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Five Factors for Success of Research, Science and Technology Parks - A state of the art bibliographical overview

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Abstract

This study centers its analysis on research parks as important agents of technological innovation. It presents a systematic and most recent bibliographic review, including the theoretical background, concepts, a historical perspective on the emergence of RPs, and five important factors reflecting the success of RPs in the U.S. and around the world by using empirical data from important studies available in this field.

keywords

Technology Transfer, Research Parks, Innovation Ecosystems, Technological Innovation, Knowledge-based Economy.

Researchers in fields related to technology transfer assume that technological innovation capacity is a fundamental way to improve the living standards of the society and has an unquestionable impact on the economic growth of nations (e.g., Solow 1957; Nelson 2005; Jorgenson, Ho and Stiroh, 2005). Because of such benefits, there is an ongoing race among nations vying for markets with high-technology products, with other countries prone to enter this competition as well.

Among others, some Asian countries have invested in research parks (RPs) with the hope that such an initiative will allow them to increase the level of sophistication in local industries, attract foreign investment and establish the foundation of a knowledge-based economy (e.g., Koh et al. 2005, p.219). These governments continue to devote their efforts to upgrade government research institutions, improve collaboration between universities and local industries, establish intellectual property rights and related legal frameworks and on top of that create complex institutional structures and interfaces to become competitive in globalized markets.

For instance, China's national and local governments have a relatively aggressive policy for the development of RPs. An example of this would be the growth of the park-like Zhangjiang High-Tech (ZHT) Park, where government authorities clustered thirty research institutions, multinational corporations, two hundred domestic Small and Medium Enterprises (SMEs) and biotechnology-related companies. Near the park, two universities, namely the Shanghai Jiao Tong University and the Fudan University, contribute to the innovation system with a group of 8,600 scientist and researchers (Su and Hung, 2008). These clusters for research and technology provide a promising future for China, which is developing a sophisticated physical and intellectual infrastructure and a highly trained workforce.

China has demonstrated its determination to become globally competitive by making significant national and regional investments in science-based economic growth (Walcott 2002). Its plans for development are driven by technological progress, and one of the strategies that they have adopted to carry out this goal has been the creation of large-scale RPs (Motohashi and Yun 2007). China has 54 state-level science and technology industrial parks, which are devoted to electronics and information technology, biomedicine as well as new materials (Wessner, 2009).

However, there are three different types of research facilities in China. The first type is the multinational development, which follow the transnational corporation model. Prominent examples are located in Shenzhen, Dongguan and Suzhou. The second type of research facility is the multinational learning zone. The most important of this type is located in Shanghai and serves as the ideal model for other parks of this kind. The third type of research facility is the local innovation-learning zone that is devoted in generating and transferring technology domestically having limited business relations with foreign companies. One example is Xian, which depends strongly on local university resources and even more on China's defense industry (Walcott, 2002).

On the other hand, research results from innovation activities based on the United States have made many important contributions worldwide in areas like medicine, engineering, communications, transportation, information systems, biotechnology and nanotechnology. These have been the result of the innovation capabilities of U.S. scientists and their public and private research institutions. Important discoveries and inventions, later transformed into products in many areas of science, allow the U.S. innovation system to outperform most other countries focused in innovation (Leydesdorff and Wagner, 2009).

The main strengths of the U.S. innovation system are its diversity, expressed in the decentralized and properly distributed organization of universities and research institutions across the nation, which are the agents of technological innovation; the high mobility of scientists and researchers, the permeability of trained workers between private and public institutions; and the workforce flexibility and adaptability within changing circumstances. Additionally, the scale and openness of the U.S. economy has been divided in homogeneous segments of the U.S. domestic market. A culture of innovation and entrepreneurship is structured to allow to take place in the economy towards new technologies and industries (Abramson et al., 1997).

