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Technology Business Incubation: *An overview of the state of knowledge*

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ABSTRACT

This paper introduces Technology Business Incubation (TBI) as a field of study and practice, exploring the concept, its evolution, and scholarship. Science parks, incubators and accelerators are TBI mechanisms considered to be important policy tools for supporting innovation and technology-oriented entrepreneurial growth. Their popularity is premised on the belief that these mechanisms provide critical value-added inputs essential for the creation and development of innovative Technology-Based Firms (TBFs). However, determining what type of TBI mechanisms and policies are most conducive to achieving the desired results is very much mission-driven and context-specific. A review of the past three decades of incubation literature, emerging practice, and future trends reveals that despite ongoing debate about their contribution and challenges, the future of TBIs is promising, and there are rich opportunities for research.

1. Introduction

This article introduces the Special Issue on Technology Business Incubation (TBI) and addresses the following key questions: *How do we define TBIs? Where do we stand in terms of understanding the incubation process and developing theory? How have TBI models, along with related research, emerged over the past three decades?* And, *what are the future prospects and challenges?*

While Technology-Based Firms (TBFs) lay the foundation for new wealth-creating industries, the race to develop appropriate policy and program mechanisms to help create and develop regions that enable new technology start-ups continues to pose challenges for policy makers seeking relevance in their planned interventions (Mian, 2011). This warrants policies that place an emphasis on the effective exploitation of new knowledge and the development of innovative technologies that are rapidly commercialized for economic gain. Consequently, scholars, policymakers, and practitioners increasingly recognize the importance of seeding and accelerating entrepreneurship and technological innovation through incubation mechanisms that offer economic well-being through sustainable competitive advantage (Aernoudt, 2004; Barbero et al., 2012). Consequently, there is a tremendous value in understanding the mechanisms that make TBIs more effective.

TBI are operationalized as science parks, technology incubators, innovation centers and accelerators. They are considered to be promising policy tools that support innovation and technology-oriented entrepreneurial growth. TBIs are generally established through public-private collaborations among universities, industry, and all levels of government (Etzkowitz, 2002). The purpose of TBIs is promoting technology transfer and diffusion of products, thereby developing local innovative firms (EU, 2010).

The modern business incubation movement began with the establishment of an incubator program in New York (1959) and a research park in California (1951). Subsequently, Birch (1979) and others (Kirchhoff, 1994) highlight the importance of innovative small firms in both employment and economic growth. This research provided the impetus to the burgeoning incubation industry. A core set of TBI mechanisms have developed during the past half-century and are in use globally. As several thousand TBIs operate throughout the globe (InBIA, 2015), further consideration through special issues such as this are needed.

After defining Technology Based Incubators (TBIs), the development of different incubator mechanisms is summarized. The gaps between incubation practice and scholarship are illuminated through a systematic review of the extant literature. Next, an introduction to the papers included in this special issue highlighting their contributions is provided. Finally, concluding remarks provide research direction for further study.

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2. Defining TBIs and understanding the incubation process

Technology Business Incubators (TBIs) are recognized by different names such as technology/business incubators, innovation/technology centers, science/research/technology parks, and business/seed accelerators. The terminology reflects scope of function as well as location.

Smilor and Gill (1986) first articulate the concept of TBIs as offering a link between: technology, know-how, entrepreneurial talent, and capital. TBIs are property-based initiatives providing tenant firms with a portfolio of new venture support infrastructure, including: business services, networking (Bergek and Norrman, 2008), access to professional services (Sherman and Chappell, 1998), university resources (Mian, 1996) and capital (Aernoudt, 2004). The intent is to help start-ups by providing enabling linkages to help the new businesses survive, scale up, and grow.

Hochberg (2015) describes accelerators as fixed-term, cohort-based TBIs providing education and mentoring for start-up founders. Additionally exposing new venture teams to former entrepreneurs, venture capitalists, angel investors, and corporate executives. Thereby, preparing founders for *public pitch events* in which *graduates* pitch their businesses to large groups of potential investors. In practice, accelerator programs combine distinct services and functions that are difficult and costly for an entrepreneur to find and obtain. Accelerator programs have been widely adopted by both public and private sponsors of TBIs (Cohen and Hochberg, 2014).

The start-up cycle of a technology business is considered to better understand the relationship of each TBI mechanism to the incubation support process (Table 1). While some science parks support the entire incubation continuum-germination, incubation and consolidation-most facilities do not. This heterogeneity leads to inconsistent: definitions, criteria for evaluating effectiveness, determination of how much value TBIs add, and determination of key success factors (Albort-Morant and Ribeiro-Soriano, 2015). These differences in organizational structure and objectives hamper the development of a unified conceptual framework for TBI research.

Researchers have used various theoretical lenses to study the business incubation process (Table 2).

Researchers have used various theoretical lenses to study the business incubation process (Table 2).Table 2 illustrates how incubation theory spans various disciplines. Much of the incubation literature is fragmented and anecdotal with a focus on success stories and outcomes, hence much of the research is best described as atheoretical (Hackett and Dilts, 2004; Mian, 2011). These complexities coupled with the lack of systematic longitudinal research, make development of generalizable theory challenging. Phan et al. (2005) note that generalizable theory may not be possible due to the idiosyncrasies of science parks, incubators (and accelerators) in relation to geographic, political, social, and economic systems. Hence, the major challenges for research on Technology Business Incubators (TBIs) is the lack of an agreed upon definition and unified theory.

Table 1
Phases of the Incubation Process and associated Technology Business Incubator Mechanisms.

Phase 1: Pre-Incubation/Idea development	Phase 2: Incubation and Acceleration	Phase 3: Post-Incubation, Consolidation and Growth
Technology Business Incubator/ German Innovation Center		
	Science Park/Research Park	
	Accelerator	
French Academic Incubator	*Pépinière* and Hatchery	Technopolis

(*Adapted from EU* (2002))

3. Tracking the evolution of TBIs

Two pioneering programs—Stanford Research Park, California, established in 1951 and the Industrial Center of Batavia, New York, an incubator established in 1959 — started the TBI movement. The *first wave* (till 1980) of incubator programs aimed at economic restructuring and job creation. These programs provided affordable space and shared services. By 1980, there were 20 research parks and 11 business incubators in the United States. By 2000, an estimated 600 incubators and 160 research parks were in the United States. The research/science park model evolved from a stand-alone *technology garden* to a *networked commercialization enabler*. The *second wave* of incubation programs offered a more complete menu of value-adding services, including: counselling, skills enhancement

Table 2
Theoretical Lenses Employed to Study the Business Incubation Process.

