Noname manuscript No.
(will be inserted by the editor)

The growth of commercialization - facilitating organizations and practices: A Schumpeterian perspective

Sten Thore[1], **Robert Ronstadt**[2]

[1] The IC^2 Institute, The University of Texas at Austin, 2815 San Gabriel, Austin, Tx 78705 (e-mail: thore@mail.telepac.pt)
[2] The Technology Commercialization Institute, The University of Boston, Mass., (e-mail: ronstadt@bu.edu)

Abstract During the long economic upswing of the 1980s and 1990s, the successful commercialization of new technology went together with the appearance of new financial vehicles, new organizational forms, and new practices promoting and mediating the transfer of the new technology from lab to market. They included business incubators, technology parks, venture capitalist firms, operators specializing in mergers and acquisitions, venture funds, and initial public offerings in the stock market. Commercialization-facilitating organizations and practices like these (here called "commercialization facilitators") are themselves born by dynamic processes in a capitalist economy that can be analyzed in Schumpeterian terms. We discuss at some length a unique university-based institution that has an impressive track record of creating and operating new facilitating models: the IC^2 Institute (Innovation, Creativity and Capital) of the University of Texas. During a twenty-five year period, IC^2 came to be instrumental in the conversion of the local economy to the high tech age. The Institute's activities span the range of the technology transfer and commercialization process, from the development and dissemination of new knowledge to the actual running of business incubators. We identify the IC^2 Institute as a "second order" facilitator and discuss its possible global evolution into a "third order" facilitator.

Key words commercialization facilitators – commercialization infrastructure – research to wealth continuum

Correspondence to: Sten A. Thore, post box 1284, 8400 Carvoeiro, Portugal

1 Introduction

During the long economic upswing of the 1980s and 1990s, the successful commercialization of new technology went together with the appearance of new financial vehicles, new organizational forms and new practices promoting and mediating the transfer of the new technology from lab to market. They included business incubators, technology parks, venture capital firms, operators specializing in mergers and acquisitions, venture funds, and initial public offerings (IPOs) on the stock market. Commercialization-facilitating organizations and practices such as these (here called "commercialization facilitators") are themselves born by the favorable commercial conditions during a prolonged business boom; at the same time, they sustain and reinforce the regional impacts of the boom. In the scramble to convert the progress of basic research and new knowledge into new products, commercialization facilitators promote and speed up the transfer of new technology from the (academic, government, or commercial) laboratory to its successful introduction in the market.

A crucial aspect of Schumpeter's understanding of the business boom was the accumulation of new and as yet unrealized technological opportunities during the preceding downturn, and the cascading of innovations during the upswing. During the boom years of the 1990s, this clustering of innovations was reinforced in most regions by the appearance and operation of powerful commercialization facilitators.

Section 2 below identifies a list of model types of commercialization facilitators and discusses their characteristic modes of operation. Each facilitator typically addresses the needs of some particular group of potential entrepreneurs (located in some geographical region, or in some particular industry, such as the software industry) at some particular time during the life cycle of a new company (during the initial research phase, during test marketing, after the first round of equity financing etc.). Some facilitators promote the creation of "technoports" or high tech regions that harness powerful positive externalities spurring the growth of new technology and new companies.

Commercialization facilitators are instances of economic institutions and as such would never attract the attention of main-line economic theory. Recently, however, several authors have argued for the need to bring institutions into evolutionary growth theory, among them R.R. Nelson (Nelson, 2002). Distinguishing between "physical technologies" and "social technologies," Nelson calls for an understanding of the growth of social technologies during the evolutionary process. Others have pointed at the role of the knowledge-intensive service industry in fuelling the high technology boom. Indeed, business incubators and venture capitalists all offer knowledge-intensive business services[1] to their tenants and clients. As we see things, a novel *commercialization infrastructure* is gradually being put in place in

[1] So-called "KIBS," see Lundvall and Borrás (1997).

the modern high tech economy. This infrastructure features a new kind of economic agent – commercialization facilitators.

Wynarczyk and Wynarczyk (2002), discuss the operations of the European Business and Innovation Centers (BICs) in economically less favored regions and find their rationale in the efforts of Schumpeterian entrepreneurs to break the circular flow and inertia of established practice.[2] Our own work aims further, demonstrating that new commercialization infrastructure can spearhead high-tech innovative growth and the construction of the future technopolis.

The commercialization facilitators, in their turn, are spawned, established and grown through dynamic processes in a capitalist economy. We argue in Section 3 that the growth of commercialization facilitators should be seen as endogenous to the business cycle. The founding of new facilitators and their operations responds, like all entrepreneurship, to opportunities and favorable conditions. Indeed, it is helpful to understand the emergence of new commercialization facilitators in terms of "institutional innovation" or the development of new "institutional technology". Just as Joseph Schumpeter saw industrial innovations wax and wane in an endogenous interplay over the business cycle, we shall propose a cyclic format where industrial evolution and institutional evolution are coupled together and reinforce each other. Successful commercialization facilitators spur the growth of industry; and also evolve in response to the needs of the market.

Section 4 turns to the empirical record. We discuss a unique university-based institution with an impressive track record of creating and operating new facilitators: the IC^2 Institute (Innovation, Creativity and Capital) of the University of Texas. During a twenty-five year period, IC^2 came to be instrumental in the conversion of the Austin economy to the high tech age. The Institute's activities span the range of the technology transfer and commercialization process, from the development and dissemination of new knowledge to the actual running of business incubators.

Section 5 synthesizes and concludes by returning to the long-run perspective and the evolution of capitalism and entrepreneurship itself. Rather than being dominated by gradually larger corporations run by large management teams relying on automated decision-making and making routine investment decisions (as Joseph Schumpeter presumed), the capitalist economy has become invigorated by large numbers of small-scale entrepreneurs generating and commercializing new advanced technology. We believe that the growth of commercialization facilitators is an important part of this revival of the age of the entrepreneur. As new commercialization-facilitating organizations and practices continue to evolve, the scope of entrepreneurship and the pace of economic growth will be speeded up even further.

[2] For further comments on the BIC program, see Section 2 below.

