US university-sponsored technology incubators: an overview of management, policies and performance

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Abstract
Despite the increased worldwide interest in the university-sponsored technology incubator (USTI) as a mechanism for supporting the development of new technology-based firms (NTBFs), there is a dearth of empirical evidence on determinants of their performance, management, and policy practices. This paper presents results from a national survey of more than 30 five-year and older American USTIs.

The study focused on a sample comprising three state university-sponsored and three private university-sponsored facilities, generally viewed as being successful. The USTI practices and performance are explored using several key dimensions: organizational design, tenant performance review, funding sources, targeted technologies, strategic operational policies, services and their value-added component, and growth of the client firms.

A comparative review of these dimensions reveals that there are no significant differences between public and private sector USTIs. This suggests that entrepreneurial university spin-offs can be successfully supported through organizational innovation and technology transfer, instrumentation and the modeling of technological development and diffusion.

1. Introduction
Historically, the mission of US universities has been education, research, and public service. However, during the past two decades there has been an emerging trend on the part of some entrepreneurial universities toward a more direct involvement in supporting new business development activities. This proactive role is generally motivated by their desire to participate in regional economic development efforts and, at the same time, encourage the commercialization of the university’s own research.

One mechanism used for this purpose is the establishment of business incubators in or around the university campuses. By 1992, more than fifty
American universities and four-year colleges had participated in this effort [2], thus redefining their missions to better serve the economic development needs of their respective constituencies. This industry has been growing at a steady rate since the early 1980s (see Fig. 1). Despite the growth in the number of USTIs, there is a paucity of information on their working and related performance [3, 4].

This article provides a preliminary review of university-sponsored incubators in the US by exploring their organization and management, policy, and performance dimensions. The study is based on six cases of USTIs, representing a population of 30 five-year and older facilities. The various USTI policy and management dimensions explored include their origins and objectives, organizational design, governance and policy guidance, tenant performance review procedures, funding sources, targeted technologies, tenant entrepreneurs’ personal traits, impact on tenant firms, strategic operational policies, services, and their value-added to the client firms. The data were collected during 1991 and updated in late 1993.

2. The existing knowledge and study framework

With the popularity of the business incubation concept, numerous studies have been conducted to assess the emerging incubator industry across the nation [5–10]. Most of these studies are primarily descriptive, lacking conceptual and/or methodological grounding. Only a handful of these studies [8, 10] were comprehensive enough to mention the role of universities in providing business incubation support. However, none of these studies specifically focused on the university-sponsored technology incubators, generally understood to provide a resource base necessary for the development of NTBEs.

From the incubation business literature reviewed, it is clear that most of the incubator-related knowledge does not have a sound theoretical base of its own and is, by and large, anecdotal in nature. Hence, our understanding of the business incubation function in general and the university-sponsored business incubation support for developing new technology-based firms in particular remains fairly rudimentary. Consequently, there is no consensus on what makes up the content of successful policies and management practices in the area of business incubation and how to improve the performance [6, 7, 9]. This is even more true in the case of USTIs [3].

The USTIs’ salient policy and business-management practices in four key functional areas (management, marketing, finance and operations) form the basis of various dimensions explored in this study. These dimensions are derived from parallel but separate incubator studies reported in the literature, and are described below [3, 12].

- Origins of facilities — to understand the USTI contextual settings, their origins, growth in physical facilities and other resources are assessed.

- Objectives — beyond the common objective of participation in the economic development, facilities articulate objectives differently, depending on their sponsors’ interests.

- Organizational design — most USTIs are physically located on or near their respective sponsoring university campuses; however, their organizational relationships with the university differ. Additionally, the state and local community involvement has to be determined.

- Governance and policy guidance — generally, all USTI facilities are run by various types of boards with varying degrees of university, state, local government and private sector representations. These boards provide overall direction.

- Tenant performance review — formal periodic (annual, biannual and quarterly) and informal tenant performance reviews are held at each of the USTIs which are assessed.

- Institutional support — various USTI programs take advantage of their respective university technology transfer programs, research centers, and technology and business development assistance centers, such as SBDC and SBIR projects which vary in their levels of activity.

- Staffing — the facilities employ varying numbers of administrative/clerical and professional staff depending upon the size and nature of each operation.

- Funding sources — the funding parameters which are explored in the respective USTIs include state funding and university support for the USTI as well as funds to support the growth of tenant firms.

- Technologies targeted — the type of technology targeted for development is generally a function of the available resources at a particular facility.