Theoretical Lens Employed	Authors
New Venture Creation or Addressing Market Failure – The incubator compensates for perceived failures or imperfections in the market place to counter the problems caused by an inefficient allocation of resources.	Plosila and Allen (1985); Bøllingtoft and Ulhøi (2005)
Resource Based View-The incubator as an organization awarding a stock of tangible and intangible resources to client firms that result in development of the client firms.	McAdam and McAdam (2008); Patton et al., (2009); Todorovic and Moenter (2010); Mian et al., (2012)
Stakeholders' View – Incubators act as a bridging mechanisms to implement the interests of key regional stakeholders (triple, quadruple helix).	Mian (1997); Corona et al. (2006); Etzkowitz (2002)
Structural Contingency Theory – Incubation mechanisms are configured to fit the external environment and be tailored to local needs and norms.	Ketchen et al., (1993); Phan et al., (2005)
Social Network Theory-Incubation mechanism as a system for increasing client firms' internal and external network density.	Tötterman and Sten (2005); Hansen et al., (2000)
Real Options View – Client firms are supported from a pool of available options through selection criteria based on fit with incubator strategy.	Hackett and Dilts (2004)
Dyadic Theory-An interdependent co-production dyad where incubation assistance is co-produced by the incubator and tenant entrepreneur.	Rice (2002); Warren et al., (2009)
Institutional Theory – The incubator's support mechanism rules and contracts offer a more structured approach to reduce uncertainty and risk, and accelerate the process.	Guerrero and Urbano (2012); Phan et al., (2005)
Mechanisms-Driven Theory – The incubator implements its own internal policies through an understanding of the relations that are value laden and context-based within the incubator organization.	Ahmad (2014); Bergek and Norrman (2008)
Virtual Incubation View – The Incubator offers knowledge brokering and information dissemination in the market space of ideas to develop innovative ventures.	Nowak and Grantham (2000); Gans and Stern (2003)

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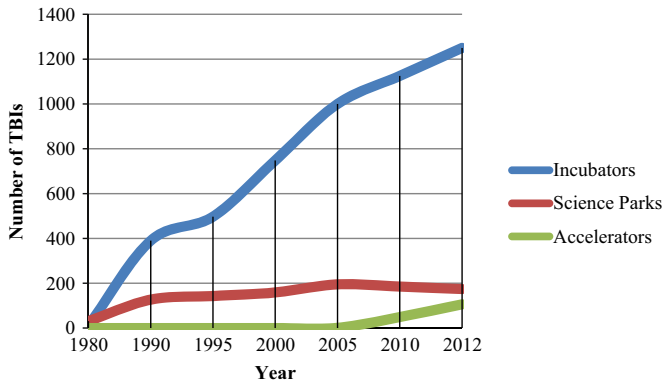

Fig. 1. Growth of United States Business Incubation Mechanisms (*Sources*: AURP, 2013; InBIA, 2015; NESTA et al., 2015).

and networking. Since the new millennium, research parks have moved towards a *mixed-use* science park equipped with a technology incubator. In some cases, the facility cohabits with commercial and residential facilities. Currently, there are over 1,250 incubators in the United States (Fig. 1) and many more globally.

Several factors contributed to the rapid growth of incubator programs (Adkins, 2002): (a) advocacy and support of the United States Small Business Administration (SBA), (b) the State of Pennsylvania's pioneering Ben Franklin Technology Development Program, and (c) Control Data Corporation funding incubators in several American cities. Recognition of the apparent failure of state policies for attracting investment by large multinational firms and the work of researchers such as Birch (1979) and Kirchhoff (1994) emphasize the importance of start-ups and small firms in terms of job growth and contribution of growth to the national economy, helped catalyze the country's incubation movement (Mian and Plosila, 2011).

Concern over the loss of industrial competitiveness in the 1980s in the United States prompted initiatives to encourage technology commercialization through enterprise development. The results include research universities establishing research/science park and incubator programs through public-private partnerships. Many university-related TBIs continue to be models of best-practice (Mian, 2011). Following the success of early TBIs there has been extensive worldwide activity in establishing TBIs (EU, 2010).

The United Kingdom and Sweden established science parks in the 1960s. In the 1970s, 50 science parks were established in over a dozen countries, including: France, Germany, Belgium, Japan, Korea, and Taiwan. In 1992 Science Parks were globally distributed, the top participants were: United States-398, Germany-106, Japan-104, China-52, United Kingdom-50, France-35, Australia-33, Canada-31, Sweden-15, and Russia-14 (Lindholm Dahlstrand and Lawton Smith, 2003). Usually, universities initiate science parks. Sometimes science parks are supported by local or national government may provide financial support. However, by the 1990s the European Union has become directly involved in supporting science parks (EU, 2013).

Differences in definition complicate counting the global population of incubators. The websites of national and regional professional associations for incubators indicate the latest available figures of existing programs in: Germany 300 (ADT, 2012), UK 300 (UKBI, 2012), France 113 (RETIS, 2010), Canada 120 (CABI, 2012), Brazil 400 (ANPROTEC, 2008), Mexico 191 (AMIRE, 2006), China 670, Japan 190, India 110, Singapore 120, Malaysia 110, and Australia 80 (AABI, 2009). Globally there are about 7,000 incubator programs worldwide, one third of which are technology-oriented (InBIA, 2015).

