms in the knowledge economy (Etzkowitz et al. 2000, Rasmussen et al. 2006).

An entrepreneurial university can be seen as "a university that develops a comprehensive internal system for the commodification and commercialization of knowledge" (Jacob et al. 2003, p. 1556). While undertaking the new role of knowledge commercialization opens up opportunities for the universities, it brings its own challenges. On the one hand, universities deal with increasing the extent of commercialization and finding ways to improve the economic contribution. On the other hand, they need to balance the commercialization and the other core activities (Rasmussen et al. 2006). To promote knowledge commercialization, universities go through various formal and informal initiatives. Building the infrastructure, such as establishing offices of patenting and licensing and incubator facilities for supporting new ventures, is one step that many universities take to become entrepreneurial universities (Rasmussen et al. 2006). Besides, legislation and policies are made at country levels to facilitate the commercialization of university research. However, infrastructure and policies are not sufficient for creating a culture of entrepreneurship, and making the individuals desire entrepreneurial activities is another important part of the knowledge commercialization.

Via the viewpoint of a researcher, Nilsson et al. (2010) explore why and how researchers engage in the commercialization process. Researchers desire to be academic entrepreneurs in alignment with the changing role of the university perceived in society as contributing to innovation and economic development as Nilsson et al. (2010) elaborates on. An academic entrepreneur is a university scientist, mostly a professor, sometimes a doctoral student or a post-doctoral researcher who establishes a company to commercialize the results of his/her research. Teaching at different universities, conducting consulting activities (Goldfarb, Henrekson 2003), conducting research projects (Louis et al. 1989), participating in patenting and licensing activities (Siegel et al. 2004), and founding new companies are considered academic entrepreneurship. The concept of academic entrepreneurship, illustrated by the activities that universities have carried out to contribute to commercialization in the regions they are in, has changed considerably in recent years. As a result of this change, universities are approaching the concept of academic entrepreneurship more strategically, and more stakeholders are involved (Siegel, Wright 2015). The supportive infrastructure that the university has and being located in a region where there are companies in need and capability to work with form the essential determinants of engaging in knowledge commercialization (Jensen, Thursby 2016, Melese 2006, Nilsson et al. 2010, Shane, Stuart 2002). The network links and trust between the researchers and industrial actors also affect knowledge commercialization (Nilsson et al. 2010).

In answering the question of how researchers transfer knowledge, Bercovitz, Feldmann (2006) conceptualize four different modes of knowledge transfer that are sponsored research, licenses, hiring of students particularly those working on sponsored projects, and spinoff firms. In addition to these, there are other informal mechanisms such as serendipity (Nilsson et al. 2010). In a similar vein, governance structures can also be described on a continuum where on one end, the knowledge can be commercialized and transferred through a Technology Transfer Office (TTO) , and establishing a new organization with an entrepreneurial structure on the other (Bengtsson et al. 2009).

Using these structures, in the past years, universities have reached wider regions surrounding themselves by offering new programs and closer relationships with the business world (Boucher et al. 2003, Bramwell, Wolfe 2008, Duch-Brown et al. 2011, Goldstein, Renault 2004, Hudson 2006, Lazzeretti, Tavoletti 2005). Thus, the commercialization of knowledge has begun to be seen as an important stimulus of economic growth, particularly of development capability and boosting the economic performance of the regions (Agrawal 2001, Baycan, Stough 2013, Bok 2003, Etzkowitz 1990, 2002, Kochetkov et al. 2017, Litan et al. 2008, Viale, Etzkowitz 2010).

2.2 Geographical Embeddedness of Entrepreneurial Universities

The entrepreneurial potential of a regional university is determined by its engagement in a regional economic system (Kochetkov et al. 2017). An entrepreneurial university cannot be thought independent of its environment. As a key player in the regional economy, the entrepreneurial university needs to be evaluated from the point of its geographical embeddedness to the other players in the triple helix.

Agglomeration economies deal with the aggregation of various activities and different players in clusters, which is closely related to knowledge externalities. The cost of transmitting tacit knowledge increases with distance, supporting the argument that knowledge spillovers are geographically bounded (Audretsch 2002). When knowledge transfer is taking place, geographical proximity is crucial in exploiting the knowledge spillovers. Geographical proximity is linked to interactive learning and innovation as a facilitator of coordination and control in the prior literature of economic geography (Boschma 2005). There are four other dimensions of proximity identified in the literature – cognitive, organizational, social, and institutional – that need to be evaluated with geographical proximity (Torre, Gilly 2000). Boschma (2005) argues that geographical proximity is needed for better performance; however, it is not sufficient since geographical proximity facilitates interactive learning through other dimensions of proximity.