- Personal traits of tenant entrepreneurs — personal characteristics of tenant entrepreneurs such as average age, education level and initial financial contributions need to be explored.

- Strategic operational policies — the key elements of strategic considerations in operating a successful USTI facility include: tenant selection policy, tenant graduation policy, intellectual property safeguards for tenant firms, and graduate-firm USTI linkages.

- Services and their value-added — there are two main categories of service: shared rental space, including other typical shared incubator services; and the university-related services, including faculty consultants and student employees. Tenant firms’ perceived value-added by these services also needs to be determined.

- Survival and growth of tenant firms — impacts on the survival and growth of tenant firms are measured in terms of dropouts, annual sales and employment growth.

This framework captures most of the key USTI characteristics described in the literature and is able to address the major aspects of the USTI organizational, management and policy practices employed in supporting the development of NTBEs. The approach is systematic and is applicable to those USTIs which have a track record. The following sections employ this framework in analyzing selected cases.

3. Methodology and sample

This study used a multiple-case design with an embedded survey of the client firms and employed a comparative-does-on evaluation approach [13, 14]. For data collection, on-site interviews were conducted with the incubator managers and involved the faculty, and were supplemented by information obtained through mail surveys administered to the client firms of the selected USTI cases (the number of firms accessible for survey in each case is reported in Section 4.1). Out of the total of 150 client firms contacted, 47 responded to the survey (a response rate of 31%). Additionally, interviews were conducted with several incubator experts to help refine the methodology and set criteria for selecting the sample. The USTIs studied were chosen to represent programs which:

- were sponsored by a ‘major’ university in the US;

- represented both public and private university types;

- were generally viewed as successful or otherwise unique;

US university-sponsored technology incubators
were at least five years old.

The Appendix provides a list of 30 five-year and older USTIs, out of which the following six facilities were selected:

1. Technology Advancement Program, University of Maryland, MD;
2. Advanced Technology Development Center, Georgia Tech., GA;
3. The Ben Craig Center, University of North Carolina at Charlotte, NC;
4. Technology Innovation Center, Northwestern University, IL;
5. NET Ben Franklin Technology Center, Lehigh University, PA;
6. Enterprise Development Inc., Case Western Reserve University, OH.

4. Findings

Each of the six cases is assessed and compared under the aforementioned thirteen dimensions as described in this section. Table 1 and Figs. 2-4 provide a summary of the significant findings.

4.1. Origins of facilities

The Technology Advancement Program (TAP) at University of Maryland, College Park (a state university) was established in September 1984. TAP rents its 15 700 square feet (1460 m²) space to a select group of 5 to 19 tenants at a rate of $7.50 per square foot, which is about 30% less than the market rate. TAP's program growth and facilities such as new buildings, number of staff, additional services and new programs have been moderate during the past six years. Accordingly, it received an enhanced state grant, resulting in increased operational budget and more clients served. All of TAP’s current 15 tenants and 10 graduates were accessible for the client firm survey.

The Advanced Technology Development Center (ATDC) at Georgia Institute of Technology (a state university) is the oldest of the six facilities studied and was established in 1980. It rents 83 000 square feet (7700 m²) space at its main facility on Georgia Tech campus, at a rate of $9.50 per square foot, which is more than 30% cheaper than the market rate. ATDC program’s growth has been substantial during the more than ten years of its operation. This includes the addition of two new branches, with additional personnel and client firms, made possible by additional state grants. According to the ATDC management, the facility has 41 clients and 24 graduate firms; however, only 20 tenants and 17 graduates were made accessible and were included in the survey. This may be explained by the fact that some clients are not tenants, and a large number of graduates were not accessible for various reasons.

The Ben Craig Center (BCC) at University of North Carolina at Charlotte (a state university) was established in March 1986. The BCC’s 87 000 square feet (8080 m²) rentable space at its newly built facility is available at $10.50 per square foot, which is slightly higher (0-15%) than the market rate. Due to this recent growth in rentable space the management has been soliciting tenants to fill the empty space, at the same time trying to keep to the entry policy guidelines (discussed in Section 4.11). All the 16 tenants and 3 out of 6 graduate firms were included in the client's surveys.

The Technology Innovation Center (TIC) at Northwestern University (a private university) started its operation in June 1986. TIC rents its 33 000 square feet (3070 m²) of rentable space at its new facility at a rate of $14.75 per square foot, which is market competitive. TIC program growth has been relatively high; for example, the recent 1990 expansion has more than doubled its physical facilities and accordingly more services and new programs have been added. All of the center’s 25 tenants and 6 graduate firms were included in the client firm survey.