In the 1990s, a new incubation model emerged-the Internet-based virtual incubation model that supports new venture growth, particularly in specialized ventures such as Information Communications Technology (ICT) start-ups. For example, Idealab (founded in 1996) as a for-profit Internet incubator grew rapidly, but waned within months of the April 2000 NASDAQ technology stock crash (InBIA, 2015). Additionally, focused *brick and mortar* incubators in areas such as biotechnology and aerospace are integrated into science parks and grow well. Fig. 2 summarizes the development of TBI models.

The digital economy has given rise to a new form of TBI mechanism, the *accelerator*. Y Combinator of Massachusetts was the first accelerator (established in 2005). By 2013, over 213 accelerators were reported worldwide supporting about 3,800 new ventures (NESTA, 2011, 2015). Having considered the changing practitioner landscape of TBIs, the scholarly literature is now considered.

4. Scholarly literature: a systematic review

A Systematic Literature Review (Cook et al., 1997; Denyer and Neely, 2004; Pittaway et al., 2004; Transfield et al., 2003) is used to identify key contributions to the Technology Business Incubation field. This approach limits bias, while producing a summary of the specific area of knowledge (Petticrew, 2006). The basic principles are: transparency, clarity, focus, unified research and practitioner

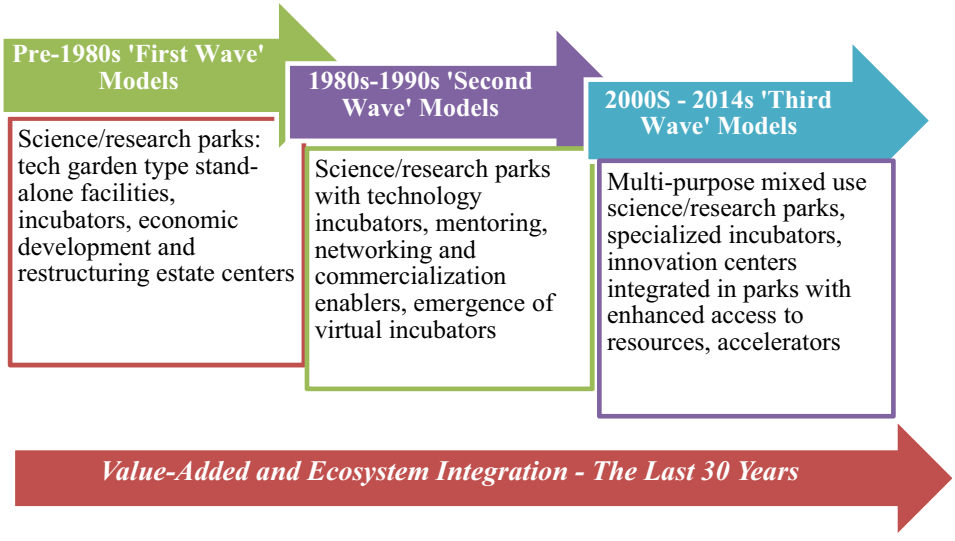

Fig. 2. The Evolution of Technology Business Incubation Models (Adapted from Mian, 2014).

communities, equality, accessibility, broad coverage and synthesis (Thorpe et al., 2005) allowing for replicability by other researchers (Jones et al., 2011).

4.1. Methodology

The eleven steps review methodology (Appendix A) identifies all relevant research published from 1985 to 2014 in peer-reviewed journals (Step 1). Four databases were utilized: ABI/INFORM of ProQuest, Business Source Premier (including EconLit), Science Direct, and Web of Science. To target the TBI domain, the following terms were considered: technology incubator, business incubator, technology business incubation, science park, technology park, research park, technopole, business development center, technology development center, and accelerator. These terms were searched for in titles, abstracts and keywords for each paper in each database. The abstracts and introduction of each article was read to ensure that the articles fitted the established criteria.

Subsequent steps further enriched and cleaned the data set. If articles were unavailable electronically, the authors or editors were contacted to confirm that the article should be retained in the list (Steps 2 and 3). All papers that were not about TBIs were excluded. For example, studies on technology transfer or academic entrepreneurship were removed (Step 4). Furthermore, educational case studies, proceedings, interviews and book reviews were excluded. The procedure resulted in 406 relevant articles (Step 5).

The list was filtered to limit it to the top level scholarly journals which are often cited and ranked first and second in the 2015 Harzing Journal Quality List that is based on 17 international rankings (Step 6) – thereby, eliminating 232 articles (Steps 7 and 8). This list highlighted 27 academic journals (Table 3) as being prominent internationally. The abstract, introduction and discussion/conclusion were read for the remaining 174 articles to ensure a contribution to the field of Technology Business Incubation (Step 9). Articles with a strong practitioner focus, but little tangible data were eliminated (Step 10) resulting in a final set of 149 articles published in high-ranked scholarly journals (Step 11). An Excel workbook was created and shared among the research team to support coding the content of each article by its author (s), journal title, subject area, investigated area, number of citations, sub-topics, and methodologies (Petticrew, 2006). Having explained the methodology to obtain and assess the articles on TBI, the results of the literature review are now considered.

4.2. Analysis of the final set of scholarly studies

Allen and Rahman (1985) in the *Journal of Small Business Management* trigger the first wave (1985-2001) of incubation related publications. During this period, articles oscillated from 0-3 articles/year (85% qualitative and conceptual papers). After 2002 this increases, averaging 10 articles/year (2002–2013) for the second wave (54% qualitative, 37% quantitative and 9% conceptual– Fig. 3). In 2005 research on incubation peaked at 19 publications (Fig. 4), due in part to a special issue in the *Journal of Business Venturing*.

In terms of national/regional share of incubation research, in earlier years (1985-2001), 60% of activity was noted in North America (mainly the US), 20% in Europe, and only 7% in Asia. Research then shifts to Europe-63% of the output from Europe, 34% from North America (USA and Canada) and 27% from Asia. Only one publication came from the Africa. The geographic distribution of incubation research shows pioneering work in North America. Activity then shifts heavily towards Europe with increasing Asian participation. (Fig. 5)

The 149 published papers were distributed over 27 journals. Table 3 shows that seven journals published five or more of the articles included in the sample. The largest share of articles appeared in *Technovation* (36), followed by the *Journal of Technology Transfer* (24), *Research Policy* (14) and *R&D Management* (10). The top three outlets account for about half of all TBI articles (see Table 3).