The geography of innovation activity matters more in industries where new knowledge is a crucial ingredient (Audretsch, Feldmann 2007). In considering the production and dissemination of new knowledge, spatial proximity plays a role in the transfer of knowledge between the university and the domestic industry, which does not happen to occur internationally (Kuttim 2016). According to the "university spillover thesis", the innovative activities of local entrepreneurial firms are positively affected by the knowledge spillovers from universities (Audretsch et al. 2012). While this effect is heterogeneous, which is likely to depend on the region and the university characteristics, the indirect and less tangible effects can be greater than the visualized. Classifying the entrepreneurial universities into three groups – potentially entrepreneurial, adaptive entrepreneurial, and ideal – Budyldina (2018) argues that entrepreneurial universities contribute to the region in terms of human capital attraction and detention, entrepreneurial capital, networking, and many other formal and informal means.

Entrepreneurial universities contribute and engage differently depending on their core strengths and modes of engagements, as there is no one-size-fits-all model (Benneworth et al. 2016, Sánchez-Barrioluengo 2014). While some contribute more towards commercialization activities such as producing spinoffs, others regionally engage with collaborative research, consulting, and contract research (Sánchez-Barrioluengo, Benneworth 2019).

Recent studies demonstrate that the implementation of the third mission at smaller universities generally promotes a much more regional or local approach to economic development (Rubens, Spiragelli 2017). The larger university ecosystem has been shown to have a significant impact on technology transfer while playing a critical role in providing resources and enhancing the competencies of faculty and students (Boh et al. 2016). University entrepreneurship ecosystems may differ according to their focus on internal versus external resources and connections. While some universities create a very structured network, others develop more organic entrepreneurship ecosystems, and other universities focus both internally and externally on creating connections and drawing in resources (Boh et al. 2016).

2.3 Entrepreneurial Universities and Technoparks

Dalmarco et al. (2018, p. 102) propose five distinct characteristics of entrepreneurial universities that are

1. having an entrepreneurial perspective,
2. developing external links,
3. giving access to university resources,
4. providing entrepreneurial support infrastructure for innovation,
5. carrying out scientific research.

While all are crucial for universities to develop entrepreneurial capabilities to support the third mission of knowledge commercialization and socio-economic development, we particularly focus on the fourth characteristic of innovation arrangement.

Technoparks form an important channel for universities to disseminate knowledge, especially considering their geographical proximity to universities to facilitate this process. In considering the triple-helix model, technology parks undertake a coordinating role among the various actors of research and development to collaborate and interact with each other (Jongwanich et al. 2014). Clustering firms within its body also triggers learning and innovation via reduced transaction costs of inter-firm activities (Fan, Scott 2003, Jongwanich et al. 2014). Science and technology parks form an essential means of commercializing knowledge for entrepreneurial universities.

Firms that reside in science parks are found to be associated with higher intangible outputs from innovative cooperation within the science and technology parks (Vásquez-Urriago et al. 2016). Science park firms having higher cooperation and links with universities (Löfsten, Lindelöf 2003, Malairaja, Zawdie 2008), might get more benefit from being located near and linked to the universities (Díez-Vial, Montoro-Sánchez 2016, Lindelöf, Löfsten 2002, Löfsten, Lindelöf 2003, Vásquez-Urriago et al. 2016).

3 Research Model and Empirical Analyses

Drawing attention to the rise of entrepreneurial universities in Turkey, we explore the contribution of being linked with a technopark, and the university and region-specific characteristics on the dependent most Entrepreneurial and Innovative Universities Index (EIUI) scores of the selected sample. We test the effects of variables including the university age, university size, the composition of the graduate (i.e., Masters and doctorate levels) students, the rankings of the technoparks, technopark age, and the socio-economic development index of the city on the dependent EIUI using a multiple regression model.

3.1 Data and Variables

3.1.1 The Most Entrepreneurial and Innovative Universities Index

'Entrepreneurial University of the Year' in the U.K.; 'Top Schools for Entrepreneurship' in the U.S.A., 'The Most Entrepreneurial and Innovative Universities Index' in Turkey are some of the measurement tools for ranking the most entrepreneurial universities. In Turkey, the Scientific and Technological Research Council of Turkey (TUBITAK) initiated an index to measure the 50 most entrepreneurial and innovative universities annually. Classifying universities according to their entrepreneurship levels is a new concept in Turkey that has found an important place on the agendas of various stakeholders, including university management executives, policymakers, academics, and students since its introduction in 2012 by TUBITAK. Ranking the performances of universities over the years aims to foster the competitiveness based on entrepreneurial and innovativeness activities among Turkish universities. The most entrepreneurial and innovative universities index (i.e., EIUI) is composed of four criteria and several indicators, as given in Table A.1 in the Appendix.

