The economics of university research parks.

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Abstract:

In recent years, there has been a substantial increase in public and private investment in university research parks (URPs). URPs are important as an infrastructural mechanism for the transfer of academic research findings, as a source of knowledge spillovers, and as a catalyst for national and regional economic growth. We present international evidence on the growth of URPs, review the academic literature on URPs, and outline an agenda for additional theoretical and empirical research on this topic.

Keywords: innovation | intellectual property | patents | trademarks | copyright | economics | university research parks | economic policy

Article:

I Introduction

In recent years, there has been a substantial increase in public and private investment in university research/science/technology parks (hereafter, university research parks or URPs) as well as in other property-based institutions that facilitate technology transfer (e.g. incubators). The term ‘research park’ is more prevalent in the United States, the term ‘science park’ is more prevalent in Europe, and the term ‘technology park’ is more prevalent in Asia. Many universities have established research parks and incubators in order to foster the creation of start-up firms based on university-owned or licensed technologies. Public universities, and some private universities, also view these institutions as a means of fostering regional economic development.

URPs are important for several reasons. They are a mechanism for the transfer of academic research findings, a source of knowledge spillovers, and a catalyst for national and regional economic growth. This generalization about the role and impact of URPs follows indirectly from a vast literature in economics, geography, management, and public policy on the impact of basic research, which is largely performed at universities. Studies in the literature on the economics of innovation link investment in basic research to improvements in productivity growth at the firm and societal levels (e.g. Mansfield, 1980; Link, 1981a,b; Griliches, 1986; Adams, 1990; Lichtenberg and Siegel, 1991; Link and Siegel, 2003). There is also a related literature in economic development, which focuses on the impact of research clusters on regional economic growth (Swann et al., 1998; Porter, 2001a,b).

The growth in URPs has stimulated an important academic debate concerning whether such property-based initiatives directly enhance the performance of corporations, universities, and economic regions over time. More practically, the growth in URPs has also led to interest among policy-makers and industry leaders in identifying best practices in the formation and operation of such parks. Unfortunately, few academic studies directly address these issues. The lack of such focused research may be attributed to the somewhat embryonic nature of URPs per se (discussed below) and to the fact that most URPs are public–private partnerships, indicating that multiple stakeholders (e.g. community groups and regional and state governments) have influence over their missions and operational procedures. Thus, developing theories to characterize the precise nature of the growth models and managerial practices of parks can be somewhat complex, and very difficult to test empirically. There are few managerial benchmarks to follow to ensure the growth and possible success of URPs; and, more generally, the place of URPs in a national innovation system is not yet well understood.

In sum, URPs are not well understood and attendant research on them is just beginning to burgeon. We speculate that this gap in understanding stems from the lack of well-defined constructs about what constitutes a URP, the variety of goals of a URP, and the general lack of clear metrics for measuring their impacts and successes.

II Trends in URPs

Link and Scott (2006), based on an overview of alternative definitions of a URP in the literature, propose the following definition:

> A university research park is a cluster of technology-based organizations that locate 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 given the association with the tenants in the research park.

In the United Kingdom, all research parks are located on or near a university campus. In other countries, the distance between the URP and the university varies. In the United States, for example, a number of URPs are located on or near a university campus as in the United Kingdom, but other URPs are a substantial distance from their associated university, in part because the parks were formed recently and thus suitable land beside the university was not available (Link and Scott, 2006).

If the URP is located on a university campus or directly adjacent to it, the university may own the park land and/or oversee, at least in part, the activities that take place in the park, as well as provide advice on the strategic direction of the park's growth. Oversight may include tenant criteria for leasing space in the park (Link and Link, 2003). Such criteria may specify particular technologies or state that the tenant must maintain an active research relationship with university departments and their students. When the park is located off campus, it is often the case that the park land is owned by a private venture—and sold or leased to tenants—but typically, in such cases, the university has contributed financial capital to the park's formation and/or intellectual capital to its operation. Therefore, there are elements of an administrative relationship between the university and these research parks.

In the United States, the form of the relationship between the university and the research park can be very explicit, as in the case when the university owns the park land and buildings and leases space to criteria-specific tenants (e.g. tenants involved in research in a particular technology area such as biotechnology), or very implicit, as in the case when the privately owned park is juxtaposed to the university and the university owns and operates buildings on park land. Certainly, a physical relationship between the university and the park does not necessarily imply an administrative or strategic relationship. The inability to quantify all of the dimensions of the dynamics of such relationships suggests that any workable definition of a URP will be broad and general.

The formation of URPs is a post-Second-World-War phenomenon. Although data on park formations are very limited, examination of the number of URPs founded during the period 1951–98 for seven OECD countries1—the United States, the United Kingdom, Canada, France, Japan, Germany, and Italy—suggests that park formations increased sharply in the late 1970s and/or early 1980s in all countries. Siegel et al. (2003) suggest that during that time period, there were two important policy initiatives in OECD countries that are alleged to have accelerated the rate of knowledge transfer from universities to firms and that may have contributed to the sharp increase in park formations. These initiatives were targeted legislation designed to stimulate cooperation in research and development (R&D) between universities and firms and to institute a major shift, favouring universities, in the intellectual property regime. Examples of the targeted stimulation of cooperative research include various European Union Framework Programmes, and the enactment of the Bayh–Dole Act of 1980 in the United States illustrates the changes favouring universities in intellectual property ownership.