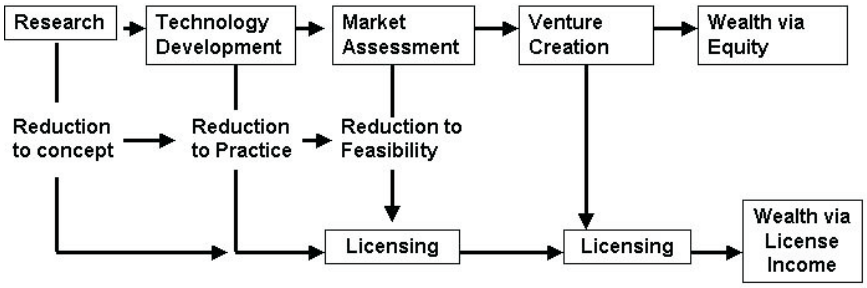

Fig. 1 The Knowledge-to-Wealth Continuum

2 A catalogue of commercialization facilitators

The commercialization of new technology converts basic and applied knowledge into economic values: sales, revenues, profit, and enhanced market capitalization of the innovating firm. Figure 1 illustrates the knowledge-to-wealth continuum extending from research via venture creation and/or licensing to the creation of new wealth.

The commercialization facilitator occupies an intermediate position in this continuum, promoting and assisting the development and commercialization of new products or processes at one or several subsequent steps.

The commercialization of new products and new technologies can be promoted, facilitated and accelerated in many ways. Some well-known *institutions* and some evolving *institutional developments* are listed below.

- *The business incubator.* Incubators can be operated on a "for profit" or "non-profit" basis by local governments, academic institutions, or private businesses. To incubate means to maintain controlled conditions favorable for hatching or developing. The incubator houses and aids start-up companies. It provides manufacturing and office space and other amenities; it may offer secretarial support, computer services and management consulting services. It may physically house start-ups or only offer services (called "incubation without walls"). Hopefully, after a few years, the tenants at the incubator will "graduate," moving out from the incubator and making it on their own.
- *The venture capital firm.* The venture capital industry specializes in high-risk equity investments. It invests equity money in fledgling companies that it takes under its wings. Many venture capitalists (or venture capital companies, as the case many be) center their attention on emerging high technology corporations whose expansion is restricted by lack of equity capital. With few assets and without proven cash flows, such corporations are often unable to raise capital from conventional sources
- *Venture capital funds and limited venture capital partnerships* that private individuals can buy into. A partnership has a general partner, usually the venture capitalist's investment firm, which acts as manager.

The limited partners – the investors – are passive. During the 1980s, investors poured more than $100 million into partnerships that put the money into investments such as apartment and office buildings, airplane leasing, oil wells and able television. But as many of these investments went sour, so did the partnerships.

– *The technology park and the "technopolis"* (the techno-port or the techno-city). The first technopolis was Silicon Valley. In the formative years, the proximity to Stanford University was important. The University had started a research park, – the Stanford Industrial Park – and Hewlett-Packard was among the first firms to locate there. There arose in the Valley at an early point the required infrastructure: suppliers, markets, and financiers. The technopolis feeds on the development of new technology – a continuous flow of new products and new designs that leave the laboratories and enter the marketplace.

We also list some important commercialization-facilitating *procedures or practices.*

– *Strategic alliances.* U.S. corporations have entered into thousands of research coalitions with other partners, both domestic and foreign. By pooling their resources of research and product development, two corporations can create a temporary match powerful enough to unlock the next step in the accelerating technological race.
– *Mergers and acquisitions.* One of the most important sources of venture funds is tapped when an existing company buys a minority stake in a start-up company. Large companies often have particular strengths in marketing, distributing and selling, as well as sources capital. Their weaknesses are apt to be innovation and speed in getting new products to market. The intuitive reaction of the manager of a large company, looking for specialized technologies that are not available in-house, would be to find a company in the marketplace that has what is needed, and to buy it. The wise move may not necessarily be to buy it outright – it may be smarter to acquire only a minority holding to make sure that the existing creative management team stays in place.
– *IPOs (Initial public offerings)* in the stock market offer an opportunity to the common investor to participate in the launching of new ventures and new technologies. The issuer of the stock may be a successful startup that has reached a critical point in its expansion, needing an additional injection of equity capital. Or, a large corporation may decide to *spin off* a separate entity, charged with developing existing or new technology under a new aegis. (Example: AT&T spinning off Lucent Technologies). Many recent IPOs in information technology and on the Internet (so-called dot-com companies) are startups still encumbered by heavy past and present development costs. Their sales and earnings may be growing, but there is still a long way to go before the IPO reaches positive profits. – Finally, the IPO may be a pure research venture, such as in biotechnology. It may yet be too early to say whether the research will

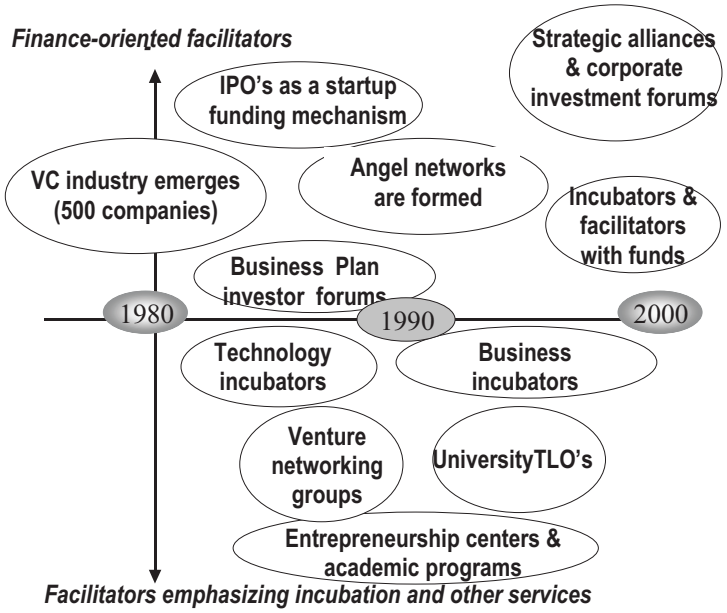

Fig. 2 Time lines illustrating the emergence of important categories of commercialization facilitators

ever result in a marketable process or product. The IPO has no current sales, no revenues, and certainly no profit.