The data for indicators are provided by several institutions, as illustrated in the last column of Table A.1, including the Ministry of Industry and Technology, TUBITAK, Council of Higher Education, Turkish Patent and Trademark Office, and Small and Medium Enterprises Development Organization of Turkey. Nineteen different indicators reflect the four main criteria that are listed in the first column of Table A.1. Some indicators count the number of scientific papers, citations, and doctoral graduates to assess the research performance in a typical university ranking index, such as U.K.'s Times Higher Education (THE) rankings or Quacquarelli Symonds' (Q.S.) World University Rankings. Some other indicators focus on companies owned or partnered by graduates or students, similar to the Princeton Review's annual rankings of top universities for entrepreneurship. TUBITAK's EIUI also includes other indicators mainly focusing on the innovativeness of the university measuring the number of patent and utility model applications, and the R&D and innovation projects carried out by university, industry, and international cooperation.

Ranking the universities according to the indicators given in Table A.1 in the year 2018 results in Table A.2 in the Appendix. The total scores range between 29.63 and 93.16, where the average total score is 53.29. When the scores for each criterion is normalized to 100, the average scores are calculated as 56.34, 47.53, 60.19, and 47.63 for CSTR, IPR, CI, and ECC, respectively. The average criterion-based scores indicate that universities get lower scores in both Intellectual Property Pool and Economic Contribution and Commercialization measures (i.e., 47.53 and 47.63) relative to the other components. While the universities overall seem to be competent in scientific and technological research, transforming these assets into tangible outputs such as the number of patents or firms established by the students, graduates or academics appear to be low as compared to the other criteria of entrepreneurship and innovation. We also notice the change in the positions of the universities when the universities in the list are re-ranked according to the individual subcriterion components. Although the scores are totaled and weighed over subcomponents as shown in the last column of Table A.2, the breakdown of the total scores across subcomponents provides a good overview of the strong and weak areas in the path to becoming a more innovative and entrepreneurial university for all universities.

3.1.2 The Performance Index for Technoparks

The Bayh-Dole Act of 1980 in the U.S. had been designed and employed to facilitate the technology transfer from the universities to the industry, stimulating the patenting and licensing activities of American universities (Mowery et al. 2001). Similar actions also took place in Europe and all around the world to create and promote entrepreneurial universities (Kirby 2006). In Turkey, several initiatives were also taken on the path to developing entrepreneurial universities. The Turkish Government passed legislation to establish 85 technoparks within the country in 2001. Seventy-one of these planned eighty-five technoparks were established, and they are active as of 2020. The technoparks are also called technology development zones with geographical locations, as shown in Figure 1. Technoparks are targeted to be made attractive to entrepreneurs with the support and incentives provided by the government (Cansiz 2017).

As of October 2020, 6,119 firms operate at these technoparks. 322 of these are foreign firms or have foreign partners, 1,289 of them have academic partners. These firms completed 37,605 projects, with 10,484 more in progress. Various intellectual and industrial property rights have been granted at these technoparks (Table 1).

While the numbers of intellectual and industrial property, as shown in Table 1, reflect the success and performance of these technoparks, establishing a comprehensive performance index for technoparks or science parks is not an easy task. As an example, Bigliardi et al. (2006) identify several areas of performance, including economic and financial aspects, human resources, and technical-scientific productivity, as well as international and inter-regional relationship development in measuring the success of science parks. Berbegal-Mirabent et al. (2019) draw attention to how the objectives and strategies of a science park might affect its performance, such that focusing on a few relevant components in mission statements might result in higher performance.

In Turkey, the Ministry of Industry and Technology developed an index to measure

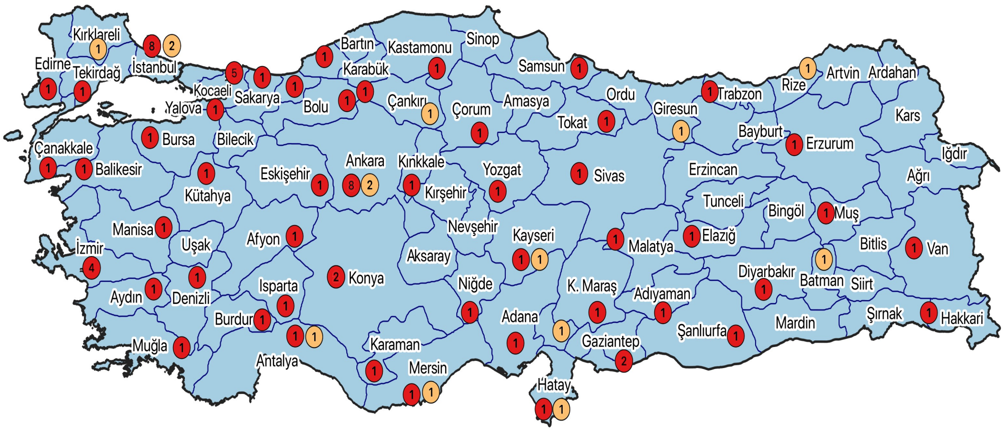

Figure 1: Technoparks in Turkey: Red and yellow circles denote the active and inactive technoparks, respectively