North East Tier of the Ben Franklin Technology Center (BFTC) at Lehigh University (a private university) was established in May 1983. The center rents 21 900 square feet (2040 m²) of its currently available space in four different buildings. The rental rates vary from $5.00 to $15.00 per square foot, depending upon the type of customer and the quality of space. These rates are very much less (more than 30%) than the market rate, as reported by the management and confirmed by 75% of the clients responding to the firm survey. During the more than seven years of its operation the facility has experienced relatively moderate growth in its physical facilities and services. All of BFTC’s 15 tenants and 14 graduates were included in the client firm survey.

Enterprise Development Inc.’s (EDI’s) Edison Technology Incubator at Case Western Reserve University (a private university) started working in March 1984. The facility rents 13 000 square feet (1210 m²) of its space in its multistory building.

TABLE 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>TAP-Maryland U.</th>
<th>ATDC-Georgia Tech</th>
<th>Ben Craig N. Carolina</th>
<th>TIC-Northeastern U.</th>
<th>BFTC-Lehigh U.</th>
<th>EDI-Cas Western</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) Objectives</td>
<td>state’s aim: dev. tech. transfer; no. den.</td>
<td>state’s aim: dev. tech. transfer; no.</td>
<td>state’s aim: dev. tech. transfer; no.</td>
<td>state’s aim: dev. tech. transfer; no.</td>
<td>state’s aim: dev. tech. transfer; no.</td>
<td>state’s aim: dev. tech. transfer; no.</td>
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<tr>
<td>(3) Organizational design</td>
<td>separable units</td>
<td>separable units</td>
<td>separable units</td>
<td>separable units</td>
<td>separable units</td>
<td>separable units</td>
</tr>
<tr>
<td>(4) Governance and policy guidance</td>
<td>12-member board of directors</td>
<td>National Advisory Board</td>
<td>12-member Board of Directors</td>
<td>12-member Board of Directors</td>
<td>12-member Board of Directors</td>
<td>12-member Board of Directors</td>
</tr>
<tr>
<td>(5) Funding sources</td>
<td>state share 20% of operational expenses</td>
<td>state share 20% of operational expenses</td>
<td>state share 20% of operational expenses</td>
<td>state share 20% of operational expenses</td>
<td>state share 20% of operational expenses</td>
<td>state share 20% of operational expenses</td>
</tr>
<tr>
<td>(6) Technologies served</td>
<td>biotech/medical electronics/robotics</td>
<td>biotech/medical electronics/robotics</td>
<td>biotech/medical electronics/robotics</td>
<td>biotech/medical electronics/robotics</td>
<td>biotech/medical electronics/robotics</td>
<td>biotech/medical electronics/robotics</td>
</tr>
<tr>
<td>(7) Strategic operational policies</td>
<td>strict entry, exit + 3 to 4 yrs. stay; equity up to 5%</td>
<td>strict entry, exit + 3 to 4 yrs. stay; equity up to 5%</td>
<td>strict entry, exit + 3 to 4 yrs. stay; equity up to 5%</td>
<td>strict entry, exit + 3 to 4 yrs. stay; equity up to 5%</td>
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on the university campus. The rental rate varies from $4.50 to $12.50 per square foot, depending upon the type of customer and the quality of space. Though the management believes that the rents are better than the market, the client firm respondents are split in their assessments, with half responding that there are no rental breaks and the other half reporting rental breaks from 15 to 30%. The EDI program's growth in facilities and new programs has been relatively slow to moderate during the past six years of its history; therefore, only a handful of select tenants have been served. All of the 7 tenants and 4 graduates were included in the client firm survey.

4.2 Objectives

The objectives set forth by the above six USTIs have a number of common features. Examination of these objectives shows that participation in economic development activities for supporting the development of NTBFs was the overarching common objective. Also, technology transfer and commercialization of university research were another set of objectives which were commonly articulated by most of the facilities. Providing a laboratory for the development of entrepreneurial skills among aspiring students and faculty was also emphasized to a varying degree by all of the six facilities studied. The other less commonly mentioned objectives included: reaping long-term financial benefits for the sponsoring university, achieving economic self-reliance, capturing small business development activity for the neighboring research park, or helping small businesses from various government funding programs, and supporting the development of manufacturing firms.

4.3 Organizational design

All of the six facilities are somewhat different in terms of their organizational design. Though all are physically located on their respective sponsoring university campuses, the organizational relationships with the university differ. There are two main types of organizational design.