Link and Scott (2006) are less certain of the reasons for the rise in the founding of URPs in the late 1970s and early 1980s in the United States, identifying several potential causes. They note that there were a number of US policy initiatives in the early 1980s, promulgated in response to the moderate decline in productivity growth in the early 1970s and the more pronounced decline in the late 1970s that extended into the early 1980s. These initiatives included the Bayh–Dole Act of 1980, and also the R&E (research and experimentation) Tax Credit of 1981 and the National Cooperative Research Act of 1984. As well, Link and Scott (2006) argue that real R&D performed in US industry had been decreasing since 1970 and not until 1977 did it return to its 1969 pre-decline level. Thus, in the late 1970s industrial firms were looking for cooperative research partnerships to expand their research portfolios and universities were responding by providing research locations.

It is important to note, too, that productivity growth declined in most industrial nations during roughly the same periods as it did in the United States. It is thus not unreasonable to hypothesize that the international trends suggesting a pronounced increase in park formations in the late 1970s and early 1980s are coincidentally related to the increase in R&D that occurred in the productivity growth recovery periods (Link and Siegel, 2003).

The most complete time-series of data on research park formations documented in the academic literature relates to URPs in the United States (Link and Scott, 2003b, 2006). According to Link and Scott (2003b, 2006), there were, as of 2002, 81 active URPs in the United States. Even with information on the population of US URPs, the pattern of park formation over time suggested above still holds. The UK Science Park Association (UKSPA, 2003) reports that there are 100 science parks in the United Kingdom, most of which are based on or near UK universities. According to Lindelöf and Löftsen (2003), there were, as of 2001, 23 science parks in Sweden. Phan et al. (2005) identified, as of 2003, over 200 science parks in Asia, with 111 based in Japan. China has over 100; Hong Kong and South Korea each report two parks; and Macau, Malaysia, Singapore, Taiwan, and Thailand have one each. India established 13 parks in the late 1980s but, with the exception of Bangalore, India's Silicon Valley, all have failed.

III Theories on the formation of URPs

Surprisingly, the extant literature in economics, geography, management, and public policy does not offer a fully developed theory about the formation of URPs. Case studies have documented the institutional history of a number of research parks, university affiliated or not. Castells and Hall (1994) describe the Silicon Valley (California) and Route 128 (around Boston, Massachusetts) phenomena; Luger and Goldstein (1991), Link (1995, 2002), and Link and Scott (2003a) detail the history of Research Triangle Park (North Carolina); Gibb (1985), Grayson (1993), Guy (1996a,b), and Vedovello (1997) summarize aspects of the science-park phenomenon in the United Kingdom; Gibb (1985) also chronicles the science/technology park phenomenon in Germany, Italy, the Netherlands, and selected Asian countries; and Chordà (1996) reports on French science parks, Phillimore (1999) on Australian science parks, Bakouros et al. (2002) and Sofouli and Vonortas (forthcoming) on the development of science parks in Greece, and Vaidyanathan (forthcoming) on technology parks in India.

Scholars have not yet formally tied the emergence of URPs to cluster theory, although such theory has been applied to the formation of biotechnology and other science-based agglomerations of firms near universities, so the potential application is not unreasonable. Drawing on cluster theory—and location theory was, in part, a prequel to the popularization of cluster theory, as reviewed by Goldstein and Luger (1992) and Westhead and Batstone (1998)—one could argue that there are both demand and supply forces at work that result in the clustering of research firms near universities (Baptista, 1998).

On the demand side, there are sophisticated users of developed technologies within a park, and the search costs for such users are minimized by locating on a park. Of course, there are disadvantages associated with being in a park, mainly greater competition for the developed technologies. On the supply side, there is skilled and specialized labour available from the university or universities involved in the park, in the form of graduate students and consulting faculty, although there is also more competition for that pool of human capital. Also, for a firm, location on a URP provides a greater opportunity for the acquisition of new knowledge—tacit or experiential knowledge, in particular. As well, for the university, having juxtaposed firms provides a localized opportunity for licensing university-based innovations. The theory of agglomeration economics emphasizes knowledge spillovers and enhanced benefits and lowered costs caused by the presence of multiple organizations and the externalities they create (Swann, 1998). Jaffe (1989), Jaffe et al. (1993), Audretsch and Feldman (1996, 1999), Audretsch (1998), Breschi and Lissoin (2001), and Rothaermel and Thursby (2005a,b) also provide empirical support for the agglomeration effect.