Table 1: Intellectual and Industry Property at Technoparks

Intellectual and Industry Property	Count
Number of patent registrations (National/International)	1,239
Number of patent applications (in progress)	2,793
Number of utility model registrations	431
Number of utility model applications (in progress)	261
Number of industrial design registrations	181
Number of industrial design applications (in progress)	122
Software copyright (acquired)	419

Source: https://btgm.sanayi.gov.tr

the performances of technoparks, which we refer to as the Technopark Performance Index (TPI) within the context of this study. The index is employed every year starting from 2011 and monitors the performances of technoparks relative to each other over the years. Thus, the Ministry aims to provide the necessary support to technoparks in achieving its target R&D and innovation levels by revealing their strong and weak areas of performance and relative positions among all technoparks. Tracking the performance of technoparks via the index also gives direction to decisionmakers in drawing future strategies for the growth of the universities and the overall economy. The proximity of technoparks to universities is shown to positively affect university growth by shifting academic research from basic to applied (Link, Scott 2003). Technoparks' performance, on the other hand, bolsters economic diversity and jobs (Dabrowska 2011). The policymakers can align the interests of both the university and the technopark in the direction of specialized fields with the highest performance.

The index is composed of 25 different indicators targeting to measure three main criteria of performance – Inputs, Activities, and Outputs – as shown in Table A.3 in the Appendix. The subcriteria of the Inputs are measures of Financing, Incentives, and Infrastructure, where they are altogether weighed as 16.67%. Activities are formed of five different subcriteria that are R&D Activities, Incubation Activities, Technology Transfer & Collaboration, Institutionalization, Sustainability and Developing Ecosystems, and Technology Product Investment. Activities have the highest weight, with 51% on the overall score of performance. Lastly, the criterion Outputs consists of indicators measuring three subcomponents that are R&D Outputs, Intellectual Property, R&D Impact, and Internationalization with a weight of 32.33% on the overall performance score.

The performances of technoparks are ranked according to their scores as measured by the performance indicators given in Table A.3. The rankings of all technoparks in the year 2018, the same as the year that EIUI was measured, are provided in Table A.4 in the

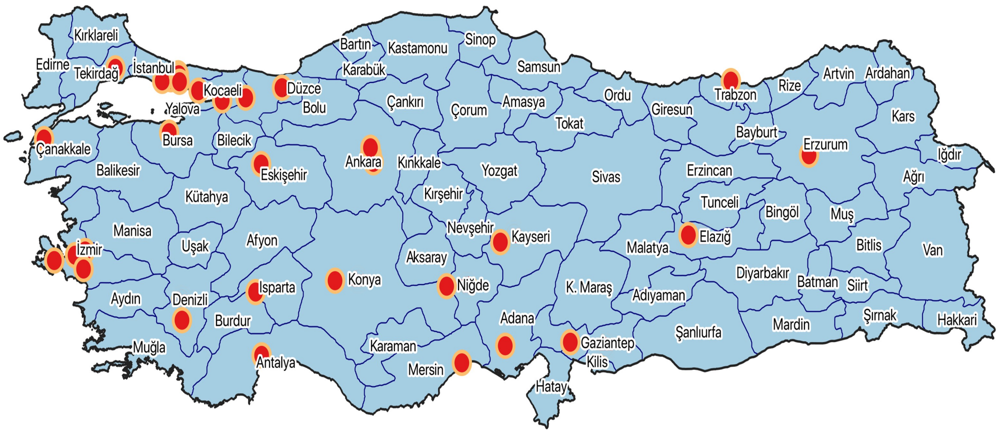

Figure 2: The geographical distribution of the 34 technoparks that are used in empirical analyses

Table 2: Descriptive Statistics and the Correlation Matrix of the Model Variables

	EIUI	TPI	Technopark Age	University Age	University Size	Log GradStudent	SEGE
EIUI	1						
TPI	-0.631**	1					
Technopark Age	0.485**	-.547**	1				
University Age	0.425*	-.360*	0.301	1			
University Size	-0.297	0.098	-0.126	0.395*	1		
LogGradStudent	0.397*	-0.334	0.269	0.992**	0.465**	1	
SEGE	0.739**	-0.349*	0.159	0.321	-0.202	0.336	1
Mean	56.94	22.71	11.76	39.76	10.53	8.60	1.69
Std. Dev.	18.44	14.29	3.89	17.95	0.72	0.83	1.43
Min.	31.69	1	4	12	8.55	6.52	-0.53
Max.	93.16	49	17	85	11.36	9.96	4.05

*, ** Correlation is significant at the 0.05 and 0.01 level (2-tailed).

Appendix. The date of establishment and the associated university are also given. The oldest technopark in the rankings was established in 2001, and there are a few technoparks established every other year between 2001 and 2015.

3.2 Empirical Analyses

When two indices are merged, 34 technoparks in the list of TPI are found to be associated with a single university in the list of EIUI in the same year, 2018. Thus, the dataset for the analyses is composed of these 34 universities. The universities are scattered around the country in 22 different cities. There exist more than one university-technopark couple in only three cities. There are 6, 5, and 4 universities in the cities Istanbul, Ankara, and Izmir, respectively. The distribution of the 34 technoparks across the country is shown in Figure 2.