Table 3
Top Journals by Number of Papers Publishing Business Incubation Research (1985–2014).

Rank	Journal name	Number of papers	Total Share	Cum. Share of total
1	Technovation	36	24.2%	24.2%
2	Journal of Technology Transfer	24	16.1%	40.3%
3	Research Policy	14	9.4%	49.7%
4	R&D Management	10	6.7%	56.4%
5	Journal of Business Venturing	9	6,0%	62.4%
6	Small Business Economics	8	5.4%	67.8%
7	International Small Business Journal	5	3.4%	71.1%
8	Economic Development Quarterly	4	2.7%	73.8%
9	Entrepreneurship Theory and Practice	4	2.7%	76.5%
10	International Journal of Industrial Organization	4	2.7%	79.2%
11	Journal of Small Business Management	4	2.7%	81.9%
12	Technological Forecasting and Social Change	4	2.7%	84.6%
13	Entrepreneurship & Regional Development	3	2.0%	86.6%
14	IEEE Transactions on Engineering Management	3	2.0%	88.6%
16	Journal of Business Research	3	2.0%	90.6%
17	Regional Studies	3	2.0%	92.6%
18	Journal of Product Innovation Management	2	1.3%	94.0%
19	Growth & Change	2	1.3%	95.3%
20	Academy of Management Journal	1	0.7%	96.0%
21	Business History	1	0.7%	96.6%
22	Industrial Management & Data Systems	1	0.7%	97.3%
24	Journal of Economic Geography	1	0.7%	98.0%
25	Journal of World Business	1	0.7%	98.7%
26	OMEGA-International Journal of Management Science	1	0.7%	99.3%
27	Urban Studies	1	0.7%	100.0%
	Total	149		

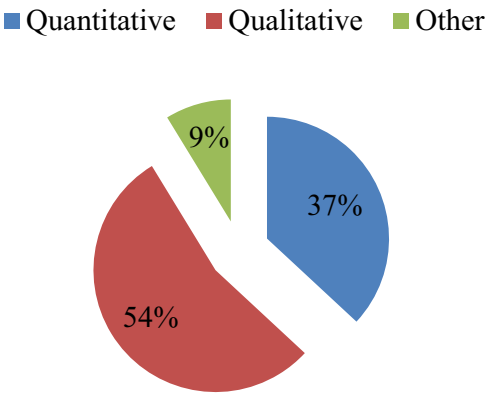

Fig. 3. Research Approach Utilized in Business Incubation Literature.

Incubation research is dispersed across several disciplines (Fig. 6). As expected, journals associated with the disciplines of innovation, entrepreneurship and economic development account for 53%, 22% and 11% of all publications, respectively. More minor roles are associated to not-for-profit public management (7%), sociology (2%) business strategy (1%), business history (1%), management science, (1%), and human resource management (1%).

Analysis of the 149 papers with regard to authorship indicates that the 17 most active scholars have published more than two

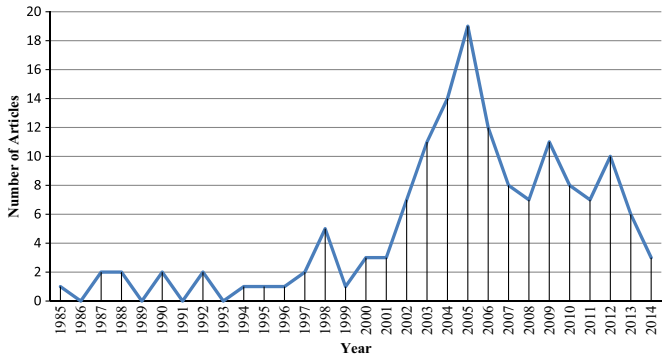

Fig. 4. Number of Articles per Year on Business Incubation.

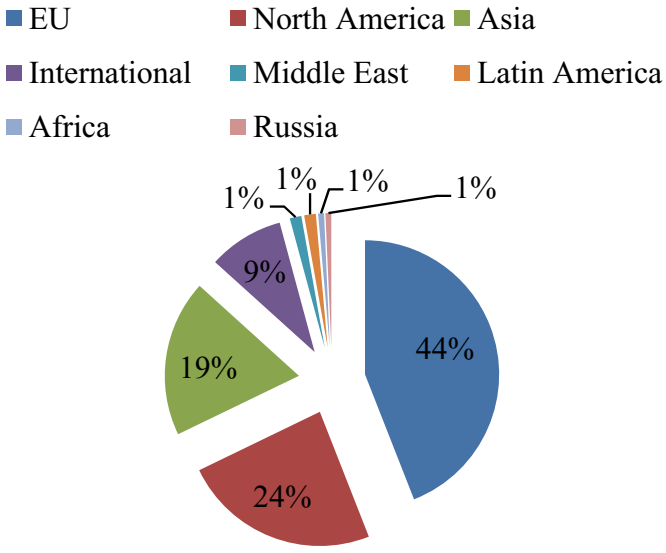

Fig. 5. Publication of Business Incubation Research Based on Authors Location (1985–2014).

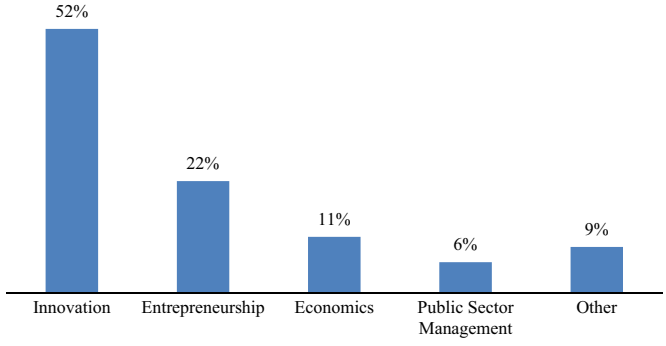

Fig. 6. Distribution of Authors of Business Incubation Research by Discipline.

articles and 175 authors who have published one article. (Fig. 7)

A citation analysis of the 149 papers found five articles with more than 100 citations. An additional 15 papers with 50 or more citations; 39 papers with 20-49 citations; 39 papers with 10–20 citations, and the remaining 51 papers with fewer than ten citations. Appendix B lists the 20 articles with 50 or more citations. Highly cited TBI articles focus on incubator assessment, business incubator model, links between incubator firms and universities, incubator added value, the incubator's bridging role between industry and university, and incubation management practices. These results also correspond to the themes of the overall set of 149 scholarly papers included in this research.