The time lines in Figure 2 gives an approximate dating of the emergence of some important categories of commercialization facilitators. Inspecting Figure 2, perhaps the most important observation is the late date of most of these innovations. By 1980, there were only 12 business incubators in the US, but the number rose to 850 incubators by 2001 (see Wiggins and Gibson, 2003). The venture capital (VC) industry is of similar recent origin. The first venture capital company, ARD, was created in 1947; however most firms emerged in the 1980's and numbered approximately 500 by the early 1990's, a number that stabilized by the turn of the century. Figure 2 also illustrates the rapidly diversifying range of arrangements, such as business "angels" (wealthy individuals funding startup companies) and university technology licensing arrangements (TLO's).

Other arrangements were less successful. The landmark R&D consortium MCC (Microelectronics and Computer Technology Corporation) in Austin, pooling the research efforts of all major computer makers in the US except IBM, never blossomed the way the founders had hoped. Many for-profit incubators (often demanding up to a 50 percent equity fee from their tenants) found it difficult to generate the expected profit rates. Many small business development corporations (SBDCs), some of them operated under local government aegis, were never able to fulfill initial expectations.

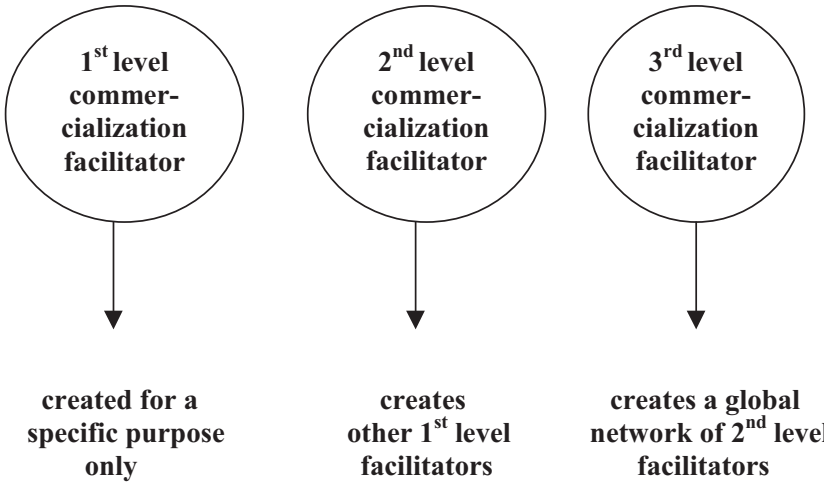

Fig. 3 A generic classification of commercialization facilitators

Given the intense experimentation searching for new specialized facilitating forms and practices, it should be of no surprise that some of these attempts did not fare well. As in all entrepreneurship, some initiatives will succeed and others will be less favorably received in the marketplace. Failure is an essential part of institutional as well as industrial evolution.

Facilitators of the second and higher order A commercialization facilitator of the *first* order promotes and mediates the commercialization of new technology. All the examples listed up to now are facilitators of the first order.

A facilitator of the *second* order promotes and contributes to the formation of facilitators of the first order. The IC^2 Institute of the University of Texas, to be described in some detail in section 4 below, is a commercialization facilitator of the second order: it has created a number of other commercialization facilitators in Austin and elsewhere. IC^2 innovated one of the first and most successful business incubators, has helped start over a dozen other incubators in other parts of the world, created one of the first venture capital networks, and has promoted numerous other commercialization accelerating initiatives. It may be argued that the existence of this second order facilitator hastened the formation of the Austin-San Antonio corridor as a modern technopolis. See Figure 3.

The European Business and Innovation Centers (BICs), set up by the EC Directorate-General for Regional Policy and the Directorate General for Enterprise, may also be viewed as 2nd order facilitators. Since 1984, over 150 BICs have been set up in economically less favored regions of the EU. Each BIC features a partnership between operators in the local and regional economic development process, such as a local chamber of commerce, development agencies, university and research bodies, financial

institutions, science and technology parks, as well as individual businesses. They contribute to the development of incubators and clusters.[3]

On the US scene, only a few 2nd order commercialization facilitators have ever been created. The IC^2 Institute is one. CONNECT of San Diego is another. A few others exist, but they are still relatively rare.[4]

Responding to market demand, the IC^2 Institute is currently engaged in a program to build "IC^2-like institutions" both domestically and abroad, thus possibly converting the Austin headquarters into a third order commercialization facilitator ... one that spawns other 2nd order facilitators and organizes them into a global network.

3 Toward a theory of commercialization facilitators

Commercialization mediation takes many forms, but the basic function is the same: promoting and facilitating the transfer of a new product or a new process technology from the laboratory to the market place. In order to describe this function, we shall imagine an abstract theory of the micro behavior of facilitators, just as there is a micro theory of the firm, of the financial institution, etc. What does this theory look like? We are entering un-chartered waters here. What follows are some elements of such theory – building blocks of an integrated theory yet to be written. It begins with the selection of research projects, extends through business startups, and concludes with the institutionalization of an organization as a going concern.

3.1 Prioritization and selection of startup projects

Selection occurs, for example, when an incubator or other facilitating organization admits a prospective client startup company and takes it on as a tenant. Other applicants may be turned down. Selection also occurs when a large company decides to enter into a strategic alliance with a startup. Other prospective candidates may be passed over.

Facilitating organizations are always on the lookout for promising new candidates. The hallmark of the successful management of an incubator or a venture capital firm is the ability to spot early the winners of the future.

Quite generally, the selection problem involves (i) an identification of a number of prospective clients to be compared, (ii) the ranking of the performance and relative attractiveness of these various alternatives, and (iii) establishing criteria for acceptance or rejection.

The problem of selection and prioritization of R&D projects under a range of different institutional settings was recently dealt with in Thore (2002). A convenient tool for this purpose is *data envelopment analysis*, a

[3] For a recent study, see Wynarczyk and Wynarczyk (2002).