The best performing universities data are supported with additional data on variables such as the age of technopark, the age of the university, the total number of students, the ratio of graduate students to all students, and the socio-economic development index that are obtained from the Council of Higher Education and the Ministry of Industry and Technology. The descriptive statistics and the correlation matrix of all variables are presented in Table 2.

The average age of the technoparks is 11.76, where the minimum and maximum age is 4 and 17, respectively. On the other hand, the average age of universities is 39.76, where the oldest and youngest universities are 85 and 12 years old. The average score of EIUI is 56.94 ranging in the interval between 31.69 and 93.16. We use the total number of students as a proxy for the university size; thus, this variable is constructed as the natural logarithm of the total number of students. Because of the large deviations in the total number of students and the ratio of graduate students to all students, we employ the logarithm of these variables and present the descriptive statistics for the transformed variables in Table 2. The average for the total number of students is found to be 44,778, where the smallest size university has 5,172, and the largest size university has 85,520 students. The average ratio of graduate students, including students that are at both masters and doctorate levels to all students, is 0.16, which changes in the range between 0.06 and 0.33. Lastly, the variable SEGE represents the development of the region related to social, economic, cultural, and environmental issues. SEGE scores are calculated annually. For our analyses, we use 2017 scores, which is the closest year to 2018. SEGE scores of the cities that the university-technopark couple reside in change between -0.53 and 4.05, which corresponds to cities Istanbul and Erzurum, respectively.

We run two different regression models to test the effects of the explanatory variables described in Table 2 on the dependent EIUI. The first model is the main effects model where we test the direct effects of the rank TPI, the age of technopark, the age of university, size of the university, the graduate student composition, and the SEGE on EIUI. The establishment and growth of graduate programs offering education in higher degrees and producing scientific knowledge take time. Thus, to test how these two variables, i.e., graduate student composition and the university-age, interact on the dependent EIUI, we add the two variables' multiplication to the first model. This gives us the second model, where we refer to the interaction effects model with the newly included interaction term. The parameter estimates of the ordinary least-squares regression models for both are presented in Table 3.

The high adjusted coefficients of multiple determination for both models highlight the good fit of the models to the data. In the main effects model, TPI, university size, and SEGE are found to significantly affect the entrepreneurship and innovation related scores of the universities. The coefficient for TPI is negative and significant, pointing to the importance of climbing up in the technopark rankings on the scores of universities being more entrepreneurial and innovative. The university size, on the other hand, is found to have a reverse effect on EIUI. The negative and significant coefficient of university size indicates that smaller universities obtain higher scores of EIUI. SEGE is the third variable for which its effects are significant, implying the higher the SEGE scores of the city, the higher the scores of EIUI. The ages of the technopark and the university are found not to have any significant effects on EIUI.

While the university's composition of graduate students does not appear to be significant in the main effects model, the interaction effects of the ratio of graduate students to all students with the university age happen to be significant when both variables are present in the model. The direct effects of the ratio of graduate students to all are positive and significant. The larger the share of the graduate students (that are at master's and Ph.D. levels) to all students, the higher the university obtains a score as measured by EIUI. However, its interaction with the university age is negatively significant, revealing that the younger universities benefit more from the higher composition of graduate students among all students. The significant effects of TPI, the university size, and SEGE remain the same considering the direction of effects in the second model.

4 Discussions and Concluding Remarks

Entrepreneurial universities have emerged via the second academic revolution, which transformed the traditional university missions of teaching and research into new missions of economic and social development (Etzkowitz 2003). For so long, universities have transformed and organized their functions to translate the knowledge they produce into the economic activities that benefit the regions in which they reside (Clark 1998). The university arranges the innovation activities providing an entrepreneurial structure in the form of technology transfer offices, incubators, and technoparks (Dalmarco et al. 2018). Technoparks function as a key mechanism in the triple helix of university, industry, and government in creating and strengthening the entrepreneurial capacities of the university and the region. The extant literature has focused on the issues linking technoparks to

Table 3: Parameter Estimates for the Dependent most Entrepreneurial and Innovative Universities Index

	Main Effects Model		Interaction Effects Model	
	Unstd. Coeff.	Std. Coeff.	Unstd. Coeff.	Std. Coeff.
Intercept	116.865		43.060	
TPI	-0.366	-0.283 (0.016)*	-0.336	-0.260 (0.019)
Technopark Age	0.680	0.143 (0.192)	0.582	0.123 (0.234)
University Age	0.127	0.124 (0.327)	2.618	2.548 (0.030)
University Size	-13.983	-0.544 (0.017)	-12.279	-0.478 (0.026)
LogGradStudent	8.582	0.388 (0.102)	14.504	0.656 (0.013)
University Age× LogGradStudent			-0.272	-2.653 (0.037)
SEGE	5.163	0.401 (0.002)	6.354	0.493 (0.000)
Adj. R^2	0.757		0.787	

*p-values are given in parentheses

knowledge spillovers to firms (Díez-Vial, Fernández-Olmos 2015, Montoro-Sánchez et al. 2011); however, how universities benefit from the proximity of technoparks is an area which requires further questioning. We explore the link between entrepreneurial universities and technoparks from a regional perspective considering the university region-specific factors.