The most researched theme (Fig. 8) is incubator value-added (58%), covering incubator tenant support, impact on economic and

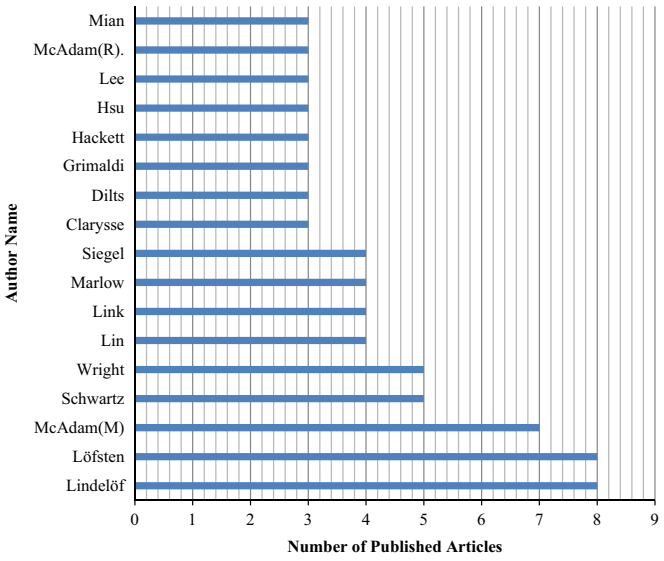

Fig. 7. Top Scholars Based on Publication Rate in the Technology Business Incubation Field (1985–2014).

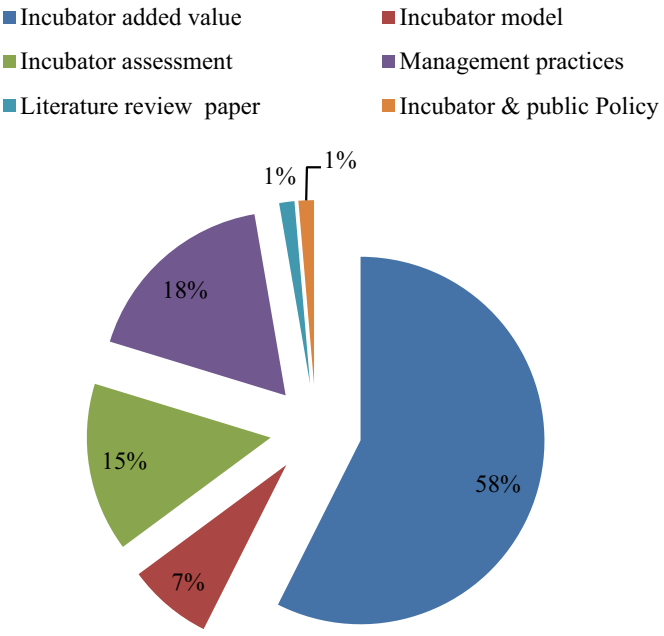

Fig. 8. Technology Business Incubation Publications by Theme (1985–2014).

regional development, and university-industry technology transfer. Management practices within the incubator (18%) include incubation strategies, tenant selection screening, success factors, entrepreneurial orientation of the incubator, and its best practices. Incubator performance assessment (15%) proposes theoretical approaches to conducting empirical studies and comparative analyses to assess performance. Incubator models and their longitudinal evolution (7%) is also a common theme. There is a clear gap and need for research into the public policy role of business incubators.

5. Special issue contributions

The emphasis during paper solicitation was on the Technology Based Incubator (TBI) as a knowledge-based entrepreneurial development concept employed to strategically engage in activities that nurture high value-added technology-oriented firms.

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Following a general call for papers 43 interesting articles covering various incubation topics were received. Out of these articles with a strong fit with TBI knowledge domain were considered and sent out for a rigorous double-blind review. Five articles successfully completed the review process and are now summarized along with their contributions.

Charlotte Pauwels, Bart Clarysse, Mike Wright, and Jonas Van Hove in their paper *Understanding a new-generation incubation model: the accelerator* consider the accelerator as a novel and emerging incubation mechanism that has generated considerable excitement in the incubation industry. Modern accelerators address the key challenge faced by traditional incubators—the 'life support trap'. Functionally, accelerators are designed to provide a rich service structure of mentorship, networking opportunities, and access to funding. As Pauwels et al. (2016) indicate the real challenge is to understand the distinctive characteristics and profiles and how they may be useful for individual entrepreneurs and their start-ups. The study investigates multiple cases from Europe's three richest urban ecosystems—London, Paris, and Berlin. Through inductive research, the article contributes to the literature by extending recognition of the heterogeneity of incubation models, describing the accelerator as a distinctive incubation model and introducing the design lens as a useful theoretical framework to pinpoint three accelerator types.

Next, Danny Soetanto and Sarah Jack in their paper *The impact of university-based incubation support on the innovation strategy of academic spin-offs* explore a new dimension of the incubatee spin-off firm's implementation of innovation strategy. By considering various permutations of exploration versus exploitation, the study determines how a tenant spin-off firm's performance is enhanced through value-adding support services provided by the university incubator. The spin-off firms investigated are from the: United Kingdom, Netherlands, and Norway. Soetanto and Jack (2016) assert that by studying the interactions between innovation strategies and incubation support services, a more refined understanding of the strategy selected by spin-offs is provided. The work enhances understanding of the type of incubation support that has a greater impact on incubatee firm's strategy and performance.