Henderson (1986) and Krugman (1991) emphasize, conceptually as well as empirically, the importance of location per se with regard to knowledge spillovers. Localization has an effect on resource prices. To the extent that new technology embodies new knowledge, geographic closeness implies lower new technology prices and thus presumably greater usage. Firms achieve economies of scale more easily with newer technologies. Arthur (1989) underscores the related importance of network externalities with regard to such scale economies. David (1985) also argues in general—and his argument could apply particularly well to URPs—that chance or historical events can lock a technology on a particular path of development. If that technology had a university origin, then creating a URP, from the university's perspective, and locating in the park, from a firm's perspective, gives positive feedback to continue the path dependency of the particular technology. The idea of path dependency, according to Arrow (2000), has its origins in the early writings of economists Veblen and Cournot, but it can also be traced to the Nelson and Winter (1982) concepts about evolutionary economics (Hébert and Link, 2006).

Relatedly, Leyden et al. (forthcoming) outline a theoretical model, based on the theory of clubs, to describe the conditions under which a firm would be located in an existing URP. The authors conjecture that a URP acts like a private organization, so that membership in the research park is the result of mutual agreement between the existing park tenants, including the university, the club, and a potential new member firm.

The decision to admit the new firm depends on the marginal effect of that firm on the well-being of the firms already in the park. For the representative in-park firm, the value of belonging to the park is the opportunity to engage in synergistic activities, which can be used to increase its profits in the output markets in which it participates, net of the direct costs (e.g. maintenance cost of being in the park and maintaining infrastructure) and indirect costs (e.g. congestion and competition for new knowledge) of being in the park.

IV Empirical studies of URPs

In addition to case studies documenting the institutional history of URPs in a variety of countries, as referenced above, the empirical literature on URPs broadly falls into five categories, and each is discussed below. Further, the URP empirical literature generally takes one of two forms: descriptive studies of survey data from which broad propositions are supported or not, and econometric studies of public-domain or survey data from which specific hypotheses are tested statistically. Because the academic URP literature is burgeoning, both forms of analysis are important, and important and meaningful insights can be drawn from each.

(i) Factors affecting firm decisions to locate on a URP

The pioneering descriptive analysis of factors that attracted firms to locate on a URP was done by Westhead and Batstone (1998), based on a matched-pairs sample (i.e. on-park firms and off-park firms) of 1986 UK data originally collected by Monck et al. (1988) and later updated to 1992 and expanded by Westhead and Storey (1994). The data are also summarized in Westhead (1997). Westhead and Batstone (1998) found that the major determinant of a firm's decision to locate on a URP is a desire to acquire access to research facilities and scientists at the university.

The ability to develop linkages between higher education institutions (HEIs) and firms is, according to Westhead and Bastone (1998), the key criterion by which to judge the success of the science-park phenomenon. Goldstein and Luger (1992) arrive at the same conclusion from their descriptive analysis of university-based and non-university-based research parks established before 1989 in the United States. Hansson et al. (2005) conclude from case studies of science parks in Denmark and the United Kingdom that an important role for parks is to foster the social capital needed to facilitate entrepreneurial growth and network formations within an HEI environment.

Finally, Leyden et al. (forthcoming) model the decision of a firm to locate on a URP, or more precisely the likelihood that a firm will be invited to locate on a URP. Their empirical model shows that firms doing higher-quality research are more likely to be invited to locate on a URP because of the spillover benefits to existing park tenants. They measure research quality in terms of the level of a firm's R&D expenditures, and they hold constant in their regression analysis the extent to which each firm is diversified in the output market, because diversification can also afford spillover benefits to existing park tenants. Their analysis of US public firms in 2002 strongly suggests that the likelihood of a firm locating on a URP—that is being invited to enter and agreeing to enter—is positively related to the level of its R&D, other things, including the firm's sales, being the same. Certainly, more R&D-intensive firms confer benefits to existing tenants and to the university, but the locating firm must also realize research externalities.

(ii) Formation of a URP and university performance

Link and Scott (2003b) quantify the growth in US URPs over time as a Gompertz survival-time model. They argue that URPs are an infrastructural innovation and universities will ‘adopt’ this innovation over time much like product or process innovations diffuse throughout a market. In fact, when time-series data on park formations are analysed as cumulative totals, the resulting S-shaped patterns of URP formations that result are not dissimilar to observed diffusion curves for innovations.

The Gompertz model describes the adoption of the URP innovation as a stochastic diffusion process with an increasing hazard rate. The probability of the establishment of a URP by time t, F(t), is:

$$F(t) = 1 - S(t)$$

where $S(t)$ is the probability that, for a particular observation, the adoption has not occurred by time t.

Link and Scott (2003*a*) also invoked this model to explain the growth in tenants entering Research Triangle Park, North Carolina. They argue that firms adopt the location of Research Triangle Park over time and thereby adopt the URP innovation.

Based on responses by university provosts to a 2001 survey about the benefits associated with his/her university's research park, Link and Scott (2003*b*) report that the relationship of the university to the park was important. Universities with a formal relationship (e.g. an institutional arrangement, such as ownership of the park land or advisory control over types of tenants) with their research park realize greater benefits from that relationship as quantified through increased publications and patenting activity, greater extramural funding success, and an enhanced ability to hire pre-eminent scholars and to place doctoral graduates.