[4] Ronstadt et al. (2002) conducted a preliminary identification and analysis of 2nd order commercialization facilitators for five city regions in the United States.

mathematical technique for ranking projects or alternatives that are characterized by an entire vector of performance attributes (rather than a single figure of merit). The procedure can briefly be outlined as follows. Use the notation

$i = 1, 2, \ldots, n$ a list of R&D projects or prospective startup companies to be evaluated, ranked and prioritized;

$k = 1, 2, \ldots, s$ a list of inputs such as research hours and research costs of various categories;

$r = 1, 2, \ldots, t$ a list of performance criteria or outputs, such as expected sales volume, sales revenues, profit;

$X_{ik}, k = 1, 2, \ldots, s$ quantities of inputs used by project or startup company i;

$Y_{ir}, r = 1, 2, \ldots, t$ the amounts of outputs obtained by project or startup i.

Then the ranking of a given project, say project $i = 0$, is obtained by its so-called efficiency score θ_0, determined from the linear programming problem

$$\begin{array}{l} \max \theta_0 \\ \text{subject to} \\ \sum_i \lambda_i X_{ik} \leq \theta_0 X_{0k}, k = 1, 2, \ldots, s \\ Y_{0r} - \sum_i \lambda_i Y_{ir} \leq 0, r = 1, 2, \ldots, t \\ \lambda_i \geq 0, i = 1, 2, \ldots, n \end{array} \tag{1}$$

See further *ibid.*

Re-enumerating the projects $i = 1, 2, \ldots, n$ in the order of monotonically increasing efficiency scores, one has

$$\theta_1 \leq \theta_2 \leq \ldots \leq \theta_i \leq \ldots \leq \theta_n \tag{2}$$

Projects scoring below some low threshold value are slated for *rejection* or *termination*. Projects scoring above some high threshold are slated for immediate further development.

Ideally, prioritization and selection in this manner should occur intermittently during the life cycle of a project – when it is initiated, and as it moves along its path toward commercialization. All data and variables in program (1) are to be indexed by date. Accounting for uncertainty, they may even be indexed by several possible states of the world.[5]

Since there are many decision-points between project conception and project completion (successful commercialization, or termination), these decisions will combine retrospective assessments with forward-looking appraisals.

[5] *Ibid*, Chap.3 ("The Life Cycles of Sales and Profits: Dealing with the Uncertainties of the Commercialization Process").

3.2 The concept of capture, and assisting startups to capture markets

The "law of capture" (Norton and Bass, 1992) describes the manner in which the latest technological generation of a product or a process takes over demand from earlier generations. As the sales of the startup venture expand, they slowly eat into the market for earlier product generations. Because of the exhaustion of diffusion of the earlier generations, they may continue to grow for some period of time, but will eventually start to decline. Geometrically, we may think of a series of sales cycles, where each new cycle eventually drives the sales of the earlier generation to approximately zero. The cyclical downturn of the preceding generation is the result of consumers substituting the new generation for the old one. The law of capture states that the manner in which the latest technological generation takes over demand from earlier generations is fundamentally the same across different product categories.

To accelerate the diffusion of a new technology is therefore also to accelerate the capture of existing markets. Commercialization facilitators can assist this process by identifying technological and marketing opportunities at hand.

A simple mathematical model of evolution by capture is presented below (we follow here the general evolutionary schema of Nicolis and Prigogine, 1977). We use the following notation

X_t = total sales of old generation of product or process at time t
Y_t = total sales of new generation of product or process by startup company at time t
A = saturation level of total sales (both new and old generation)

and assume that the growth of the two variables over time is determined by the two-coupled equations

$$X_{t+1} = aX_t(A - X_t - Y_t) \tag{3}$$
$$Y_{t+1} = bY_t(A - X_t - Y_t) \tag{4}$$

where a and b are known parameters. In other words, the two cycles are coupled together. The expansion of the old generation (eq. 3) slows down as the sales of the new generation gradually build up; the expansion of the new generation (eq. 4) is enhanced as it captures market share from the old one.

As is well known, equations like (3)-(4) may lead to a smooth sequence of cycles, or to chaotic explosions.[6] The launching of a new product is not necessarily an orderly process, neither to the startup venture nor to the assisting facilitator. The new generation can be a wild success, or it can fizzle into nothing.

[6] The original work is Yorke and Li (1975). For a non-technical discussion of chaos theory, see Prigogine and Stengers (1984). The apparent randomness in many physical and social systems, and the relation between complexity and evolution in such systems is discussed in depth by Wolfram (2002).

3.3 Valuation of the startup company, searching for suitable merger or buyout partners, or assisting the company with an IPO

The economic wealth created by the construction and installation of new production capital was by earlier economists referred to as "quasi-rent" (see e.g. Marshall (1890) and Schumpeter (1934)). Geometrically, quasi-rent would accrue as the area below a monotonically falling curve of the marginal product of capital. Similarly, the term quasi-rent may also be applied to the economic wealth created by the development and commercialization of new know-how and human capital – the surface below a monotonically descending curve of the marginal returns.

Eventually, the R&D costs of a successful new venture can be financed by its own quasi-rents. In addition, the quasi-rents of earlier generations of the new product or process may be drawn upon to cover the costs.

The market value of a new venture equals the present value of its future stream of quasi-rents. For a company not yet quoted on the stock exchange, this market value may seem purely hypothetical – until one day the company eyes the possibility of selling the entire venture, or a part of it, or to enter into some kind of merger or acquisition with a cash payout. Such a deal amounts to monetizing economic wealth already created. For a number of reasons, such a strategy may seem attractive to the current ownership – the owners may feel that their relative strength lies in R&D rather than the management of an ongoing company, they may hesitate bringing in new ownership and management interests, etc.

Commercialization facilitators will often want to encourage such developments. The mediating institution cares less about personal factors such as retaining management control to the initial startup group, and more about the timely equity financing of the new product or process. Seen from the point of view of the facilitator, it may be a definite advantage that ownership and management control of the new venture is partly or wholly transferred to an experienced company with its own management team.