Isabel Diez-Viala and Ángeles Montoro-Sánchez in their paper *How knowledge links with universities may foster innovation: The case of a science park* highlight the benefits to science park tenants of dense knowledge links. Díez-Vial and Montoro-Sánchez (2016) evaluate how technological knowledge flows through university-firm and inter-firm networks increase innovation by science park residents. They determine that firms with the capacity to acquire and assimilate knowledge from universities—due to either being academic spin-offs or having long-term relationships—receive more knowledge from them. It is also argued that firms with central positions in local firm networks access complementary sources of technical knowledge. Empirical evidence was gathered from the Madrid Science Park. A positive relationship between technological knowledge obtained from universities and firms' innovation was observed. Finally, it was confirmed that firms with a significant role as intermediaries between other co-located firms are more innovative – regardless of the presence/absence of relations within the university.

Enrico Baraldi and Malena Ingemansson Havenvid, in their paper *Identifying new dimensions of business incubation: A multi-level analysis of Karolinska Institute's incubation system* use an in-depth case study of the incubator at the Swedish Medical University's Karolinska Institute (KI) to identify new analytical and strategic dimensions of incubation. Departing from the current literature's prevalent focus on incubators as organizations performing a predefined set of activities for incubatees, the authors' multilevel analysis integrates the incubator's organization to broader institutional and inter-organizational goals. The analysis focuses on seven key components of incubation: time, place, sources, resources, control/governance, activities/services, and outcomes. Baraldi and Havenvid (2016) view incubators as strategic actors engaged in value creation on a global level rather than an incubator level. Choices and interactions are considered through the lens of various streams in the business strategy literature. The six specific strategic drivers of business incubation identified are: (1) positioning in the value chain, (2) risk-taking/time perspective, (3) revenue model, (4) governance/control, (5) internationalization, and (6) cooperation/competition.

Finally, Maura McAdam, Kristel Miller, and Rodney McAdam in their paper *Situated regional university incubation: A multi-level stakeholder perspective* employ stakeholder theory to develop university incubation models with respect to their unique regional and organizational characteristics and constraints. The quadruple helix of stakeholders is utilized. Regional university characteristics are accounted for. The research methodology employed is a comparative case analysis of incubation programs of two different universities within the United Kingdom. Macro, meso, and micro environmental factors were found to influence the incubation mechanisms of the two universities. Stakeholder influences, both regional and university-specific, impacted incubation programs through resource dependency relationships and withholding/usage strategies. Quadruple helix actors are viewed as stakeholders. Variances in incubation models occur despite being located in the same region. The research contribution is empirically illustrating the importance of both considering regional factors and university characteristics when designing incubation strategies for regional and national development as opposed to adopting a best-practice approach.

Having considered the papers in this issue, concluding notes are offered with a call for future directions in a field that has proven to be valuable for economic development, improving success rate and growth of start-ups, academic entrepreneurship and technology intensive businesses.

6. Conclusion and future research directions

Since the 1950s the TBI's have grown in influence, number and variety. Today, those interested in stimulating knowledge-based entrepreneurial development foster the use of TBIs for nurturing firms. Global support of TBIs has resulted in developing new types of mechanisms. Economic regions interested in technology-based economic development actively employ a myriad of incubation programs. Despite decades of progress and experience, Technology Business Incubation is complex and multi-faceted, many gaps and unanswered questions regarding the incubation process remain.

Using insights from the extant literature, one can move beyond question of why TBIs exist, to define Technology Business Incubation and the underlying constructs as applied to science/research parks, technology-oriented incubators, and accelerators. There is relative clarity in understanding the differences among TBI mechanisms in supporting the startup cycle of technology businesses during incubation. However, definitional confusion is caused by differences in the elements that comprise a TBI-physical space, professional management, entry and exit policy, a mix of business support and professional services, networking, access to capital, and university resources. For example, physical space is needed for science/research parks and incubators. However, mentoring and seed capital is needed for accelerators (Cohen, 2013).

The wide variety of approaches shows the diverse and multi-disciplinary of the field. Though this analysis reveals the need to develop a unified theory of incubation covering TBI mechanisms, the challenge is the tremendous variation in program sponsorship and policy objectives. Consequently, a contingency approach to incubation is proposed to address varying objectives, organizational form, and context.

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Phan et al. (2005) rationalized public support for incubation by emphasizing how societal objectives and social returns of innovation exceed the private returns of these activities by providing indemnification of the entrepreneur's risk by supporting an embryonic technology that may not emerge otherwise. For technology-intensive incubation, the need is now to explore why innovation market failures adversely impact TBFs and how TBIs are designed differently to support technology-intense firms.

As stated earlier, TBIs increasingly create regional integration and provide enriched value-added services-from tenant mentoring to integrated living. Consequently, a nested view of TBIs as bridging mechanisms embedded within a dynamic innovation ecosystem has been explored with different levels of analyses-national, regional/state, park/incubator, and entrepreneur/team level (Etzkowitz, 2002; Corona et al., 2006). This work points to the appropriateness of regions treating TBIs as complementary rather than competitive. Hence networks of parks and incubators can create a dynamic innovation ecosystem. This multi-level research thread has been illustrated in this issue by McAdam et al. (2016) and needs to be pursued further.

As an organization the TBI mechanism's governance needs to be explored with respect to the relationships between management, client firms, and other key stakeholders. For example, university incubation programs need to address the TBI's role in bridging entrepreneurial firm-university relations. Díez-Vial and Montoro-Sánchez (2016) take a step in this direction. At a more micro level an in-depth exploration of the incubation process is still needed (Clarysse et al., 2005; Ahmad, 2014). Baraldi and Havenvid (2016) take a novel approach to this need by focusing on the incubation system in a dynamic global environment.

Accelerators are highly promising as a new post-start-up incubator model for providing targeted assistance over a limited period (e.g. three to six months) to help young TBFs achieve sustained growth. While accelerators have proliferated, research on the role and efficacy of these programs is limited (Hochberg, 2015), providing opportunity and need for study. Pauwels et al. (2016) offer better understanding of the incubation process of modern accelerators through the inductive use of the design perspective for theory development. Three different accelerator archetypes are identified. This line of research requires special attention.