(iii) Growth of URPs

The most complete longitudinal database on URPs relates to park formations in the United States. Link and Scott (2003*b*, 2006) created the database and identified with a regression framework correlates with the growth over time in the number of employees in the park. As of 2002, there were 81 URPs operating in the United States with another 27 in the planning stage.

Their regression model begins with a growth equation:

$$y(t) = ae^{gt}e^{\varepsilon}2$$

where $y(t)$ is the URP's employment t years after being established, a is a minimum efficient start-up scale for a URP, g is the annual rate of employment growth of the park, and ε is a random error term. Link and Scott (2006) hypothesize that g for a park is a function of various explanatory variables (e.g. distance from the university to the URP, and the presence of an incubator) as represented by the vector **X**:

$$g = \mathrm{f}(\mathbf{X}).3$$

Two findings from the estimation of a regression model derived from equations (2) and (3) are especially important given the number of US parks being planned. First, the annual rate of employment growth is greater the closer, in miles, the park is to the university, ceteris paribus. This finding is expected, based on cluster and location theory, as discussed above. It also follows from the empirical work of Adams and Jaffe (1996), which suggests that communication costs related to collaborative R&D activity increase with distance, and Wallsten (2001), which shows geographic proximity to other successful innovating firms is associated with the firm's own success. Second, parks that have incubator facilities—and about one-half of the URPs in the United States have an incubator facility—grow more slowly than parks without them, ceteris paribus. This finding reflects the fact that incubators assist the growth of small firms and then those firms leave the park for other locations.2

(iv) Location on a URP and firm performance

The most complete evidence about the economic effects on firm performance of being located in a URP is from the United Kingdom. Several studies were based on selected years of longitudinal data, consisting of performance indicators for firms located on URPs and matched pairs of firms not located on URPs (Monck et al., 1988; Westhead and Storey, 1994, 1997; Westhead, 1995; Westhead and Cowling, 1995; Westhead et al., 1995). The authors find no difference between the closure rates of firms located on URPs and similar firms not located on URPs, implying that sponsored park environments did not significantly increase the probability of business survival or enhance job creation.

With respect to the importance of the university, Westhead and Storey (1994, 1997) found, from matched pairs of firms in the UK data for 1986 and 1992, a higher survival rate among science-park firms with a university relationship than firms without such a relationship. Westhead (1997), examining descriptively differences in R&D outputs (i.e. counts of patents, copyrights, and new products or services) and inputs (i.e. percentage of scientists and engineers in total employment, the level and intensity of R&D expenditure, and information on the thrust and nature of the research undertaken by the firm) of firms located on URPs and similar firms located off URPs, found no significant differences between the park and off-park firms.

However, Siegel et al. (2003), examining the Westhead and Storey (1994) data, found, using econometric techniques, that park firms have slightly higher research productivity than comparable off-park firms, where productivity is measured in terms of generating new products and services and patents, but not copyrights. Their regression analysis is based on a model of the general form:

ResearchOutput = f (InnovationCapacity, SciencePark)

where ResearchOutput is a vector of alternative innovation- and research-related output measures relevant to a firm (e.g. number of new products and services), InnovationCapacity measures the internal capabilities of the firm (e.g. internal R&D expenditures), and SciencePark defines dichotomously if a firm is on a science park or not. Their findings are relatively insensitive to the specification of the econometric model and control for the possibility of an endogeneity bias (i.e. a firm being on a science park is not independent of, say, its technology focus and its R&D activity). This preliminary evidence suggests that university science parks could constitute an important spillover mechanism because they appear to enhance aspects of the research productivity of firms.

There have also been several evaluation studies of Swedish science parks. Lindelöf and Löfsten (2003, 2004) conducted a matched-pairs analysis of 134 on-park and 139 off-park Swedish firms for 1999, using descriptive techniques similar to those employed by Westhead and Storey (1994). The authors report that there are insignificant differences between science-park and non-science-park firms in terms of patenting and new products. However, they find that firms located on science parks appear to have different strategic motivations than comparable off-park firms. More specifically, they seem to place a stronger emphasis on innovative ability, sales and employment growth, market orientation, and profitability. Lindelöf and Löfsten (2004) also find that the absolute level of interaction between the university and firms located on science parks is low, but that science-park firms were more likely to have formal (e.g. contracts for research) or informal (e.g. transfer of personnel) interactions with the university than non-science-park firms.3 Ferguson and Olofsson's (2004) analysis of Swedish science-park firms, using 1995 data, found no significant differences between park and off-park firms in terms of sales or employment.

Fukugawa (2006) analysed the 2003 value added to firms by Japanese science parks. In Japan, unlike the United Kingdom but like the United States, not all science parks are associated with a university. He found that firms located on these parks are more likely than observationally equivalent non-park firms to develop links with universities. It appears that the range of these universities is not necessarily localized. The author also reports that park firms are not encouraged to develop linkages with universities any more than off-park firms are. Taken together, these findings show that localized spillovers from parks are not as great as they could be. This conclusion complements Felsenstein's (1994) earlier finding that there is greater interaction between park firms and universities in Israel, using 1992 matched-pairs firm data, than between off-park firms and universities, but their interactions have ‘a weak and indirect relationship with innovation’ (p. 93).