The first type is closely linked with the respective university, which can include TAP, ATDC, and initially TIC. The facility is either part of the university's particular school or department (as in the case of TAP) or an independent department-like entity (as in the case of ATDC, and previously TIC). Therefore, these USTIs are virtually organizational components of their respective universities, for which the latter generally feel responsible. They are maintained like a special program of studies within the university which ensures the flow of funds, predominantly obtained from the respective states. Consequently, their dependence on the sponsoring university is heavy, with resultant direct influence on their policies. It is interesting to note that both University of Maryland (TAP's sponsor) and Georgia Tech (ATDC's sponsor) are land-grant institutions.

The second type of USTI consists of stand-alone non-profit entities such as BCC, BFTC, EDI and now TIC. They were established by the universities but now rely on heavy private and local funds provided by some of the major private sector interests in their respective communities. An arms-length relationship exists between these USTIs and the university. The university does provide necessary oversight and emergency financial and in-kind support, guaranteeing operational success.

4.4 Governance and policy guidance

A close comparison among the six facilities revealed a heavy involvement of the private sector with university representation at five out of the six sites. Only ATDC had a national advisory committee which provided broad policy guidance, but this committee is no longer active. An alternate to seeking this broad policy guidance was present at BFTC in the form of a large 77-member Ben Franklin advisory board, comprising business and community leaders from throughout the state. Similar state-wide arrangements were found at BCC, EDI and TAP. TIC's advisory oversight is provided by the host city's business community with the help of the university management.

The involvement of area business leaders has helped BFTC, TIC, EDI and even BCC not only by giving advice on policy but also by providing substantial private funds. On the other hand, although facilities such as TAP and ATDC were able to involve the private sector in policy guidance, they depended heavily on state funds.

4.5 Tenant performance review

Formal periodic (annual, biannual and quarterly) reviews are held at TAP, ATDC, BCC and BFTC. At TIC and EDI tenant reviews are informal, carried out by the incubator manager or director on a one-to-one basis which includes indirect evaluations made by obtaining feedback from other in-house sources providing funds to the firms. More formal tenant evaluation procedures helped the management at TAP, ATDC and BFTC keep a sense of purpose for their facilities as well as the client firms. The less formal evaluations at TIC, BCC and EDI kept the clients' attention away from striving for short-term financial gains. In general, the tenant evaluations provided the necessary expert feedback for improved performance.

4.6 Institutional support

All six programs take advantage of their respective university technology transfer programs, technology and business development assistance centers, and the SBIR projects which vary in their levels of activity. Two of the land-grant institutions, University of Maryland and Georgia Tech, have technology/industrial extension services which provide the necessary technology transfer environments. Both Georgia Tech and Northwestern University have established industrial research institutes and industrial research laboratories for contractual applied research purposes. For as certain specialized areas, Northwestern University and Case Western Reserve University both have biotechnology centers.

Georgia Tech has an Information Technology Center. Only BCC at University of North Carolina at Charlotte has a focused international program to help develop foreign businesses in the US.

4.7 Staffing

ATDC has the most extensive staffing, with two officers, three professionals, and seven others including administrative assistants and workers. Second to this is BCC with one officer, four professionals and three other administrative assistance staff. The remaining four USTIs (TAP, TIC, BFTC and EDI) have lesser staff consisting of a manager/director, program coordinator/administrative assistant, and one or two secretaries. When compared in terms of the number of tenants in each facility, TIC and BFTC have more tenants per staff than the other USTIs.

4.8 Funding sources

All six programs studied have benefited from state grants in one form or another. TAP draws about half of its operational budget from the state; ATDC has even more dependence on state dollars; both appear in the form of a line-item in the university budget. Both BCC and TIC have received lump-sum state grants on different occasions. In the cases of BFTC and EDI, states helped to maintain these non-profit entities, with major shares coming from the local private sector, and with participation (generally, in the form of in-kind support) from the host university in terms of the university's financial help, with the exception of ATDC and TAP (which were set up by the state funds) all the other facilities have received some kind of initial university funding and/or in-kind support in the form of staff salaries, buildings, and their maintenance and utilities. However, aside from TAP and to some extent ATDC, the remaining four have evolved arms-length relationships with the sponsoring universities. These relationships also influenced funding decisions in the sense that they became less dependent on direct university support.