This study centers its analysis on research parks as important agents of technological innovation. It presents a systematic and most recent bibliographic review, including the theoretical background, concepts, a historical perspective on the emergence of RPs, and five important factors reflecting the success of RPs in the U.S. and around the world by using empirical data from important studies available in this field.

Theoretical Background

Different researchers and academics have studied the research park phenomenon from a variety of perspectives. However, from a theoretical perspective, Phan et al. (2005) suggests that there is no systematic framework to understand RPs due to a) the failure to realize their dynamic characteristics as well as those of the tenants that locate within a RP; and b) the lack of precision for identifying how RPs operate.

In the available literature, scholars have not yet offered a fully developed theory about the formation of RPs. However, cluster theory has been applied to the agglomeration of firms close to universities in the field of biotechnology (Link & Scott 2007). Baptista (1998) argues that the accumulation of companies near universities has been the result of supply and demand forces: on the supply side, the availability of a highly trained labor force (i.e., faculty and graduates from universities near the RP), and on the demand side, the tenants from the park competing for newly developed and sophisticated technologies.

Link and Scott (2007) provide the effect of a research park in a model of innovation for a technology-based manufacturing firm. The science base at the root of the model is the accumulation of scientific and technological knowledge resulting from basic research activities funded mostly by the government and accomplished in universities and federal laboratories. These activities are within the public domain.

If the companies perform research and development (R&D) activities within their facilities (in-house R&D), these activities, in the form of basic and applied research, continue through the proof of concept of a new technology, usually targeting discrete technology jumps to make its competition obsolete. This entrepreneurial activity takes such companies to manufacture a new product as the materialization of basic and applied R&D occurring within their own laboratories. The impact of the RPs in this model expands the science base and facilitates the flow of knowledge between companies and other companies as well as between universities and companies when a university is present, thus influencing innovation and competitiveness (Link and Scott, 2007).

The Research Park Concept

The Association of University Research Parks (AURP), which reports the characteristics and trends in North American Research Parks, defines a research park (RP) as a set of public and private facilities as well as support services devoted to R&D, where technology-based companies perform research in close proximity with university researchers to foster collaboration and innovation and promote "the development, transfer, and commercialization of technology" (AURP 2007, p.3).

While the term RP is predominant in the United States, in Europe the term science park is more commonly used. The term Technology Park or Technopark is prevalent in Asia. All of these terms represent a similar concept and can be used interchangeably (Link and Scott 2007). A RP is "a cluster of technology-based organizations located on or near a university campus in order to benefit from the university's knowledge base and ongoing research. The university not only transfers knowledge but expects to develop knowledge more effectively with the tenants in the research park" (Link and Scott 2006, p.128).

These different definitions of RPs include similar components, which include the following: (a) a shared objective – the incubation of technology-based companies, and (b) a shared need – a common physical space with a high level of service support and facilities. RPs also require a permanent administrative body and formal links to a higher education or research institution located in the area and networked with similar institutions and specialized markets.

The ideas and research partnerships flow between the generators of technology and private companies established in the RP. These partnerships allow access to specialized university laboratories, which stresses the importance of the RPs' geographical location and proximity to the university or research institution that facilitates such collaboration. The outcome of the mentioned cooperation between businesses and research institutions is the generation of knowledge, innovation and technology. This dynamic allows the commercialization of intellectual property, drives the creation of new companies (Start-ups) and strengthens the companies already in the RP, contributing to the economic growth through new jobs and the generation of income to the RPs' surrounding regions.

Origins and growth of Research Parks

The first concept of a RP appeared in the 1950s and was more related to real estate. U.S. industries realized the advantages and importance of being closer to well-known universities and started building facilities around academic institutions. Indeed, the formation of RPs has been a strategy for local economic development (Hall and Castells 1994). The first RPs that emerged in the U.S. were the Stanford Research Park in 1951 in Palo Alto, California; the Cornell Business & Technology Park in 1952 in Ithaca, New York; the University Research Park—originally Swearingen Research Park—in 1957 in Norman, Oklahoma; Research Triangle Park in 1959 in Raleigh-Durham, North Carolina (Link 2003; Link and Link 2003); and the Purdue Research Park in 1960 in West Lafayette, Indiana.