(v) URPs and regional economic development

Most URPs have financial support, either directly through a governmental growth initiative or through targeted taxes. One rationale for public support of URPs is that they have the ability to leverage regional economic growth. Goldstein and Luger (1990) initiated the research in the United States on the spillover benefits from a URP to the regional economy. They argue, conceptually, that the potential economic development impacts of a URP include: location of new R&D activity, R&D firm spin-offs, location of new manufacturing activities and attendant supply-chain businesses, and increased firm productivity.

Goldstein and Luger (1992) also provide some of the first descriptive evidence, based on a 1989 survey of directors of research parks in the United States, that URPs have, indeed, contributed to regional growth. In particular, surveyed park directors state that their park has improved the quality and reputation of the host university; and the park has leveraged population growth, new business start-ups, and employment opportunities, especially among minorities.4 Shearmur and Doloreux's (2000) analysis of Canadian science parks reaches a similar conclusion.

V Policy conclusions

The elements of a national innovation system include competitive firms and a competitive environment, an effective educational system, strong university research, a legal system with property rights, and a capital market that includes venture capital (Nelson, 1993; Cohen, 2002). We conclude our review of the economics of URPs by asking if URPs in particular, and research parks in general, have a unique place within a national innovation system.

Although the literature related to research parks and URPs is still embryonic, the evidence suggests that parks enhance the two-way flow of knowledge between firms and universities. Thus, parks enhance innovation and, subsequently, competitiveness.

Many nations' sectors have to varying degrees informally encouraged the formation of industry/university linkages. France's central government, like those of Japan, the Netherlands, and the United Kingdom, has actively fostered the creation of science parks (Goldstein and Luger, 1990; Hilpert and Ruffieux, 1991; Westhead, 1997), and Germany has long promoted academic innovation centres to incubate and develop small and medium-sized enterprises (Sternberg, 1990).

In the United States, public investment at state universities is used to underwrite the formation and development of URPs, and in 2004 and again in 2007 the US Congress considered, but did not pass, a bill to provide grants and loans to states and local authorities for the development and construction of URPs. Implicit in these bills is the assumption that research parks are an important element in the US national innovation system, and as such should be fostered because of both the knowledge- and employment-based spillovers that will result.

This US action may be the most obvious example of public-sector support for URPs. Hand-in-hand with public-sector support is the need for public accountability, namely the development and implementation of evaluation methods and tools not only to support the assumption that URPs are, in fact, an important element of the national innovation system, but also to quantify the net spillover benefits that result from public-sector support.

The matched-pairs studies discussed above are a preliminary form of evaluation. That is, it is useful to know that there is evidence that firms on a research park are more productive than firms not on a research park, ceteris paribus. However, when substantial public-sector resources are devoted to park formations, a more in-depth evaluation approach is warranted, namely the application of what Link and Scott (2001) call the spillover evaluation method. The spillover evaluation method applies to publicly funded, privately performed research projects and, in the case of URPs, research project is defined in terms of the research activities that occur in the park rather than simply the construction of the park.5

There are important projects where economic performance can be improved with public funding of privately performed research. Public funding is needed when socially valuable projects (e.g. research on a URP) would not be undertaken without it. If their expected rate of return from creating a URP environment falls short of their required rate, called the hurdle rate, then the university or local firms would not invest in the research park environment. None the less, if the benefits of the research spill over to consumers and to firms other than those investing in the research, the social rate of return may exceed the appropriate hurdle rate, even though the private rate of return falls short of the private hurdle rate. It would then be socially valuable to have the investments made, but since the university or local firms will not make them without public support, the public sector should support the investments. By providing public funding, thereby reducing the investment needed from the university and local firms doing the research, the expected private rate of return can be increased above the hurdle rate. In this case, the public sector's support may also suggest, or affirm, the possibility of a market for a successful project, thus reducing the investors' perceived risk as well as increasing the initial investment they are willing to make. Thus, because of the public subsidy, the university and local firms are willing to perform the research that is socially desirable because much of its output spills over to other firms in the park and sectors in the local and national economies.

The question asked in the spillover evaluation method is one that facilitates an economic understanding of the potential returns to public-sector support for a portion of private-sector research, namely: what proportion of the total profit stream generated by the university's and local firms' research and innovation do the university and local firms expect to capture; and, hence, what proportion is not appropriated but is, instead, captured by others that use knowledge generated by the URP research to produce competing products for the social good?6

We conclude that URPs should not a priori be considered a primary element of a nation's innovation system, but rather that that point of view, which evidently is held by a significant group in the US Congress as well as by policy-makers in other nations, needs more study. Successful two-way knowledge flow between universities and industry is a key ingredient for a national innovation system, and we do have evidence that URPs play a role in that knowledge flow. However, URPs are not a sine qua non of the knowledge flow. Perhaps, consistent with the findings of the survey of university provosts reported in Link and Scott (2003b), URPs fall under the broader category of an effective educational system. However, URPs may in the future warrant a higher status, especially as technological life cycles continue to shorten and as basic research at universities (and to a growing extent at national laboratories (Wessner, 1999, 2001)) and applied research/development in industry become more intertwined.