The most entrepreneurial and innovative universities index is an initiative that was developed by the government in Turkey and has been successful in creating a competitive environment amongst the universities towards realizing the third mission. While the performance of the entrepreneurial universities has been measured for more than eight years now, there is little known about which ways the universities benefit in the path towards being more entrepreneurial. We empirically analyze a cross-section of the most recent data on the two indices of EIUI and TPI to understand which specific characteristics play a role in the increasing performances of the entrepreneurial universities.

Our findings highlight the importance of the performance of the technopark the university is linked to the university's scores on entrepreneurship and innovativeness. The higher the rankings in technopark performance, the more the university achieves in entrepreneurship and innovation. This finding may look like the expected outcome when one thinks of the connection between the activities and outputs measured in technoparks rankings to the collaboration, economic contribution, and commercialization dimensions in entrepreneurial universities rankings. However, in combining the two indices, the universities that are associated with 16 of technoparks out of the best 50 are not placed in the most entrepreneurial universities list. While our findings reveal the link between the two based on empirical evidence, there are certainly other characteristics that promote the entrepreneurial levels of universities.

University size happens to be a significant characteristic that inversely contributes to the university's ranking of entrepreneurship and innovativeness. Measuring the university size in the total number of students enrolled, we find that the smaller the size of the university, the more the university performs in entrepreneurship and innovation. The most entrepreneurial universities in the U.S., according to the Princeton Review's annual evaluation between 2015 and 2018, reveal that the average number of students enrolled at these universities is approximately 27,500, which are considered to be small universities (Özer et al. 2019). Rubens, Spiragelli (2017) argue that small universities adopt a more regional approach in achieving the third mission. Universities that are smaller in size are, in general, more agile and could respond to the changes faster as compared to the massively scaled universities where the management can be more complex.

Two other university-specific characteristics are found to interact with each other, which makes the interpretation more interesting, considering the context of the study. The direct effects for the student composition measured as the relative ratio of the graduate students to all students and the university age are found to be positively significant in the interaction effects model. However, their joint effect is significantly negative, indicating that younger universities benefit more from the higher composition of graduate students among all students. The other factors, including technoparks' rankings, university size, and socio-economic development index, continue to remain in the model with the same direction in their effects as before. The high graduate student ratio points to the better research productivity, which the prior literature identifies as a quality of research universities in their contributions to local knowledge spillovers and entrepreneurship activities (Smith, Bagchi-Sen 2012). Our findings suggest that this effect could be more viable for younger universities, which implies the role of small specialized universities in regional development and innovation.

Measuring the performances of entrepreneurial universities in quantitative metrics has been new for regional economies. Considering the universities' battle for bringing about the third mission, our study offers different avenues for future thinking of the university-technopark links in regional innovation and entrepreneurship. Our analyses are cross-sectional since the methodology of the rankings has changed as of 2018, which limits the number of periods to study. However, future studies can extend the analyses to longitudinal ones within different regional contexts. Besides, future case studies will help to provide an in-depth understanding of how entrepreneurial universities benefit from being associated with technoparks. Having access to information on some regional characteristics such as human capital of the region, industrial infrastructure of the region, R&D investments, and other regional development measures could take the analyses to a higher state.

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A Appendix: Data for the Most Entrepreneur and Innovative Universities Index and Technopark Performance Index

Table A.1: The Criteria and Indicators of the Most Entrepreneur and Innovative Universities Index

Criterion	Weight	Indicators	Data Sources
Competency in Scientific and Technological Research (CSTR)	23.75%	1) Number of scientific papers 2) Citations 3) Number of projects received from R&D and innovation support programs 4) Amount of funds received from R&D and innovation support programs 5) Number of national and international science awards 6) Number of doctoral graduates	TUBITAK, the Ministry of Industry and Technology, the Council of Higher Education, Turkish Academy of Sciences, Technology Development Foundation of Turkey
Intellectual Property Pool (IPR)	18.75%	7) Number of patent applications 8) Number of patent documents 9) Number of utility model/number of industrial design documents 10) Number of international patent applications	Turkish Patent Office, the Council of Higher Education, Universities
Collaboration and Interaction (CI)	28.75%	11) Number of R&D and innovation projects carried out by university-industry 12) Amount of funds received from R&D and innovation projects carried out by university-industry cooperation 13) Number of R&D and innovation projects made with international cooperation 14) Amount of funds obtained from international R&D and innovation collaborations 15) Number of academic staff/ students in circulation	TUBITAK, the Ministry of Industry and Technology, the Council of Higher Education, Technology Development Foundation of Turkey, Universities, Ministry of Foreign Affairs Directorate for European Union Affairs cooperation
Economic Contribution and Commercialization (ECC)	28.75%	16) Number of active firms that are owned or partnered by academics in technoparks and incubation centers 17) Number of active firms that are owned or partnered by university students or graduates in the last five years in technoparks and incubation centers 18) Number of people employed by firms that are owned or partnered by academics in technoparks and incubators 19) Number of patents / utility models / industrial designs licensed	The Ministry of Industry and Technology, the Council of Higher Education, Small and Medium Enterprises Development Organization of Turkey, Universities, TUBITAK, Turkish Patent Office