The commercialization facilitator may therefore make it a point of assisting the startup company in searching for suitable merger or buyout partners. It is our experience that many startup owners welcome such opportunities to cash out with open arms. The facilitator may also draw upon its contacts to lay the groundwork for the flotation and public sale of new venture stock (an IPO on the stock exchange).

3.4 Logistic growth of commercialization facilitators during a business cycle upswing

The growth of commercialization facilitators (measured, for instance, in terms of total dollar amounts of commercialization spending in a region) expresses the expectations and hopes of its tenants and clients: local startup entrepreneurs, launching new ventures. If successful, each one of those ventures will eventually embark upon its characteristic life cycle of growth. It is

a cycle of an early upswing, and subsequent maturation as the product gains market share (and the eventual decline in competitors introduce new and more sophisticated products embodying more advanced technology). As is well known, the commercialization of new products is a "leading indicator" of the business cycle. In the same manner, the growth of the facilitators themselves presumably also is a leading indicator.

It is easy to find examples that document the crucial role of commercialization facilitators during the early upswing of the business cycle. One is close to our own experience: the startup of the Austin Technology Incubator in Austin, Texas, at the depth of the Texas economic downturn in 1989 and its subsequent role in electrifying a local economy that eventually was to become one of the fastest growth areas in computer and information technology in the nation. (See our discussion of ATI further below.)

For another example, of even wider scope, one may recollect the spectacular rise of the junk bond in the 1980s and the ascendancy (and subsequent infamy) of the investment-banking firm of Drexel Burnham Lambert. As it turned out, junk issues were critical to the US computer industry, providing between 1985 and 1989 some 80 % of all its finance. The crucial breakthrough for the fiber optics industry was MCI's fiber phone network. Drexel provided no less than $3 billion of capital. Seeing the advent of the "electronic superhighway" earlier than others, Michael Milken financed large building blocks of the electronic infrastructure that would become one of the major drivers of the US economy in the 1990s. Turner Broadcasting and TCI spearheaded the innovative drive in cable broadcasting, financed by multi-billion dollar junk issues. (See also Gilder, 1993 and Thore, 1995, Chapter 11.)

Commercialization facilitators provide synergy of stimulus to the local economy. The same principles apply here as in Joseph Schumpeter's well-known analysis of the clustering of innovations during the upswing of the business cycle. Not only do innovations cluster around the facilitators during the upswing - the facilitators themselves are powerful innovations, providing synergy to their tenants and clients. The synergy flows in several directions at once: from the local economy to a facilitating organization, from the facilitator to the local economy, and between its tenants and clients. Indeed, the totality of an organization and its present (and past) tenants and clients will ideally form a Schumpeterian growth cluster.

We now sketch a simple mathematical model of the growth of a commercialization facilitator (or a group of facilitators) and the snowballing effects transmitted back and forth between the facilitator and the local economy. This time, use the following notation

X_t = total sales of tenants or clients of the facilitator at time t
A = saturation level of sales of tenants or clients
Y_t = total sales of local economy at time t
B = saturation level of sales of local economy

and assume that the growth of the two variables over time is determined by the two-coupled equations

$$X_{t+1} = aX_t(A - X_t) + bY_t(B - Y_t) \quad (5)$$
$$Y_{t+1} = cX_t(A - X_t) + dY_t(B - Y_t) \quad (6)$$

where a,b,c and d are known parameters. In other words, rather than assuming that each sales statistic would follow its own separate cycle (in which case $b = c = 0$ in the two equations above), the two cycles are coupled together. The expansion of the facilitator over time depends not only on its own cycle but also on the local economy and its growth potential (the strength of the cross-effect is measured by the parameter b). Conversely, the growth of the local economy is stimulated by the growth of the facilitator (the impact is measured by the parameter c).

It is not necessary here to go into the details of the dynamic paths that can be generated by equations (5)-(6). The standard case is that the facilitator rides on the back of the growth curve of the local economy, benefiting from it and reinforcing it. There are also other possibilities. Systems of difference equations like (5)-(6) may produce chaotic behavior, just like the system (3)-(4) for a single product category.[7] Chaos will be associated with both explosive growth and collapse. Commercialization is always a risky business. Like a corporation, a facilitator may succeed beyond one's wildest dreams, or it may go bankrupt and have to fold.

4 A success story from Texas

We now turn to a striking example of the scope for creating synergy between entrepreneurs and facilitators that we have had a chance to observe first hand. The example actually involves synergy in a *triple* hierarchy:

- An academic institution devoted to the development of commercialization-facilitating initiatives, locally, nationally and internationally.
- A local business incubator and an affiliated venture capital network,
- Individual entrepreneurs and corporations commercializing new products and new technologies,

In this particular instance, the academic institution – an arm of the University of Texas – acted as the stimulus and primus motor of the ensuing development. Furthermore, this policy was quite deliberate and the goal of creating a Texas "technopolis" was spelled out clearly and at an early stage.[8] We describe events and institutional innovations below.[9]

[7] See Nicolis and Prigogine (1977) for an early account of multi-species diffusion systems like (5)-(6).

[8] For a quite prophetic statement, see Smilor et al. (1988).

[9] See also Porter (2001) and Ronstadt and Furino (2001).

4.1 The IC 2 institute

A powerful institutional innovation on the US scene occurred in 1977 with the founding of the IC^2 Institute (Innovation, Creativity and Capital), at the University of Texas at Austin. Focusing on technology, entrepreneurship and ideology, IC^2 gradually evolved into a hybrid organization that combined the research activities of a think tank with non-traditional education and outreach activities.

IC^2 was the brainchild of George Kozmetsky, who had co-founded Teledyne Inc., a company that grew into one of the largest conglomerates in the nation. In 1966 he accepted an invitation to become dean of the business school at the University of Texas at Austin. The IC^2 Institute developed a unique mission: to explore new organizational and management structures that can facilitate the commercialization of high technology. The philosophy behind the new creation was this: As the pace of commercialization of high technology accelerates, the nation's universities would have to assume a new role not only in the development of science and technology, but also in actually converting that technology into viable businesses[10].