Footnotes

1 These data come from the Association of University Related Research Parks (AURRP, 1998). This data set represents the most encompassing set of information about URPs that is publicly available, but, as discussed by Link and Scott (2003b, 2006), it is not complete because the

information comes from AURRP members and not all worldwide URPs are members. Nevertheless, the AURRP data are a useful starting point to discuss trends in URPs formations.

2 There is a vast literature on the economics and management of business incubators and business incubation, much of which has been expertly reviewed by Hackett and Dilts (2004) and McAdam et al. (2006), and in the references therein. There is a void in research specifically related to incubators on URPs.

3 There is a related literature on universities as research partners (e.g. partners in a cooperative research venture) (Hall et al., 2001, 2003). Hall et al. (2003) contend that universities are invited to participate with firms in research projects that involve what may be called ‘new’ science. Industrial partners perceive that the university could provide research insight that is anticipatory of future research problems and could be an ombudsman anticipating and translating to its research partners the complex nature of the research being undertaken.

4 Phan and Siegel (2006) provide a comprehensive review of the literature related to university start-ups and spin-offs. The only research that has focused specifically on spin-offs to URPs is by Link and Scott (2005). They find that in the United States, university spin-off firms are a larger proportion of firms in parks that are geographically closer to their university and in parks that have a biotechnology focus.

5 If one defined narrowly the output of the use of public-sector resources as the park itself, then, following Link and Scott (1998), the counterfactual evaluation method would be appropriate. When publicly funded, publicly performed research investments are evaluated, and the public is building the park, one should ask: what would the private sector have had to invest to achieve the benefits associated with the park in the absence of the public sector's investments? The answer to this question gives the benefits of the public's investments, namely, the costs avoided by the private sector.

6 The part of the stream of expected profits captured by the innovator is its private return, while the entire stream is the lower bound on the social rate of return (because of the additional benefits of consumer surplus and assuming any cannibalization of existing surplus is relatively small). The spillovers evaluation weighs the private return (in practice—see Link and Scott (2001)—estimated through extensive interviews with the private-sector organizations receiving public support regarding their expectations of future patterns of events and future abilities to appropriate returns from R&D-based knowledge) against private investments. The social rate of return weighs the social returns against the social investments.

References

Adams J. D. Fundamental Stocks of Knowledge and Productivity Growth. Journal of Political Economy 1990;98(4):673-702.

Adams J. D., Jaffe A. B. Bounding the Effects of R&D: An Investigation Using Matched Establishment-firm Data. Rand Journal of Economics 1996;27(3):700-21.

Arrow K. J. Increasing Returns: Historiographic Issues and Path Dependence. European Journal of the History of Economic Thought 2000;7(2):171-80.

Arthur W. Competing Technologies, Increasing Returns, and Lock-in by Historical Small Events. The Economic Journal 1989;99(2):116-31.

AURRP. Worldwide Research & Science Park Directory 1998. 1998. BPI Communications Report, Washington, DC, Association of University Related Research Parks.

Audretsch D. B. Agglomeration and the Location of Innovative Activity. Oxford Review of Economic Policy 1998;14(2):18-29.

Audretsch D. B., Feldman M. P. R&D Spillovers and the Geography of Innovation and Production. American Economic Review 1996;86(3):630-40.

Audretsch D. B., Feldman M. P. Innovation in Cities: Science-based Diversity, Specialization, and Localized Competition. European Economic Review 1999;43(2):409-29.

Bakouros Y. L., Mardas D. C., Varsakelis N. C. Science Parks, a High Tech Fantasy? An Analysis of the Science Parks of Greece. Technovation 2002;22(2):123-28.

Baptista R. Clusters, Innovation, and Growth: A Survey of the Literature. In: Swann G. M. P., Prevezer M., Stout D. , editors. The Dynamics of Industrial Clustering. Oxford: Oxford University Press; 1998.

Breschi S., Lissoin F. Knowledge Spillovers and Local Innovation Systems: A Critical Survey. Industrial and Corporate Change 2001;10(4):975-1005.

Castells M., Hall P. Technopoles of the World. Oxford: Oxford University Press; 1994.

Chordà I. M. Towards the Maturity State: An Insight into the Performance of French Technopoles. Technovation 1996;16(3):143-52.

Cohen W. Thoughts and Questions on Science Parks. 2002. paper presented at the National Science Foundation Science Parks Indicators Workshop, University of North Carolina at Greensboro.

David P. A. Clio and the Economics of QWERTY. American Economic Review 1985;75(2):332-37.

Felsenstein D. University-related Science Parks—“Seedbeds” or “Enclaves” of Innovation? Technovation 1994;14(2):93-110.

Ferguson R., Olofsson C. Science Parks and the Development of NTBFs: Location, Survival and Growth. Journal of Technology Transfer 2004;29(1):5-17.

Fukugawa N. Science Parks in Japan and Their Value-added Contributions to New Technology-based Firms. International Journal of Industrial Organization 2006;24(2):381-400.