According to data from a 2007 survey of 134 university-based parks by the Association of University Research Parks and Battelle, an international science and technology enterprise related to commercialization of science and technology, university RPs in the United States and Canada cover about 47,000 acres and have more than 300,000 workers. With every job in these RPs, an average of further 2.57 jobs are created and contribute in the local and state economy (AURP 2007). These numbers clearly demonstrate the influence of university- based RPs on the North American economy.

The survey for the following period, 2007 through 2012, reports that university RPs have been effective at creating new employment opportunities for technology companies and have the encouragement of innovation and entrepreneurship as their top priority. Survey results claim a 27% increase in job gains with respect to the previous period and 963 new businesses graduating from RPs' incubators, with only a 19% mortality rate (i.e., start-ups no longer in business) compared with the 50% national average (AURP and Batelle 2013).

In Europe, the first investments in RPs started in the early 1960s, but it was in 1969 when the first known research park, the Sophia-Antipolis, started in southern France. Up until now, the Sophia-Antipolis remains the largest RP in Europe, with about 24,500 individuals employed by tenants, sitting on a 2,300-hectare property. Now, high densities of RPs are found in the United Kingdom and in Nordic countries like Finland and Sweden. Europe is now the continent with the largest number of parks with approximately 400 RPs in 2015 (Ruiz Villacres, 2015).

Five Factors for Success of Research Parks

Kang (2004) mentions some factors for the success of RPs that should be taken into consideration. Kang emphasizes aspects related to the location of the park, facilities and infrastructure, availability of good services, a desirable living environment, supporting mechanisms of collaboration between universities, firms and research laboratories and capital markets for entrepreneurs. According to Kang (2004), key factors for the success of a RP is the proximity to a reputable engineering university with renowned academics and scientists as well as a high production of knowledge.

While RPs' characteristics vary depending on which part of the world they are located, in the symposium "Understanding Research, Science and Technology Parks: Global Best Practices", organized by the National Academy of Sciences, some common internal and external elements inherent to successful RPs have been mentioned. Strong industrial and scientific organizations, accessibility to venture capital, presence of entrepreneurs, networking at the individual level and close collaboration among universities, industries and other organizations were the identified elements (Link 2009). In order to examine in further detail the essential elements that lead to successful RPs, they've been categorized into the following five factors: (a) science and technology policy, (b) geographical proximity to research institutions, (c) quality of research universities, (d) access to capital markets and (e) entrepreneurial skills of scientists.

Science and Technology Policy

In the United States, legal initiatives have promoted additional private sector R&D activity. For example, the Technology Innovation Act of 1980 (also known as the Stevenson-Wydler Act) established technology transfer as a federal government mission aiming to enable transferring of federal-owned technology to nonfederal parties. Also, the University and Small Business Patent Procedure Act of 1980 (also known as the Bayh-Dole Act) reformed federal patent policy by providing increasing incentives for the diffusion of federally funded innovation results. Through this legislation, universities were able to acquire titles to innovations to be developed with government funds (Tran et al., 2011).

The research and experimentation (R&E) tax credit was enacted soon after in 1981, providing a tax incentive to companies to increase their R&D expenses. Later, the National

Cooperative Research Act was legislated in 1984 to promote the formation of joint research ventures among U.S. companies and universities (Tran et al. 2011). The Federal Technology Transfer Act, which has been introduced in 1986, made it possible to transfer technology from federal labs to industries by creating a charter and funding mechanism for the Federal Laboratory Technology Transfer Consortium (FLTC). The Act also enabled federal labs to partner with private sector parties for a Cooperative Research and Development Agreement (CRADA). Overall, these important pieces of legislation, among other administrative measures by the U.S. federal government, facilitated the transfer of technology from public research institutions to industry (Tran et al. 2011).