4.2 Commercialization facilitating innovations: the IC 2 record

New institutions, just as corporations, need to respond to opportunities in the marketplace. As a result, their operations and their characteristics evolve over time. Certainly, this has been true of the commercialization-facilitating organizations and practices that are the subject of our present inquiry. In a fashion, this increasing diversification and specialization mirrors the general trend in the high tech economy toward an ever richer supply of "niches" of products to cater for ever more discerning consumers.

The following list of new commercialization-facilitating services is not exhaustive. It just catalogues some of the initiatives that grew out of the IC^2 operations over a 25 year time span that the present authors have witnessed first-hand.

- *Innovations of incubation operations:* Tenants admitted to the Austin Technology Incubator (see below) must be in possession of a workable and demonstrated technology or product. They are admitted for a period of three years, after which they "graduate," leaving the incubator premises. The network of past graduates ("exes") reaches out to new tenants. The tenants are offered the option to employ business school Ph.D. students as non-paid trainees (these trainee jobs are very much sought after). The incubator is available to the business school as a real-life laboratory, testing the commercialization process. Commercialization classes are taught in situ, on the incubator premises.[11]

[10] See Rogers (1998), Tanik (1999) and Zacks (2000).

[11] For a detailed discussion of ATI practices and various metrics of its success, see Wiggins and Gibson (2003).

- *Innovation of operations of venture capital firms:* The Texas Capital Network (operating under the IC^2 umbrella) created the idea of electronic matching of would-be entrepreneurs looking for venture funds and business "angels." The initiative is currently being replicated in other states. The Texas Capital Network also has arranged a series of "venture fairs" designed to get entrepreneurs and venture capitalists together.
- *Innovations of academic activities:* The community of IC^2 fellows (currently more than 250 fellows) forms a worldwide resource of technology commercialization expertise. The fellows have interests that cross the traditional academic and professional boundaries. They come from business, government, academia, the media, and the non-profit world. They represent both the brain trust and the major implementing mechanism of the Institute. The fellows greatly extend IC^2's reach and capabilities as a "quasi-virtual" organization.
- *Innovations promoting emerging technopolis areas around the world.* Such missions operated by the IC^2 Institute are located in Curitiba, Brazil, in Guayaquil, Ecuador and in the Caribbean Basin. These efforts typically draw on the expertise of several institute fellows, and may include benchmarking, education, and incubation. Similar approaches are also being applied to transitional situations, such as along the Texas/Mexico border region, in Tblisi, Georgia, in Yerevan, Armenia, and in Medallin, Colombia.
- *Innovations of educational activities:* Drawing upon two decades of research into the nature of the commercialization process, the IC^2 Institute in the spring of launched its new Masters program in the Commercialization of Science and Technology. Originally taught in Austin and in Washington, D.C., the program has expanded into a multi-continental, multimedia classroom, with programs offered in Australia, Mexico, Poland, and Portugal. The same degree program is also offered on-line. The most recent item of this line of educational innovation is a Masters degree offered to employees of IBM, designed together with IBM management.

Overall, the genius of IC^2 has been to use Austin as its laboratory for learning how to effectively harness capitalism to innovation and creativity. In particular, IC^2 has worked closely with the city and county to nurture and grow a technology community and to build a sound basis for technology entrepreneurship and regional economic growth.

4.3 The incubator

The Austin Technology Incubator (ATI) was founded by the IC^2 Institute in 1989. It was formed by a coalition of university, government and business leaders as a three-year experiment to create wealth, generate jobs, and diversify the Austin economy, then in the grip of a severe recession. The experimental years were successful enough to be extended indefinitely and ATI became one of the model incubators in the nation.

Table 1 Recent valuations of some successful ATI tenants

Year acquired	Company	Price
1999	Metrowerks	Purchased by Motorola for $95 million
1999-2000	Evity	Purchased for $100 million by BMC
1998-2001	Exterprise	$75 million to Commerce One
2001	DTM	Merged at $45 million valuation

ATI provided strategic, operational and infrastructure support to its tenants, including office space in a high-profile university locale. The office facilities included conference rooms, telecommunications, Internet access, receptionist, copy machines etc. The resident companies tapped into a variety of resources including in-house market research and public relations assistance, University of Texas faculty and students, and a network of professional service providers.[12]

Over the last dozen years, ATI has worked with approximately 110 high growth ventures. Of these, 65 graduated from ATI; 5 became public companies; another 13 were acquired or merged with other enterprises and several of these were acquired at high valuations. For instance, most recently:

To the best of our knowledge, only 10 of the 65 ventures can be classified as "failures."

The National Business Incubator Association named ATI "the incubator of the year" in 1994. Two years later, ATI won the Justin Morrill Award from the Technology Transfer Society. Several of its graduates have received similar distinctions. In 1996, Evolutionary Technologies, Inc. won national recognition as "Graduate of the Year" in Technology Start-ups. Applied Science Fiction and Infoglide were each recognized as "Client of the Year."

The achievements of ATI have prompted several mayors' councils nationwide to send representatives to Austin to learn more about how to generate business development and revitalize ailing municipal economies. ATI founded three additional incubators around the US and also the Austin Multimedia Incubator and the Clean Energy Incubator. ATI has established a network of international contacts by recruiting startup companies from Brazil, Israel, India, Canada, Australia and Japan.

4.4 Impact on the local economy

The operations of the IC^2 Institute, and the various initiatives operating under its umbrella, have resulted in significant impact on the local economy. In large measure, ATI served as a catalyst for Austin's economic recovery in the 1990s by developing an entrepreneurial support infrastructure.

Several measures compute the local economic impact. For instance, the average high tech wage in Texas is about $55,000 - approximately 75% higher than the average per capita job. ATI companies have created about

[12] See Wiggins and Gibson (2003).

2,850 jobs yielding in year 2000 a total of $156,750,000 in wages. The 1% city tax on consumable spending would net the city $1,567,500 if a person spent all his or her income on consumable goods. Since only about 60% is so spent, the net to the city is approximately $940,500 this past year.

The cumulative revenues of ATI companies have had a major impact on the city. By 2000, these revenues totaled $1.25 billion. Since these sales stimulate other sales, the multiple impact is estimated at $2.625 billion.