All the six facilities helped their tenants in seeking funds from public and private sources.
Providing information and professional help in competing for SBIR grants was common. Private venture capital and seed financing support were also available, but with varying degrees of ease; for example, ATDC with its Georgia Capital Network, TIC and BFTC had software and/or information technology firms dominating (in number) as clients. In the case of TAP, it was biotechnology and/or medical technology firms, and at EDI it was instrumentation firms which were the dominant clients (in number). A total inventory of the clients surveyed in all six facilities is ranked in terms of the firms' relative numbers as below:

1. Software/information technology
2. Biotechnology/medical
3. Electronic/telecommunication
4. Instrumentation
5. Telecommunications
6. Specialty chemicals
7. Materials
8. Robotics/automation
9. Food/nutrition
10. Energy/environmental
11. Aerospace
12. Photonics/optics

4.9. Technologies targeted

Four out of the six facilities — ATDC, BCC, TIC and BFTC — had software and/or information technology firms dominating (in number) as clients. In the case of TAP, it was biotechnology and/or medical technology firms, and at EDI it was instrumentation firms which were the dominant clients (in number). A total inventory of the clients surveyed in all six facilities is ranked in terms of the firms' relative numbers as below:

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4.10. Personal traits of the entrepreneurs

The average age of the entrepreneurs surveyed showed a typical entrepreneur as a mature young person (average age 40 years). The age varied from 36 to 47 years, with the youngest at ATDC (36 years) and the oldest at TIC (47 years). A review of the entrepreneurs' educational backgrounds showed that a large number of them had attended college or university, with the lowest at TAP (90%) and the highest at EDI (100%). The average initial financial contribution of the individual entrepreneur varied from $900 to BCC to $134,000 at TAP (with a facility-wide average of $41,050).

4.11. Strategic operational policies

Selection policy: in all six USTI cases studied, tenant selection (or entry) policies were quite elaborate. The various salient entry policy elements with the facilities espousing them are given below:

1. Technology-based startup — all 6 USTIs.
2. Firms with high growth potential — all 6 USTIs.
3. Strategic business plan developed — TAP, ATDC, BFTC, EDI.
4. Qualified management team — TAP, ATDC.
5. Commercializable product/process/service — TAP, ATDC, TIC, EDI.
6. Existing cash flow stream — BCC only.
7. Manufacturing firm preference — BCC, BFTC.
8. Ability to pay the rent — TIC, TAP.
9. Fit with the university resources/mission — TAP, TIC, BFTC.
10. Inventor's commitment — TAP, ATDC, TIC.

For only elements 1 and 2 (technology-based startup and firms with high growth potential) do all six facilities concur. The next ranking key elements, stated by four out of six facilities, are, respectively, element 3 (the presence of a strategic business plan) and element 5 (commercializable product/process/service).

Graduation policy: similarly, tenant graduation (or exit) policies were spelled out in all the six cases, with or without a predetermined incubation period. A period of three years seemed to be the norm, while, practically, it had been kept flexible (depending upon the need) in all the facilities studied. At BCC and BFTC, the incubation period was negotiated and/or planned with the client firms at the time of entry. BCC raised the rent (at the rate of $2 per square foot per year) after this agreed-upon period was expired. At EDI, an extension beyond two years required approval by a special committee. ATDC had an elaborate exit criterion in terms of levels of achievement in one or more of the following: sales and employees, space need, acquisition by a larger corporation, three to four products, venture capital obtained, and self-sufficiency in professional services.

Client firms suggested two to five years of flexible incubation periods; also suggested were a few proposals of tying the incubation period to the growth and space needs of the client firm.

Intelectual property safeguards: intellectual property safeguards for the client firms are generally available in the form of an unspoken trust between the incubator management and the client firm. At ATDC, incubator management is willing to sign a non-disclosure agreement on demand. At BFTC the Incubator Manager has signed an agreement with its management, at the time of accepting the job, for protecting clients' proprietary information.

Most of the responding clients expressed no concern about any violation of their intellectual property rights at the hands of the incubator management. Therefore, they did not express a need for a formal written policy.

Equity or royalty policies: these policies varied considerably from facility to facility. Generally, the states discourage holding equity and use their grant money as leverage. Royalties are not held by any of the facilities included in the study; however, those using university technology or incubator-sponsored financial grants could obtain professional help to work out such deals. At EDI, a long-term success fee was included in only one case but was not made a common practice. Similarly, at TAP, equity of up to 5% was held in a few client firms.

Graduate firm—USTI linkage: linkages between graduate firms and USTIs have not been given much attention, and no formal policies had been developed in this regard. The graduate firms were generally encouraged by the USTIs to stay in contact. Often, they enjoyed the use of certain facilities on an 'as available' basis, and in some cases a service fee was also charged. The graduates were expected to pay back in the form of some help through involvement with the new client firms.