Gibb M. J. Science Parks and Innovation Centres: Their Economic and Social Impact. Amsterdam: Elsevier; 1985.

Goldstein H. A., Luger M. I. Science/Technology Parks and Regional Development Theory. Economic Development Quarterly 1990;4(1):64-78.

Goldstein H. A., Luger M. I. University-based Research Parks as a Rural Development Strategy. Policy Studies Journal 1992;20(2):249-63.

Grayson L. Science Parks: An Experiment in High Technology Transfer. London: The British Library Board; 1993.

Griliches Z. Productivity Growth, R&D, and Basic Research at the Firm Level in the 1970s. American Economic Review 1986;76(1):141-54.

Guy I. A Look at Aston Science Park. Technovation 1996a;16(5):217-18.

Guy I. New Ventures on an Ancient Campus. Technovation 1996b;16(6):269-70.

Hackett S. M., Dilts D. M. A Systematic Review of Business Incubation Research. Journal of Technology Transfer 2004;29(1):55-82.

Hall B. H., Link A. N., Scott J. T. Barriers Inhibiting Industry from Partnering with Universities: Evidence from the Advanced Technology Program. Journal of Technology Transfer 2001;26(1–2):87-98.

Hall B. H., Link A. N., Scott J. T. Universities as Research Partners. Review of Economics and Statistics 2003;85(2):485-91.

Hansson F., Husted K., Vestergaard J. Second Generation Science Parks: From Structural Holes Jockeys to Social Capital Catalysts of the Knowledge Society. Technovation 2005;25(9):1039-049.

Hébert R. F., Link A. N. Historical Perspectives on the Entrepreneur. Foundations and Trends in Entrepreneurship 2006;2(4):261-408.

Henderson J. V. The Efficiency of Resource Usage and City Size. Journal of Urban Economics 1986;19(1):47-70.

Hilpert U., Ruffieux B. Innovation, Politics and Regional Development: Technology Parks and Regional Participation in High Technology in France and West Germany. In: Hilpert U. , editor. Regional Innovation and Decentralization: High Technology Industry and Government Policy. London: Routledge; 1991.

Jaffe A. B. Real Effects of Academic Research. American Economic Review 1989;79(5):957-70.

Jaffe A. B., Trajtenberg M., Henderson R. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. Quarterly Journal of Economics 1993;108(3):577-98.

Krugman P. Geography and Trade. Cambridge, MA: MIT Press; 1991.

Leyden D. P., Link A. N., Siegel D. S. A Theoretical and Empirical Analysis of the Decision to Locate on a University Research Park. IEEE Transactions on Engineering Management. forthcoming.

Lichtenberg F. R., Siegel D. The Impact of R&D Investment on Productivity—New Evidence Using Linked R&D–LRD Data. Economic Inquiry 1991;29(2):203-28.

Lindelöf P., Löfsten H. Science Park Location and New Technology-based Firms in Sweden: Implications for Strategy and Performance. Small Business Econmics 2003;20(3):245-58.

Lindelöf P., Löfsten H. Proximity as a Resource Base for Competitive Advantage: University–Industry Links for Technology Transfer. Journal of Technology Transfer 2004;29(3–4):311-26.

Link A. N. Basic Research and Productivity Increase in Manufacturing: Some Additional Evidence. American Economic Review 1981a;71(5):1111-12.

Link A. N. Research and Development Activity in US Manufacturing. New York: Praeger; 1981b.

Link A. N. A Generosity of Spirit: The Early History of the Research Triangle Park. Research Triangle Park: NC, University of North Carolina Press for the Research Triangle Park Foundation; 1995.

Link A. N. From Seed to Harvest: The History of the Growth of the Research Triangle Park. Research Triangle Park: NC, University of North Carolina Press for the Research Triangle Park Foundation; 2002.

Link A. N., Link K. R. On the Growth of US Science Parks. Journal of Technology Transfer 2003;28(1):81-5.

Link A. N., Scott J. T. Public Accountability: Evaluating Technology-based Institutions. Norwell, MA: Kluwer Academic; 1998.

Link A. N., Scott J. T. Public/Private Partnerships: Stimulating Competition in a Dynamic Market. International Journal of Industrial Organization 2001;19(5):763-794.

Link A. N., Scott J. T. The Growth of Research Triangle Park. Small Business Economics 2003a;20(2):167-75.

Link A. N., Scott J. T. US Science Parks: The Diffusion of an Innovation and Its Effects on the Academic Mission of Universities. International Journal of Industrial Organization 2003b;21(9):1323-56.

Link A. N., Scott J. T. Opening the Ivory Tower's Door: An Analysis of the Determinants of the Formation of US University Spin-off Companies. Research Policy 2005;34(7):1106-12.

Link A. N., Scott J. T. US University Research Parks. Journal of Productivity Analysis 2006;25(1):43-55.

Link A. N., Siegel D. S. Technological Change and Economic Performance. London: Routledge; 2003.

Luger M. I., Goldstein H. A. Technology in the Garden. Chapel Hill: NC, University of North Carolina Press; 1991.