Source: Created based on information at https://www.tubitak.gov.tr/

Table A.2: 2018 Rankings of Universities according to the most Entrepreneurial and Innovative Universities Index

Rank	University	CSTR	IPR	CI	ECC	Total
1	Middle East Technical University	23.63	16.24	28.54	24.75	93.16
2	Istanbul Technical University	21.93	15.89	27.59	24.75	90.16
3	Sabancı University	18.08	15.16	27.9	24.36	85.49
4	Bilkent University	21.3	14.02	26.05	23.05	84.42
5	Boğaziçi University	20.55	15.46	28.06	19.26	83.33
6	Yıldız Technical University	17.18	17.54	24.1	22.58	81.4
7	Gebze Technical University	18.18	9.93	24.64	25.07	77.82
8	Hacettepe University	20.18	12.51	24.44	18.8	75.93
9	Izmir Institute of Technology	20.99	9.3	24.93	20.42	75.64
10	Ege University	18.37	10.29	25	17	70.66
11	Koç University	18.64	13.65	27.13	9.46	68.87
12	Istanbul University	17.47	14.09	19.47	16.1	67.13
13	Gazi University	18.07	10.69	19.3	18.74	66.8
14	Özyeğin University	13.85	11.88	20.71	18.99	65.44
15	TOBB Economics and Technology University	14.43	12.8	17.31	17.26	61.8
16	Dokuz Eylül University	17.31	7.3	21.3	15.67	61.58
17	Erciyes University	15.87	7.03	18.73	19.77	61.4
18	Ankara University	18.77	5.44	22.06	13.63	59.9
19	Selçuk University	14.97	13.58	15.64	13.72	57.91
20	Anadolu University	11.54	10.4	16.16	18.89	56.99
21	Sakarya University	12.1	9.76	15.34	18.55	55.74
22	Uludağ University	11.52	11	16.74	15.27	54.53
23	Gaziantep University	12.65	14.9	12.93	11.15	51.63
24	Akdeniz University	13.92	8.45	18.85	9.89	51.11
25	Kocaeli University	10.22	4.72	17.1	18.1	50.13
26	Atılım University	10.21	5.37	14.91	17.14	47.63
27	Çukurova University	14.43	5.88	16.42	8.74	45.47
28	Abdullah Gül University	11.04	8.92	17.3	7.57	44.82
29	Istanbul Medipol University	9.94	11.24	16.69	6.59	44.46
30	Süleyman Demirel University	13.63	7.18	11.4	11.15	43.36
31	Yeditepe University	11.74	15.73	15.82	0	43.29
32	Pamukkale University	10.09	7.18	12.29	13	42.56
33	Marmara University	14.85	5.04	17.88	3.97	41.73
34	Atatürk University	16.75	6.29	11.01	6.94	41
35	Karadeniz Technical University	12.83	3.8	13.39	10.81	40.83
36	Fırat University	10.94	5.38	9.43	14.77	40.52
37	İzmir Economy University	6.43	10.07	14.23	8.97	39.7
38	Yaşar University	7.96	5.98	13.35	11.23	38.53
39	Çankaya University	8.79	6.39	11.75	10.88	37.81
40	Mersin University	9.44	4.01	12.1	9.98	35.53
41	Eskişehir Osmangazi University	11.8	3.53	10.43	8.84	34.6
42	Hasan Kalyoncu University	4.49	11.25	5.87	12.58	34.19
43	Niğde Ömer Halisdemir University	8.41	3.71	13.69	8.33	34.14
44	Bahçeşehir University	8.61	1.95	14.05	9.36	33.97
45	Acıbadem Mehmet Ali Aydınlar University	6.79	3.61	17.87	4.82	33.09
46	Başkent University	6.18	4.92	7.68	13.8	32.59
47	Düzce University	7.06	5.46	12.54	7.17	32.23
48	Çanakkale Onsekiz Mart University	9.56	2.67	13.03	6.88	32.15
49	Tekirdağ Namık Kemal University	7.14	3.18	8.49	12.88	31.69
50	İstanbul Şehir University	8.2	4.82	13.6	3	29.63