High tech jobs and sales are generally higher in value added than other sales. Assuming that the value added is 25% of sales, the total value added mediated or facilitated by ATI would equal approximately $626 million. We want to stress the word "facilitated" because we are not claiming the ATI produced this value added, nor the other output measures. The companies themselves were primarily responsible for this output, although evidence exists that a number of companies would have likely failed or significantly underachieved without ATI's intervention prior to and during their residency at the incubator.[13]

While the success of ATI has been impressive, it is yet too early to evaluate whether this model can be generalized over either space or time.

5 The changing nature of capitalism

Joseph Schumpeter of course was the great protagonist of considering technology as an endogenous variable of the economic system He studied how new science and technology during the business upswing leads to waves of innovation and economic growth. To him, technology was the great engine of capitalism itself. In the same vein, financial economists later studied the endogenous evolution of new financial instruments and new forms of financial intermediation.

But up to now, the entrepreneurial function of the capitalist economy – the very driver of both industrial and financial innovation– has been taken mainly as given by economists, lying outside the scope of scientific inquiry. A common attitude by economists has been that entrepreneurship is an "art" that will always defy any attempts to categorize it.

In breaking this impasse, we believe that it is necessary to include the evolution of the entrepreneurial function as an endogenous variable of the economic system. To us, the basic function of the capitalist economy is entrepreneurship. The commercialization of new technology occurs in response to technological opportunities, market opportunities and financial opportunities. The high tech economy feeds on a rapid flow of new technology from the laboratory to the marketplace. Facilitators such as high tech incubators, spin-offs, and technology IPOs are new and evolving tools of the capitalist system, born by the system, directed by it, and directing it.

[13] For the impact of the ATI on the local economy, see Harvard Business School, 1998.

5.1 Schumpeter on entrepreneurship

As is well known, Schumpeter's was quite ambivalent as to the question of entrepreneurship. As a young man, he had acquired fame as the most eloquent interpreter of his time of the creative force of entrepreneurs and entrepreneurship (Schumpeter, 1934). Later, while still acknowledging that entrepreneurship is "a propelling force in the rationalization of human behavior" (Schumpeter, 1950, p.125), he nevertheless took an extremely dim view on the future of entrepreneurship. In a section entitled *The Obsolescence of the Entrepreneurial Function*, he opined that

> "Technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways.... Bureau and committee work tends to replace individual action... The leading man ... is becoming just another office worker – and one who is not always difficult to replace"(*ibid*, p.133).

These lines were written in the early 1940s, during the war, when indeed much of the industrial might of the US was achieved through automated and bureaucratic organization - the manufacture of the Liberty ships, the Flying Fortresses and the Jeep.[14]

Today, in retrospect, economists are searching for reasons why Schumpeter's gloomy predictions failed completely to hit the mark. The revolutions in computing, information technology, and biotech that occurred in the 1980s and 1990s were all driven by extraordinary entrepreneurial vision, daring and risk-taking.

We believe that a major reason for Schumpeter's failure to appreciate the creative role of the entrepreneur in the modern economy was the defective understanding of competition and market formation that was the rule of his day. The entire body of received economic doctrine was based on the assumptions of "perfect competition." In 1936, Chamberlin and Robinson had added yet another market model: monopolistic competition. But the market form that was to rule in the developed economies in the late 20th century – the incessant evolution of high tech products with ever lengthening lists of desirable attributes – had not yet been discovered, neither theoretically nor empirically. To navigate a company in this storm, entrepreneurs with outstanding creative abilities are needed at the helm.

[14] For a recent detailed study of Schumpeter's view on the role of the entrepreneur, see Brouwer (2002). According to Brouwer, Schumpeter's thoughts on the matter were not unique at the time, and that "the lack of interest in entrepreneurship in the second half of the past century can be attributed to the widespread idea that entrepreneurship would become more and more obsolete as capitalism developed" (*ibid.*, p.84). Brouwer also documents how Schumpeter's bleak outlook on the viability of capitalism can be traced back to his earlier thoughts on the matter as evident in the second edition of his *Theory of Economic Development*, in 1934.

As an empirical fact, technology, production and market conditions in the Western world changed. Small scale, flexibility and customer proximity again and again led to superior performance in startups or small production units (Audretsch and Thurik, 2000). The new business opportunities could often be most suitably exploited by newly formed business organizations (Baldwin and Johnson, 1999; Acs and Audretsch, 1990). In particular, startup companies in the US computer industry enjoyed dramatically increasing returns to scale (Thore, 1995).

Briefly: Schumpeter's imagined world of hapless entrepreneurs never came into being. A new economy with new demands and new opportunities arose, requiring precisely the inventive entrepreneurial drive that Schumpeter had analyzed in brilliant terms in his youth but eventually thought would wither away.

5.2 Building an infrastructure of entrepreneurship

Returning now to our main theme and citing the rapid growth of various commercialization-promoting initiatives, we believe that entrepreneurship and commercialization can be permanently implanted in an economy as part of its institutional structure. This leads, irreversibly, to an economy where there is "more" entrepreneurship, both in terms of the number of entrepreneurs, number of companies, number of technologies commercialized, and sales of those technologies, and the number of commercialization facilitators. It also leads to a compression of the time lag between the development of new applied knowledge and its commercialization.[15]

This trend is all part of the arriving high tech society. Products and manufacturing processes are increasingly high tech; now, entrepreneurship is also becoming "high tech," drawing on sophisticated management and commercialization techniques.

This does not necessarily mean that entrepreneurship is becoming more "successful." Business failures and creative destruction are more than ever a part of the overall dynamic picture. Just as there is a rapid turnover of ever evolving technology, there is also a rapid turnover of firms. Successes and failures go hand in hand. Hicks (1991) calls this the "churn" of capitalism – high creation and high discontinuance rates. The stakes of entrepreneurship are getting higher. As a result, only the most insightful and advanced entrepreneurship survives and blossoms. Entrepreneurship itself evolves. And mediation and facilitation techniques evolve.