A systematic literature review (1985–2014) focused on scholarly publications in high quality journals proves interesting results. Reflecting the technology and innovation intensity of incubation, four of five journals most likely to publish incubation research are technologically-oriented: *Technovation, Journal of Technology Transfer, Research Policy*, and *R&D Management*. With time there is growing research interest in this area (10 articles/year from 2002–2013) showing need and importance. The research has been predominantly qualitative and covering a limited number of themes such as value-added, management, and assessment. An absence of research from African and South America is notable-more international effort is needed to advance the TBI research agenda.

Despite caveats and skepticism noted in some literature, continued efforts in experimentation and learning have resulted in significant progress in making TBI mechanisms mature, promoting continued growth, and widespread use. This consolidation offers opportunities for the TBI community for further development of conceptual understanding and underlying theory. This retrospective assessment indicates a comprehensive development of the TBI knowledge domain remains challenging due to legitimacy, research methodology, theory development, and program sustainability. In summary TBIs are successful as a policy for economic and social growth, however, the special issue assists in further understanding and theoretical development and acts as a call for further research.

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Appendix A

See Fig. A1

Appendix B

See Table B1

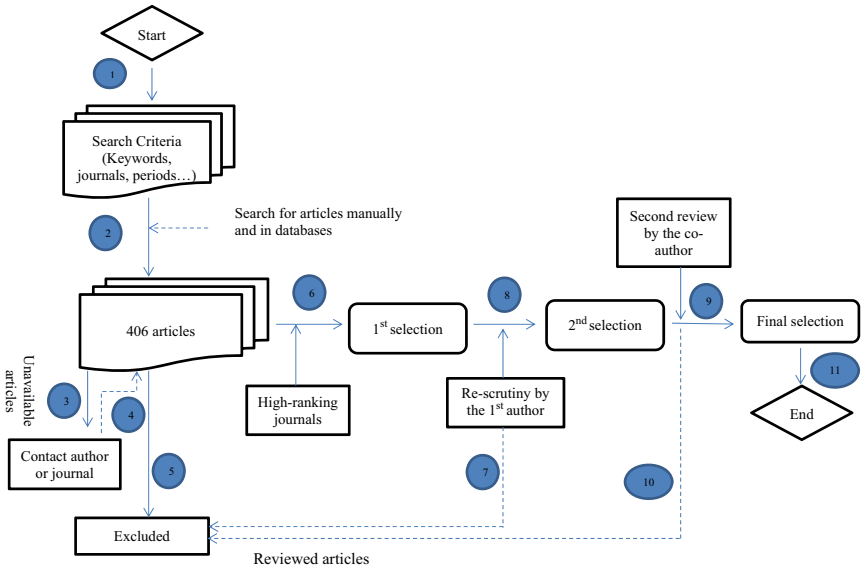

Fig. A1. Logic flow chart of the protocol used to find and select articles.

Table B1
Most cited papers in the Technology Business Incubation field

	Article	Cites	Research question	Data	Dep. variables	Findings
1	Title: Spinning out new ventures: a typology of incubation strategies from European research institutions. By: Clarysse, B; Wright, M; Lockett, A; et al. (2005)	162	What differences or similarities are there in the goals and objectives of research institutions for creating new spin-out ventures? What different incubation strategies are employed to achieve these goals in terms of the resources utilized and activities undertaken?	Stage 1: seven spin-outs Stage 2: 43 cases	N/A	Identification of three distinct incubation models to manage the spin-out process: Low Selective, Supportive, and Incubator. The different incubation models have very different resource implications in managing the spin-out process. This process identified two categories that departed from the normative models, namely the Resource-Deficient group and the Competence-Deficient group.
2	How effective are technology incubators? Evidence from Italy. By: Colombo and Delmastro (2002)	123	How effective are technology incubators?	45 NTBFs	Start-up size and post-entry growth	Incubated firms show higher growth rates than their non-incubated counterparts. They also perform better in terms of adopting advanced technologies, aptitude to participate in international R&D programs, and establishing collaborative arrangements, especially with universities. Lastly, it is easier for them to access public subsidies.
3	Science parks and incubators: observations, synthesis and future research By: Phan, PH; Siegel, DS and Wright, M (2005)	113	How can we better understand science parks and incubators?	N/A	N/A	There is no systematic framework to understand science parks and incubators. There is a failure to understand their dynamic nature as well as that of the companies located in them. There is a lack of clarity regarding the performance of science parks and incubators which is associated with problems in identifying the nature of performance.
4	Assessing value added contributions of university technology business incubators to tenant firms. By: Mian, SA. (1996)	106	What contributions do university incubators make to new technology-based start-ups in the form of various services provided? What additional benefits accrue from the university relationships? What are some of the implications for technology-based firms?	Six university incubators in the United States: three from private universities, three from public universities	N/A	There is a significant relationship between "frequency of use" and "perceived value added". Exception: cafeteria use, assistance in legal/government regulation, personal recruiting, and tax matters. All university-related services are significantly correlated. Thus, university incubators provide a nurturing environment for NTBFs.
5	Assessing and managing the university technology business incubator: An integrative framework By: Mian, SA. (1997)	103	How can we assess the performance of University Technology-Based Incubators (UTBIs)?	Four UTBIs and their 29 tenant firms	N/A	UTBIs are assessed in three categories: (i) Performance outcomes-program sustainability and growth, tenant firms' sustainability and growth, and contributions to the sponsoring university's mission; (ii) management policies and their effectiveness; (iii) services to tenants and their added value.
6	Science Parks and the growth of new technology-based firms-academic-industry links, innovation and markets. By: Löfsten and Lindlöf (2002)	92	Are there any differences between New Technology-Based Firms (NTBFs) that locate in science parks and those that locate elsewhere?	273 firms (in and outside science parks) in Sweden	Sales, number of employees	There are some differences between firms inside and outside science parks NTBFs in terms of innovation and marketing. NBTFs in science parks are more likely to have links with universities. There is no statistically significant difference in profitability between firms inside and outside a park.
7	The networked business incubator leveraging entrepreneurial agency? By: Bollingtoft, A and Ulhoi, JP (2005)	82	What is it that facilitates or hinders networking in a networked incubator?	One networked incubator	N/A	The mechanisms that facilitate or hinder networking in an incubator can broadly be divided into two main categories: (i) mechanisms connected to individuals and their relations with each other and (ii) mechanisms related to the construction of the incubator.