Source: https://www.tubitak.gov.tr/

CSTR: Competency in Scientific and Technological Research; *IPR*: Intellectual Property Pool; *CI*: Collaboration and Interaction; *ECC*: Economic Contribution and Commercialization

Table A.3: Main and Sub-criteria of the Technopark Performance Index

Main Criterion	Sub-criterion	Percentage (%)	Indicators
Inputs	Financing, Incentives, and Infrastructure	16.67	1) Supports provided to the managing company 2) Occupancy level 3) The exemption provided to firms 4) Expenditures made by the managing company
Activities	R&D Activities	14	5) R&D staff 6) R&D expenditures 7) R&D projects
	Incubation Activities	9	8) Incubation service 9) Incubation employment
	Technology Transfer & Collaboration	13	10) Knowledge and technology transfer 11) Collaboration between firms 12) International R&D collaborations
	Institutionalization, Sustainability and Developing Ecosystems	12	13) Capacity building activity 14) Services provided by the managing company 15) Clustering activities 16) Overseas activities
	Technological Product Investment	3	17) Investor activities 18) Commercialization activities
Outputs	R&D Outputs	6.67	19) Project outputs 20) Incubation service outputs
	Intellectual Property	5.99	21) Patents 22) Utility models 23) Designs
	R&D Impact and Internationalization	19.67	24) Export 25) R&D revenues

Source: Created based on information at https://www.btgm.sanayi.gov.tr/

Table A.4: 2018 Rankings of Technoparks according to their TPI

Rank	Technopark	Date of Establishment	Associated University
1	Yıldız Technical University Technopark	2003	Yıldız Technical University
2	Middle East Technical University Technopark	2001	Middle East Technical University
3	Istanbul Technical University Arı Technopark	2003	Istanbul Technical University
4	Ankara Technopark	2002	Bilkent University
5	Mersin Technopark	2005	Mersin University
6	Istanbul Technopark	2009	Istanbul Commerce University
7	Erciyes University Technopark	2004	Erciyes University
8	Batı Akdeniz Technopark	2004	Akdeniz University
9	Izmir Technopark	2002	Izmir Institute of Technology
10	TUBITAK-Marmara Research Center Technopark	2001	TUBİTAK-TTGV
11	Ankara University Technopark	2006	Ankara University
12	Gazi Technopark	2007	Gazi University
13	Trabzon Technopark	2004	Karadeniz Technical University
14	Sakarya University Technopark	2008	Sakarya University
15	Samsun Technopark	2009	Ondokuz Mayıs University
16	Hacettepe University Technopark	2003	Hacettepe University
17	Istanbul University Technopark	2003	Istanbul University
18	Ege Technopark	2014	Ege University
19	Ankara Technopark	2014	Yıldırım Beyazıt University
20	GOSB Technopark	2002	Sabancı University
21	Celal Bayar University Technopark	2012	Celal Bayar University
22	Namık Kemal University Technopark	2011	Tekirdağ Namık Kemal University
23	Gaziantep Technopark	2006	Gaziantep University
24	Selçuk University Technopark	2003	Selçuk University
25	Dokuz Eylül Technopark	2013	Dokuz Eylül University
26	Ulutek Technopark	2005	Bursa Uludağ University
27	Konya Technopark	2015	Selçuk, Necmettin Erbakan, Aksaray Karamanoğlu Mehmet Bey, KTO Karatay Universities
28	Fırat Technopark	2007	Fırat University
29	Erzurum Technopark	2005	Atatürk University
30	Boğaziçi University Technopark	2009	Boğaziçi University
31	Tokat Technopark	2008	Gaziosmanpaşa University
32	Cumhuriyet Technopark	2007	Cumhuriyet University
33	Kocaeli University Technopark	2003	Kocaeli University
34	Pamukkale University Technopark	2007	Pamukkale University
35	Eskişehir Technopark	2003	Anadolu University
36	Kırıkkale University Technopark	2013	Kırıkkale University
37	Kahramanmaraş Technopark	2011	Sütçü İmam University
38	İzmir Science Technopark	2012	İzmir Economy University
39	Düzce Technopark	2010	Düzce University
40	Çukurova Technopark	2004	Çukurova University
41	Trakya University Edirne Technopark	2008	Trakya University
42	Yüzüncü Yıl University Technopark	2012	Yüzüncü Yıl University
43	Malatya Technopark	2009	İnönü University
44	Çanakkale Technopark	2011	Çanakkale Onsekiz Mart University
45	Göller Region Technopark	2005	Süleyman Demirel University
46	Bolu Technopark	2009	Abant İzzet Baysal University
47	Afyon Uşak Zafer Technopark	2015	Afyon Kocatepe, Uşak Universities
48	Niğde Ömer Halisdemir University Technopark	2013	Niğde Ömer Halisdemir University
49	Marmara University Technopark	2014	Marmara University
50	Dicle University Technopark	2007	Dicle University

Source: Created based on information at https://www.btgm.sanayi.gov.tr/