Facilities such as BCC and TIC, which are close to or part of the university-affiliated research parks, allowed their tenants to move on to the parks and keep using most of the services. In the other hand, facilities such as EDI which did not possess such an arrangement felt the need to build a research park. No such need was explicitly mentioned at BFTC, ATDC and TAP. However, some clients at TAP expressed a desire to stay close to the facility and continue using the services even after graduating.

4.12. Services and their value-added

The typical incubator services such as shared rental space, shared office services, business assistance, inside and outside networking, etc., were provided by all of the six facilities. Business-consulting services were available but with varying arrangements. At ATDC, business and management consulting was provided by in-house consultants, while at BCC, TIC, BFTC and EDI the services were available through resident private firms. No such formal arrangement was reported at TAP, where the incubator director/manager and staff themselves seemed to have assisted tenant entrepreneurs in their business and management problems.
Most of the university-related services were available at all six facilities. Employing aggregated case-wide data, Fig. 2 shows the tenants' reported use and perceived value-added of the ten university-related services provided. The use of student labor pool, faculty consultants, library and information database facilities, and research laboratories and workshops, were reported by more than 50% of the respondents. Similarly, more than 80% of the respondents valued university image conveyance. Additionally, the figure shows that there is a high correlation between the use of most of the university-related services and their perceived value-added.

While most of the typical incubator services and university-related services were provided at each of the six facilities, their modes of delivery differed. There is insufficient data to suggest that any one of the modes is better than the other. They all suited the needs of the individual USTI.

4.13. Survival and growth of tenant firms

Among the changes considered in the tenant firms' characteristics during incubation periods are sales and employment, which show growth trends during the period of 1986-90 (see Figs. 3 and 4). As shown, sales growth varied from an average of 45% per year at TAP to an average of 400% per year at EDI (average of all the six facilities was 166% per year, N = 32). Similarly, the employment growth varied from an average of 11% per year at TAP to an average of 79% per year at TIC (average of all the six facilities was 49% per year, N = 33).

In relative terms, TAP (with 45% sales and 11% employment growth) seems to be the least effective and EDI (with 400% sales and 77% employment growth) the most effective USTI in helping the client firms grow. It may be noted here that TAP supports a larger number of relatively smaller tenants (15 tenants occupying 837 square feet [78 sq m] per tenant) and EDI supports fewer but larger tenants (? tenants occupying 1857 square feet [174 sq m] per tenant). The remaining USTIs fall between these two extremes. This means that USTIs in general have a positive impact on their client firms' growth, when measured in terms of sales and employment. No data on tenant dropouts was available for analysis.

5. Discussion

The above six case studies provide an exploratory analysis and comparison of the six most unique USTI programs in the country. The general finding that there appear to be no significant differences based on the type of university sponsorship — private such as Northwestern, Lehigh, or Case Western Reserve, and public such as Maryland, Georgia Tech, or University of North Carolina at Charlotte — is somewhat unexpected. This appears to suggest that, in the US, USTIs are deriving equally from the state and private sectors irrespective of who takes the initiative. It seems that across the board, state or local government funds, along with the university's resources, are being used to leverage private funds and involvement, creating a sense of partnership among these sectors.

It is interesting to note that, in terms of articulated objectives, there also appear no clear distinctions between the types of sponsorship. However, the fact that TIC has emphasized university technology transfer more than ATDC in the past and that TIC (associated with a research park) intends to break even is revealing. It is obvious that most state universities are primarily driven by the need for regional economic development, and that the need for self-reliance through synergy is perhaps driving the desire for an incubator-research park joint project in some private universities.

It is also noteworthy that facilities such as TAP and ATDC, which are heavily subsidized by their states, do not seem motivated to strive for a break-even operation. Only the TIC's management, and to a lesser degree the BCC's management, expressed their resolve to work for a break-even in the long run. Both TIC and BCC charge competitive rents from their tenants and are seen as less restrictive in their entry policies. This may be explained by the fact that their managers/directors may have an entrepreneurial management style. Another plausible explanation may be that the remaining USTIs (TAP, ATDC, BFTC and EDI) do not want to lower the quality of their services (and hence value-added), even if they have to continue receiving subsidies. They may contend that, by charging market-level rents and allowing entry to new tenants on the basis of their ability to pay rents, their mission of allowing only the desired technology-based firms will be violated. This conclusion is supported by the more stringent entry policies listed by these USTIs in comparison with the remaining two (TIC, BCC).