8	Science parks and university-industry interaction: geographical proximity between the agents as a driving force. By: Vedovello (1997)	79	To what extent does a science park facilitate university-firm links?	One British science park	N/A	A science park can facilitate the establishment of informal and human resource links, but links related to research activity are not substantially facilitated.
9	Co-production of business assistance in business incubators: an exploratory study By: Rice, MP (2002)	76	What are the outputs of the co-production process aimed to address the needs of the consumer producer, i.e. the incubator company? What are the inputs of regular and consumer producers? How is co-production implemented? How can variability in outputs, inputs and output elasticities be characterized?	8 incubators and 8 incubator managers. 32 entrepreneurs	N/A	This exploratory study illuminates the nature of the dyadic co-production relationship between the incubator manager and the entrepreneur, and defines co-production modalities. It also provides insight into the factors that affect output elasticities.
10	University-incubator firm knowledge flows: assessing their impact on incubator firm performance. By: Rothaermel and Thursby (2005a)	71	How does knowledge flow from universities to incubator firms? How do these flows affect the performance of new technology ventures?	79 tech ventures incubated at Georgia Tech	Firm performance	Knowledge flows from universities to incubator firms through contractual and non-contractual routes. These knowledge flows increase the firms' absorptive capacity, which is positively related to firm performance.
11	Assessing the impact of university science parks on research productivity: exploratory firm-level evidence from the United Kingdom By: Siegel et al., (2003a)	71	Empirical evidence on the impact of university science parks on the research productivity of firms	177 firms	R&D output	Firms located in university science parks have slightly higher research productivity than observationally equivalent firms not located in university science parks
12	Incubator firm failure or graduation? The role of university linkages. By: Rothaermel and Thursby (2005b)	68	How does the strength of the tie between the sponsoring university and incubator firms affect their life chances?	79 tech ventures incubated at Georgia Tech	Failure of firms remaining in the incubator, and successful graduation	Strong ties to the sponsoring university reduce the likelihood of firm failure because of strong intellectual property protection, quality signaling effect, and involvement of potential investors. Strong ties, however, retard graduation from the incubator. Weak ties, such as informal interaction with the faculty, do not affect outright firm failure or timely graduation.
13	US science parks: the diffusion of an innovation and its effects on the academic missions of universities. By: Link and Scott (2003)	68	What are the influences of science parks on the academic missions of universities?	88 US academic institutions	Outcomes of university involvement with organizations in a science park	A formal relationship between the university and the science park increases publication, patenting, extramural funding, ability to hire preeminent scholars, and placement of doctoral students. The closer the distance, the greater the influence of park tenants on the university's curriculum.
14	Incubator best practice: a framework By: Bergek, A. and Norrman, C. (2008)	63	A framework that can serve as a basis for identifying best practice incubator models.	16 Swedish incubators	N/A	This research suggests a theoretical framework which includes three distinguishing model components: selection, business support and mediation. It distinguishes idea-focused selection from entrepreneur-focused selection and selection through "picking the winners" and "survival of the fittest". Business support is seen as a continuum from "laissez-faire" to "strong intervention". Mediation strategies vary in terms of the type of innovation system in focus: technological, regional or cluster.
15	Business incubators and new venture creation: an assessment of incubating models By: Grimaldi and Grandi (2005)	58	Why there are differences in the way incubators run their businesses?	8 Italian incubators	N/A	The existence of different incubators and the evolution of their business models over time have been driven by the evolution of company requirements and needs, which in turn has prompted incubators to diversify their offer of services. Two main incubating models, Model 1 and Model 2, may provide incubators with useful strategic indications on how and where to position themselves.
16	Science parks and the performance of new technology-based firms: a review of recent UK evidence and an agenda for future research By: Siegel et al., (2003b)	58	What are the performance differentials between firms located in science parks and those outside science parks? Why do the differences exist?	N/A	N/A	The "returns" from being located in a science park are negligible. These results may be due to imprecise estimates of these returns to different types of science parks.

Table B1 (*continued*)

	Article	Cites	Research question	Data	Dep. variables	Findings
17	Science park, a high tech fantasy?: an analysis of the science parks of Greece By: Bakouros et al., (2002)	55	The links maintained between incubator firms and the university and the synergies between firms located in the park.	17 firms located in 3 science parks	N/A	Informal links have been developed between firms and the local university, but only the firms located in one science park have developed formal links. The formal links of companies in the other two parks are still infantile at this time. Synergies between science park companies are limited only to commercial transactions and social interactions. Research synergies are completely absent in all three parks.
18	Academic-industry links and innovation questioning the science park model By: Quintas et al., (1992)	54	How do science parks link academic research with industrial activity?	UK science parks from UKSPA data	N/A	Link mechanisms: spin-off firms and research collaboration. Deficiency of a science park model: (i) Mismatches between academic research output and the R&D needs of science park firms, (ii) Science park restrictions on manufacturing activity.
19	Opening the ivory tower's door: an analysis of the determinants of the formation of US university spin-off companies By: Link and Scott (2005)	51	Characteristics associated with university differences in the formation of spin-off companies, specifically university-based companies that locate in the university's research park.	51 university research parks	Percentage of park organizations that are university spin-off companies in year 2002	University spin-off companies represent a greater proportion of companies in older parks and in parks associated with richer university research environments. They also represent a larger proportion of companies in parks that are geographically closer to their university and in parks with a biotechnology focus.
20	Critical role and screening practices of European business incubators By: Aerts et al., (2007)	50	Screening practices of business incubators within the European context.	97 incubators	Tenant failure rate during stay at incubator	Most incubators do not screen potential tenants on a balanced set of factors, but concentrate either on the characteristics of the tenant's market or on those of the tenant's management team. The tenant survival rate is positively related to a more balanced screening profile.

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