The Small Business Innovation Research (SBIR) is a phased, structured program of federal economic awards that helps financing small R&D entrepreneurial initiatives which need funding to establish feasibility and technical merit. SBIR's main goal is to stimulate the culture of innovation in the U.S. by financially assisting R&D projects and new technologies with scientific value and the potential for later commercialization (Wessner 2005).

The Small Business Technology Transfer (STTR) and Federal and State Technology Partnership (FAST) programs are two other federal programs that push in the same direction as SBIR, working as a national policy intended to stimulate technology transfer from federally funded R&D innovation to the private sector and bridging basic science and commercialization.

Rasmussen (2008) points out that reforms in national research systems aiming to increase TT and the commercialization of research became a global trend. The success of the U.S. efforts in bringing new research results to the marketplace has triggered legislative initiatives in many countries all over the world, stimulating universities to strengthen infrastructure and to build human resources capabilities for the commercialization of research.

Geographical proximity to research institutions

One of the factors that influences economic growth is the geographical proximity between a university and a research park (e.g., Link and Scott [2006], Luger [1991]). The close proximity of innovation activities within a geographical area may help to develop a community of innovation needed to transfer the ideas and discoveries from research laboratories to the marketplace (Coakes and Smith 2007). This proximity also encourages more frequent interaction that builds the trust needed for mutual collaboration and for the dynamics of exchanging knowledge and skill (Saxenian 1996).

Link and Scott (2006) hypothesized that the closer a park is located to a university, the greater the knowledge flows among park tenants and the university, and, thus, the more attractive the park becomes for new tenants and employment growth. Among the 81 RPs existing in the U.S., according to the 2002 National Science Board's database, 28 parks were located on a university campus, and another eight parks were within one mile of university campuses (Link and Scott, 2006).

Bianchi (2008) analyzed the different industrial policies controlling the structural transformation process in developed as well as developing economies around the world. They concluded that the proximity brings important advantages for high technology-based starter companies including having a pool of highly-specialized and skilled human capital, having early awareness of the latest technological developments on the field of interest with access to market and specialized networks, and having access to venture capital and state-of-the-art amenities. When combining these advantages with a well-managed innovation environment, the probabilities of success increase considerably (Bianchi 2008).

Quality of Research Universities

Another important factor for the increment and success of RPs that should be taken into consideration is the quality of research universities where advancement of knowledge is of paramount importance. Nam Suh (1990) mentioned that research universities are valuable resources for technological innovation and TT efforts in the U.S. The role of these research universities in the U.S. does not end at the boundaries of academia. For example, from the discoveries and inventions made at MIT, new companies have sprung up in the area of Cambridge, Massachusetts. Similarly, new venture companies were formed around the Bay Area of San Francisco and San Jose, California, which is known as Silicon Valley (Suh 1990).

To support U.S. universities' technology transfer capabilities in the area of biotechnology, DeVol et al. (2006), in a global analysis of the transfer of commercialization and patents in biotechnology worldwide, report important findings: "More than 6,300 biotechnology patents were accounted for by the U.S. Patent and Trademark Office between 2000 and 2004. Biotechnology patents issued in the United States have increased dramatically, growing from a cumulative total of 433 through 1995 to 11,430 in 2004" (DeVol et al. 2006, p.12). Nine out of the top 10 universities in the world with patents in the field of biotechnology are U.S. universities. California has four of the top 10 universities and six of the top 25. Of the top 100 institutions ranked, only 28 are foreign universities (DeVol et al. 2006, p.12).