Flexibility in the implementation of tenant selection and graduation policies, especially when excess rental space is available (such as at BCC and TIC due to the addition of new buildings), supports the previous research findings [17]. This appears to suggest that there may be a trade-off between stringency in the application of the tenant selection and other policies and hence value-added through the provision of the ensuing services, and the ability to break even. The finding that client firms generally trusted the USTI management in providing intellectual property safeguards seems contrary to commonly held beliefs. It appears that the clients either had other arrangements to protect their technology or did not consider it necessary at this early unproven stage.

As expected, the new and emerging technologies such as information and software technology, electronics and biotechnology dominated all of the six facilities. Similarly, the average age and educational level of USTI tenants appear to be higher than those of small business entrepreneurs in the US [16]. Findings on tenant firms' performance suggest that the USTI appear to have a positive impact on their client firms' survival and growth as measured in terms of jobs and sales, which is significant. The USTIs' degree of financial self-reliance is yet to be realized, and active faculty participation in an entrepreneur and/or consultants seems a distant reality. Practically, the relations between the USTI and the sponsoring university's faculty and students were reported as evolving at the facilities studied. During the past decade, all of the universities involved had been in the process of developing policies to address a number of the issues relating to the faculty, such as intellectual property rights and problems in conflict of interest. But most of the problems occur at a more mundane level, such as maintenance of teaching loads, possible impact on tenure, and balancing the workloads. No serious attempt has been undertaken to address these issues.

While this research provided several new insights into USTIs, numerous questions remain. The study is based on comparisons between six selected USTI programs, using mostly self-report data
that were directly or indirectly collected by the investigator. Additionally, there is no way of determining to what extent the presence of the USTI could be more effective (for an entrepreneur) than its absence. In spite of these methodological limitations, these findings present an intriguing and, to a large extent, favorable picture of the USTI concept. This combines prior fragmented beliefs suggesting that incubators play an important role in the founding of growth-oriented firms [17]; the university is seen as (providing) an environment for spin-off firms [18, 19]; and the research university provides a resource-base for (developing) advanced-technology firms [8].

6. Conclusion and recommendations

The above case analyses and their comparison show that USTI are providing the necessary resource base and environment conducive to the development of NTFPs. It concludes that, despite their unique origins and types of sponsorship, successful university-sponsored technology incubator programs in the US have certain elements in common. These elements range from the origins and objectives, various policies and management practices, and services and their value-added, to less tangible elements such as the different performance outcomes. Taken together, such elements represent a checklist of issues that should be attended to by those seeking to establish a new USTI program or to evaluate an existing one.

It is recommended that universities must build their technology incubator programs by setting reasonable objectives, following policies and management practices that will encourage tangible results consistent with the new mission requirements of an entrepreneurial university.

More informal assessments suggest that, for USTI to ultimately prove to be a successful tool, the degree of faculty involvement must be increased through tangible incentives. Additionally, the development of a joint university-sponsored incubator and research park project seems to offer several potential benefits, including breaking even and greater synergy. These two areas need further research.

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Notes

1 The Small Business Development Centers (SBDCs) are set up by the US Small Business Administration. The SBDCs provide technical and management assistance to small businesses. The Small Business Innovation Research (SBIR) program is another US Federal Government initiative which is intended to address the Government's scientific R&D needs. The SBIR program is a three-phase process through which eligible small businesses receive funds on a competitive basis.

2 Client firms include both tenant firms and graduate firms.

3 Land-grant institutions are American colleges and universities initially given federal aid in the 1860s, especially by land grants, to promote agricultural and mechanical arts; they are now supported by the individual states, with supplementary federal funds.

References


### Interindustry flows of technology: an analysis of the Canadian patent matrix and input–output matrix for 1978–1989

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**Abstract**  
The author suggests that innovative development for one industry may have much wider applications in other industries, not necessarily related to the industry for which the innovation was developed. The mapping of interindustry flows of new technology greatly assists our understanding of technological change and its resultant economic impact. Policy decisions with regard to the funding of research and development are of importance once it is realized that the decisions may not be based on the industry which gains the most benefit from the innovation. The objectives of the paper are twofold:

1. To develop a model of interindustry technology flows based on Canadian industry between 1978 and 1989, to identify both sources and users of new technology and to examine their evolution over time.
2. To explore whether or not the rate of change in technology flows can be correlated with the rate of change in input–output flows of goods.

Taking into account the interindustry flows increases our understanding of the sources of information for innovation and its diffusion, and also the effects of technological change on productivity. The author mainly explores the relationship between changes over time in the technology matrix and the input–output matrix which includes an empirical test. It is suggested that the wealth of information from technology flow matrices indicates that these could become an important analytical tool for the study of technological change.