There are also attitudinal and political synergies at work, influencing the attitude towards entrepreneurship in society at large (Casson, 1995). There seems to evolve a growing appreciation of the opportunities of change (of the "American dream"). More individuals are involved in entrepreneurship, and the economic alienation of workers in the industrial age gives way to mobility, education, the cultivation of creative abilities, and founding of

[15] See Ramamoorthy (2000) on the so-called "Kozmetsky effect."

avalanches of new companies. Ours is rapidly becoming an "entrepreneurial society."

Hoping to emulate the successes of commercialization of high technology in the US and the spread of commercialization-promoting initiatives, many nations in the 21st century are embarking upon various programs of commercialization policy. Even former communist states these days place their bets on government-funded high tech incubators and the agglomeration of incubators into entire regional techno-cities.

5.3 Long term perspectives

Just as technology will continue to develop as long as man is creative, the development of new institutions and organizational forms of management designed to enhance the commercialization of new technology will also continue into the future. The present-day business incubator or IPO is just a step in a long chain of institutional developments yet to come. Looking into the future and into the next long-term economic upswing, we see the growth of a series of specialized institutions, many of them operating via the Internet, providing management advice, equity capital, and buyout opportunities for new startups.

Above all, we see future opportunities and need for a new breed of university-based institutions (commercialization facilitators of the second order) operating very much along the University of Texas model, benefiting regional development both nationally and internationally. The university has a unique impartiality and legacy of creative development that makes it natural to foster new kinds of institutions such as IC^2 that can show the way and act as a catalyst for the birth of new commercialization arrangements.[16]

References

Acs ZJ, Audretsch DB (1990) Innovation and small firms. MIT Press, Cambridge, Mass.

Audretsch DB, Thurik AR (2000) Capitalism and democracy in the 21st century: from the managed to the entrepreneurial economy. Journal of Evolutionary Economics, 10: 17–34

Baldwin JR, Johnson J (1999) Entry, innovation and firm growth. In: Acs ZJ (ed.) Are small firms important? Their role and impact, Kluwer, Dordrecht

Brouwer MT (2002) Weber, Schumpeter and Knight on entrepreneurship and economic development. Journal of Evolutionary Economics, 12: 83–105

Casson M (1995) Enterprise and competitiveness. Oxford University Press, Oxford

Gilder G (1993) America's best infrastructure program. The Wall Street Journal, March 2

[16] For infant facilitators of the second order at other academic institutions, see Ronstadt and Paulin (1996), Ronstadt et al. (2002), 1996, and MIT Media Laboratory, 1999.

Harvard Business School (1998) Austin, Texas: building a high-tech economy. Case 9-799-038, October

Hicks DA (1991) New dimensions of Dallas area economic development. The Survey of Regional Literature, 19, September: 11–24

Lundvall BA, Borrás S (1997) The globalising learning economy: implications for innovation policy. DG XII, Commission of the European Union

Marshall A (1890) Principles of economics. 8th ed.1946. Macmillan, London

MIT Media Laboratory (1999) Enabling technologies for learning and expression by people and machines. MIT, Cambridge, Mass. (March)

Nelson J (2002) Bringing institutions into evolutionary growth theory. Journal of Evolutionary Economics, 12: 17–28

Nicolis G, Prigogine I (1977) Self-organization in nonequilibrium systems: from dissipative structures to order through fluctuations. Wiley, New York

Norton JA, Bass FM (1992) Evolution of technological generations: the law of capture. Sloan Management Review, 33, 2: 66–77

Porter AW (2001) The knowledge seekers: how to turn your community into an engine for economic success. IC2 Institute, The University of Texas at Austin, Texas

Prigogine I, Stengers I (1984) Order out of chaos, Man's new dialogue with nature. Bantam Books, Toronto

Ramamoorthy CV (2000) A study of the service industry - functions, features and control. IEICE Transactions on Communications, E83-B(5): 885–902

Rogers RS (1998) Prickly research partnerships. C&EN (Sept. 21), 21–25

Ronstadt R, Furino A (2001) Creating IC2-like organizations: networking innovative organizations world-wide to design and launch new technologies, create jobs, and induce economic development. IC2 Institute, The University of Texas, Austin (working paper, October)

Ronstadt R, Furino A, Thore S (2002) Regional development strategies: creating a global network of commercialization accelerators. IC2 Institute, The University of Texas, Austin (working paper, August)

Ronstadt R, Paulin W (1996) Entrepreneurship facilitation for high technology businesses: forging a new theory. Pepperdine University, Malibu, Calif. (August)

Schumpeter J (1934) The theory of economic development: an inquiry into profits, capital, credit, interest and the business cycle, German original 1911, first English ed. 1934, 2nd ed. 1978. Oxford University Press, London and New York

Schumpeter J (1950) Capitalism, socialism and democracy. 1st ed. Harper and Brothers 1942, third edition, Harper Torchbooks 1950, New York

Smilor RW, Gibson DV, Kozmetsky G (1988) Creating the technopolis: high-technology development in Austin, Texas. Journal of Business Venturing, 4: 49–67

Tanik J (1999) University-based technology transfer: a state-of-the-art process based on evolutionary success. The IC2 Institute, University of Texas at Austin, Texas

Thore S (1995) The diversity, complexity, and evolution of high tech capitalism, Also published on the Internet, see http://www.ic2.org/pubs/sten.pdf. Kluwer Academic Publishers, Boston

Thore S (2002) Technology commercialization: DEA and related analytical methods for evaluating the use and implementation of technical innovation. Kluwer

Academic Publishers, Boston
Wiggins J, Gibson DV (2003) Overview of US incubators and the case of the Austin Technology Incubator. International Journal of Entrepreneurship and Innovation Management, 3, 1/2: 56–66
Wolfram S (2002) A new kind of science. Wolfram Media
Wynarczyk P, Wynarczyk P (2002) Turning Schumpeterian theoretical insights into public policy action: fostering entrepreneurship and innovation through European Business and Innovation Centres (EuBICs) in less favoured regions of Europe. Paper presented at the 9th International Schumpeter Society Conference in Gainesville, Florida, March 2002
Yorke J, Li TY (1975) Period three implies chaos. American Mathematical Monthly, 82: 985–992
Zacks R (2000) University research scorecard. The Technology Review, 2000, July/August: 88–90