Scientific innovation from U.S. universities has steadily increased in the last 30 years. The economic returns for some universities is substantial; the number of executed licenses reporting income grew six-fold from less than $300 million in 1995 to almost $1.8 billion in 2009 (AUTM, 2009). Some license deals provided outstanding results for some U.S. universities; most well known examples include the University of Florida’s $93 million from Gatorade patents; Stanford University $336 million from Google patents; Emory University’s $540 million from stakes HIV drug Emtriva; and New York University’s $1 billion for Enbrel, a drug to treat rheumatoid arthritis. Through the impact of scientific and technological innovation, these universities are catalysts for regional economic development (Hamermesh et al., 2011). However, these are extreme cases of extraordinary success and do not necessarily represent the typical university patent licensing operation.

However, not all institutions are successful in their research commercialization efforts. Authors have taken different approaches to analyze and compare the factors that influence commercialization activities of intellectual property of faculty and scientists from research institutions. For example, a linear programming method called Data Envelopment Analysis (DEA) (Charnes et al. 1978) has been used as an evaluation tool for multi-input, multi-output cases (Thursby and Kemp 2002; Thursby and Thursby 2002; Siegel and Phan 2003; Heher 2006), in combination with other statistical techniques, to demonstrate evidence of efficient and inefficient universities in the commercialization of technology.

Thursby and Kemp (2002), using DEA, measured the relative efficiency of 57 universities from the U.S. They discovered a substantial growth of commercial activities in universities but also substantial evidence of inefficiencies. They conclude, that the growth is due to a higher desire of industry for university technologies, while the inefficiencies has been a result of university's orientation towards basic research rather than commercial activities (Thursby and Kemp 2002).

Friedman and Silverman (2003) used regression analysis with data sets from the Association of University Technology Managers (AUTM); the National Science Foundation

(NSF); and the Nuclear Regulatory Commission (NRC). They concluded that higher royalty shares for faculty members are associated with greater licensing income for the University. Rogers, Yin, and Hoffman (2000) applied correlation analysis to data sets from AUTM, NSF and NRC to conclude that there is a positive correlation between quality of faculty, age of the Technology Transfer Office (TTO) and number of TTO staff and higher level of performance in TT. Foltz, Barham, and Kim (2000) applied linear regression to data sets from AUTM and NSF to show that faculty quality, federal research funding and number of TTO staff have a positive impact on university patenting.

Debackere and Veugelers (2005), who applied surveys and interviews to eleven research universities in Europe, concluded that research commercialization occurs more effectively in those universities that assign a higher percentage of royalty payments to faculty members. One important component of these universities has been a decentralized management style, which has been critical for success when transferring technology. Bercovitz et al. (2001) conducted a statistical analysis on AUTM data sets followed by interviews to analyze different organizational structures for TT success at Duke, Johns Hopkins and Pennsylvania State universities. They reported that differences in organizational structures might be related to TT performance.

Entrepreneurial Skills of Scientists

Wong et al. (2005) studied the impact of technological innovation on economic growth using cross-sectional data from 37 countries participating in the Global Entrepreneurship Monitor (GEM). They concluded that entrepreneurship accounted for most of the economic growth and job creation by small and medium enterprises. Entrepreneurship is closely related to TT activities, but scientists often lack these skills. To strengthen the TT process, it is therefore necessary to encourage the entrepreneurial and innovation abilities of scientists and university students (Phan, Siegel and Wright 2005). Knowledge about the area of expertise seems to not be enough. It is also necessary to understand the business specifics, the legal framework and the social characteristics of technological progress. It is important to take into account that new technologies do not happen in a “social vacuum”, nor succeed based on technical merits alone but by the interest of groups and the selection process of the target users of the invention (Volti 2010, pp. 39-40). Technological innovation requires from scientists and researchers those additional skills necessary to understand and contribute positively to the TT process. Scientists' involvement in the process of technology commercialization increases the probability of success with commercializing the invention (Thursby, Jensen and Thursby 2001).

There are different programs that are able to help to build researchers' entrepreneurial skills, even though some of these characteristics could be innate in individuals. Bordogna (2006) defines an entrepreneur as an aggressive, innovative and energetic risk-taker. Entrepreneurs contribute key competitive abilities to the knowledge-based economy, contrary to conventional wisdom's valuing of methodical, slow and risk- conservative approaches.