#### 1. Introduction

The history of innovations shows that often the idea of a new or improved product or process originated with suppliers or customers rather than in the industry that eventually uses the new production process or manufactures the new product. While some new products are sold directly to consumers, many more are intermediary inputs used by other industries. When the new technology

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**APPENDIX: List of five years and older US university-sponsored technology incubators**

<table>
<thead>
<tr>
<th>Incubator</th>
<th>Sponsoring university</th>
<th>Year of start</th>
<th>No. of tenants</th>
<th>Type of clients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. University City Science Center</td>
<td>Naval Research</td>
<td>1964</td>
<td>35</td>
<td>high tech, R&amp;D, service, etc.</td>
</tr>
<tr>
<td>5. Advanced Tech. Development Center</td>
<td>Georgia Institute of Technology (public)</td>
<td>1980</td>
<td>41</td>
<td>high tech, light manuf.</td>
</tr>
<tr>
<td>6. Metropolitan Center for High Tech. Dev., Inc.</td>
<td>Wayne State Univ. (public)</td>
<td>1983</td>
<td>52</td>
<td>high tech, R&amp;D</td>
</tr>
<tr>
<td>8. Western NY Tech. Dev. Center</td>
<td>NY University at Buffalo (public)</td>
<td>1983</td>
<td>7</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>10. NIST Entrepreneur Tech. Center</td>
<td>Lehigh University (public)</td>
<td>1983</td>
<td>12</td>
<td>high tech, R&amp;D, light manuf.</td>
</tr>
<tr>
<td>11. Science Park, New Haven, CT</td>
<td>Yale University (public)</td>
<td>1983</td>
<td>185</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>12. Technology Innovation Center, Iowa City, IA</td>
<td>University of Iowa (public)</td>
<td>1984</td>
<td>9</td>
<td>high tech, R&amp;D, light manuf.</td>
</tr>
<tr>
<td>13. Tech Achievement Program, College Park, MD</td>
<td>University of Maryland (public)</td>
<td>1984</td>
<td>19</td>
<td>high tech, R&amp;D, light manuf.</td>
</tr>
<tr>
<td>15. Business Technology Center, Columbus, OH</td>
<td>Ohio State University (public)</td>
<td>1984</td>
<td>N/A</td>
<td>high tech, R&amp;D</td>
</tr>
<tr>
<td>16. EIO’s Eidos Technology Incubator, Cleveland, OH</td>
<td>Case Western Reserve University (public)</td>
<td>1985</td>
<td>7</td>
<td>high tech, R&amp;D</td>
</tr>
<tr>
<td>17. The Res. Corp, Charleston, SC</td>
<td>Univ. of South Carolina (public)</td>
<td>1985</td>
<td>14</td>
<td>high tech, R&amp;D, light manuf.</td>
</tr>
<tr>
<td>19. Progress Center, Abakan, FL</td>
<td>University of Florida (public)</td>
<td>1983</td>
<td>21</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>20. Penn State Tech. Dev. Center, Altoona, PA</td>
<td>Penn State University (public)</td>
<td>1983</td>
<td>47</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>21. Center for Bio Innovation, Kansas City, MO</td>
<td>University of Kansas City, MO (public)</td>
<td>1983</td>
<td>20</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>22. New Mexico Bio. Innovation Center, Albuquerque, NM</td>
<td>University of New Mexico (public)</td>
<td>1983</td>
<td>12</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>23. Innovex Inc., LaFayette, IN</td>
<td>Purdue University (public)</td>
<td>1986</td>
<td>N/A</td>
<td>high tech, R&amp;D</td>
</tr>
<tr>
<td>24. London Technology Center, Inc., CA</td>
<td>Bradley University (public)</td>
<td>1986</td>
<td>18</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>25. Iowa State Univ. System, Ames, IA</td>
<td>Iowa State University (public)</td>
<td>1986</td>
<td>16</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>27. North Carolina State Univ.</td>
<td>University of Tennessee (public)</td>
<td>1986</td>
<td>10</td>
<td>high tech, R&amp;D, service</td>
</tr>
<tr>
<td>28. Technology Innovation Center, Indianapolis, IN</td>
<td>University of Alabama (public)</td>
<td>1986</td>
<td>25</td>
<td>high tech, R&amp;D, service</td>
</tr>
</tbody>
</table>

*Arranged in ascending order of the year of establishment.*