McAdam M., Galbraith B., McAdam R., Humphreys P. Business Processes and Networks in University Incubators: A Review and Research Agendas. Technology Analysis & Strategic Management 2006;18(5):451-72.

Mansfield E. Basic Research and the Productivity Increase in Manufacturing. American Economic Review 1980;70(5):863-73.

Monck C. S. P., Porter R. B., Quintas P., Storey D. J., Wynarczyk P. Science Parks and the Growth of High Technology Firms. London: Croom Helm; 1988.

Nelson R. R. National Innovation Systems: A Comparative Analysis. New York: Oxford University Press; 1993.

Nelson R. R., Winter S. G. An Evolutionary Theory of Economic Change. Cambridge, MA: Harvard University Press; 1982.

Phan P., Siegel D. S. The Effectiveness of University Technology Transfer. Foundations and Trends in Entrepreneurship 2006;2(2):77-177.

Phan P., Siegel D. S., Wright M. Science Parks and Incubators: Observations, Synthesis and Future Research. Journal of Business Venturing 2005;20(2):165-82.

Phillimore J. Beyond the Linear View of Innovation in Science Park Evaluation: An Analysis of Western Australian Technology Park. Technovation 1999;19(11):673-80.

Porter M. E. Clusters and Competitiveness: Findings from the Cluster Mapping Project. 2001a. presentation at the Sloan Industry Centers' conference, Corporate Strategies for the Digital Economy, Cambridge, MA.

Porter M. E. Clusters of Innovation: Regional Foundations of US Competitiveness. Washington, DC: Council on Competitiveness; 2001b.

Rothaermel F. T., Thursby M. C. Incubator Firm Failure or Graduation? The Role of University Linkages. Research Policy 2005a;34(7):1076-90.

Rothaermel F. T., Thursby M. C. University–Incubator Firm Knowledge Flows: Assessing Their Impact on Incubator Firm Performance. Research Policy 2005b;34(3):302-20.

Shearmur R., Doloreux D. Science Parks: Actors or Reactors? Canadian Science Parks in their Urban Context. Environment and Planning 2000;32(6):1065-82.

Siegel D. S., Westhead P., Wright M. Assessing the Impact of Science Parks on Research Productivity: Exploratory Firm-level Evidence from the United Kingdom. International Journal of Industrial Organization 2003;21(9):1357-69.

Sofouli E., Vonortas N. S. S&T Parks and Business Incubators in Middle-sized Countries: The Case of Greece. Journal of Technology Transfer. forthcoming.

Sternberg R. The Impact of Innovation Centres on Small Technology-based Firms: The Example of the Federal Republic of Germany. Small Business Economics 1990;2(2):105-118.

Swann G. M. P., Prevezer M., Stout D. The Dynamics of Industrial Clustering. Oxford: Oxford University Press; 1998. Towards a Model of Clustering in High-technology Industries.

Swann G. M. P., Prevezer M., Stout D. The Dynamics of Industrial Clustering. Oxford: Oxford University Press; 1998.

UKSPA. 2003. website of the United Kingdom Science Park Association, available at http://www.ukspa.org.uk/default.asp?t=1&channel_id=2374&editorial_id=13661 and http://www.ukspa.org.uk/?channel_id=2375&editorial_id=13885.

Vaidyanathan G. Technology Parks in a Developing Country: The Case of India. Journal of Technology Transfer. forthcoming.

Vedovello C. Science Parks and University–Industry Interaction: Geographical Proximity between the Agents as a Driving Force. Technovation 1997;17(9):491-502.

Wallsten S. An Empirical Test of Geographic Knowledge Spillovers Using Geographic Information Systems and Firm-level Data. Regional Science and Urban Economics 2001;31(5):571-99.

Wessner C. A Review of the Sandia Science and Technology Park Initiative. Washington, DC: National Academy Press; 1999.

Wessner C. A Review of the New Initiatives at the NASA Ames Research Center: Summary of a Workshop. Washington, DC: National Academy Press; 2001.

Westhead P. New Owner-managed Businesses in Rural and Urban Areas in Great Britain: A Matched Pairs Comparison. Regional Studies 1995;29(4):367-80.

Westhead P. R&D “Inputs” and “Outputs” of Technology-based firms Located On and Off Science Parks. R&D Management 1997;27(1):45-61.

Westhead P., Batstone S. Independent Technology-based Firms: The Perceived Benefits of a Science Park Location. Urban Studies 1998;35(12):2197-219.

Westhead P., Cowling M. Employment Change in Independent Owner-managed High-technology Firms in Great Britain. Small Business Economics 1995;7(2):111-40.

Westhead P., Storey D. An Assessment of Firms Located On and Off Science Parks in the United Kingdom. London: HMSO; 1994.

Westhead P., Storey D. Financial Constraints on the Growth of High-technology Small Firms in the UK. Applied Financial Economics 1997;7(2):197-201.

Westhead P., Storey D., Cowling M. An Exploratory Analysis of the Factors Associated with the Survival of Independent High-technology Firms in Great Britain. In: Chittenden F., Robertson M., Marshall I. , editors. Small Firms: Partnerships for Growth. London: Paul Chapman; 1995.