For those scientists for whom innovation is not an innate strength, an early introduction to entrepreneurism may help to unfold their potential as innovators and build the university's and the RPs' innovation capabilities. Even though entrepreneurship education is believed to be complementary to an engineering program, these training programs can have a positive impact on the entrepreneurial activities of engineers. This conclusion is supported with data from a sample of former students of an entrepreneur program and a control group not being exposed to these programs (Miller et al. 2011). The study found that 73% of former entrepreneur students reported to be more likely to start a new company, 23% were more likely to generate new products, and 59% had high confidence in managing a start- up (Miller et al. 2011).

Access to Capital Markets

The State Science and Technology Institute (SSTI, 2006) is a leading United States national organization and recognized authority on technology-based economic development. Based on the experience in Silicon Valley, Research Triangle and Route 128, SSTI indicates that there must be at least five critical components in place to cultivate a successful research park initiative: (a) public or private research laboratories that generate new knowledge and discoveries; (b) physical infrastructure, including high quality telecommunications systems; (c) mechanisms for transferring knowledge between individuals and companies; (d) a highly skilled technical workforce available locally or at close proximity; and (e) sources of risk capital (SSTI 2006).

Within the 2012 AUTM's survey of university RPs, the directors have been asked about the key factors that should be in place to develop a successful research park. Answers from 108 respondents indicated that six innovation-related activities are considered of particular importance: (a) a good match between the core competency of the affiliated university and the tenants; (b) the capacity to assist early-stage business organizations in commercialization; (c) access to capital markets for RP tenants; (d) priority availability of multi-tenant space for incubator graduates; (e) priority access to university resources, facilities, faculty and students; and (f) availability of a formal business incubator in the research park boundaries (AUTM 2013).

According to Diefendorf (1997), the United Kingdom Science Parks Association (UKSPA) has identified the following reasons for the success of sciences parks in the United Kingdom: availability of funding, spaces for incubation of start-ups, state-of-the-art support services and a solid base of scientific research results.

Conclusions

Successful innovation may only arise when new inventions are transformed into new products, which then are transferred from laboratories to the marketplace. This leads to an outstanding implementation of knowledge and contribution to economic growth and development. Only then does the “creative destruction”, which characterizes the Schumpeterian definition of innovation, take place (Schumpeter 1934).

The world is becoming more concerned about technological competition, which is evidenced by the increasing number of countries that are implementing new public policies to spur innovation, such as capacity building and incentives to SMEs (Sternberg 1990), the allocation of larger amounts towards research and development in national budgets (e.g., OECD, Research and Development Statistics, 2014) and the strengthening of higher education institutions and reshaping of public research organizations.

Many governments such as France, Japan, The Netherlands and the United Kingdom have encouraged the creation of more technology clusters—research/science parks (RPs), technopolis or knowledge cities—and they have one goal in common: the development and commercialization of new technologies (Westhead 1997; Hilpert and Ruffieux 1991; Goldstein and Luger 1990).

The concept and the theoretical background of RPs are important factors for the success of RPs, but Kirkland (1996) also describes the typical barriers for a successful technology innovation process: legal barriers; lack of legal framework for IPRs; deficiency of capital markets or financial resources; deficiency of highly skilled workers; poor communication between universities and industries; research institutions not being capable of providing innovative solutions to industry companies; and the lack of human capital with innovative culture, skills and mobility.

Authors so far have not explored the implications for a developing nation wanting to invest in and pursue this path. There are uncertainties about the necessary components and resources to ensure that these investments bring about positive results. Lessons from the U.S. and other European and Asian countries with considerable experience with RPs could be applicable to new projects by starter countries in other parts of the world. These considerations are important, as they could allow policy makers and planners of new projects in developing nations to understand how technological innovation occurs in its wider context and to follow the right steps when designing and implementing new projects within the context of RPs.

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