International Journal of Engineering Education Vol. 29, No. 5, pp. 1068–1079, 2013
Printed in Great Britain

0949-149X/91 $3.00+0.00

Entrepreneurship Education and Research Commercialization of Engineering-Oriented Universities: An Assessment and Monitoring of Recent Development in Korea*

HYUNGSEOK YOON[1]
Department of Business and Technology Management, Korea Advanced Institute of Science and Technology (KAIST), 373-1 Guseong-dong Yuseong-gu, Daejeon, South Korea. E-mail: davidyoon@kaist.ac.kr

JOOSUNG J. LEE[2]
Department of Business and Technology Management, Korea Advanced Institute of Science and Technology (KAIST), 373-1 Guseong-dong Yuseong-gu, Daejeon, South Korea. E-mail: jooslee@kaist.ac.kr

This research aims to assess and compare the entrepreneurial competitiveness of KAIST (Korea Advanced Institute of Science and Technology) and MIT (Massachusetts Institute of Technology) from entrepreneurship education and research commercialization standpoints. The assessment results have provided KAIST with strategic directions for implementation of new measures to enhance its entrepreneurial competitiveness. The new measures which brought a positive impact on the entrepreneurial performance of KAIST have been used to develop catch-up strategies for engineering-oriented universities in late-comer countries. The key findings of this research provide policy makers in late-comer countries with strategies for the successful university entrepreneurship.

Keywords: entrepreneurship education; research commercialization; catch-up strategy

1. Introduction

Universities in knowledge economy have become increasingly entrepreneurial by not only focusing on education, but also commercialization of research and technology [1, 2]. Likewise, the imperative of shifting towards a knowledge-based economy requires a significant increase in the indigenous capabilities of universities to educate students through entrepreneurship education and enhance the capability of knowledge commercialization through university-industry collaboration [3]. In the case of Korea, KAIST (Korea Advanced Institute of Science and Technology) was established in 1971 for the purpose of transforming the nation from a basic agrarian economic structure to a world leader in complex technology. In accordance with the purpose, KAIST has contributed to the national economic growth during the industrial era by developing key technologies and generating well-educated work forces for Korean conglomerates including Samsung and LG (see Fig. 1). By 1993, KAIST has become a think tank by generating academic publications accounting for almost a third of Korea's academic publications [4]. As a result, Korea has ended up achieving a position near the more developed countries with the transitional position of catching up country throughout 90s [5]. In addition, according to the Ministry of Education, Science, and Technology, KAIST has been the top higher education institution in Korea for the generation of both domestic and international patents from 2006 to 2010 [6]. Nevertheless, the university has shown an atypical phenomenon of being far from entrepreneurial university with a low commercialization rate, in spite of its global academic reputation and abundant basic science resources along with proactive government initiatives [7]. In light of these issues, Korean government has initiated projects to transform KAIST into entrepreneurial model for it to act as the new growth engine.

As a part of on-going projects over the last few years at KAIST, this research assessed the entrepreneurial capabilities of KAIST. The research was conducted in a comparative analysis with MIT, as MIT has been KAIST's benchmark including its founding initiative and goals, which are to make KAIST as good as MIT. KAIST and MIT share similarities of being the best engineering and research-oriented universities in the U.S and Korea respectively, as well as being located in industrial clusters, Route 128 for MIT and Daedeok Innopolis for KAIST. Also, MIT has been playing the role as one of the most important source of university technology and start-up creation. Its impact on the world economy was found to be as follows: "25,800 MIT alumni founded companies

[1] Corresponding author; [2] Co-Corresponding author.

* Accepted 11 March 2013.

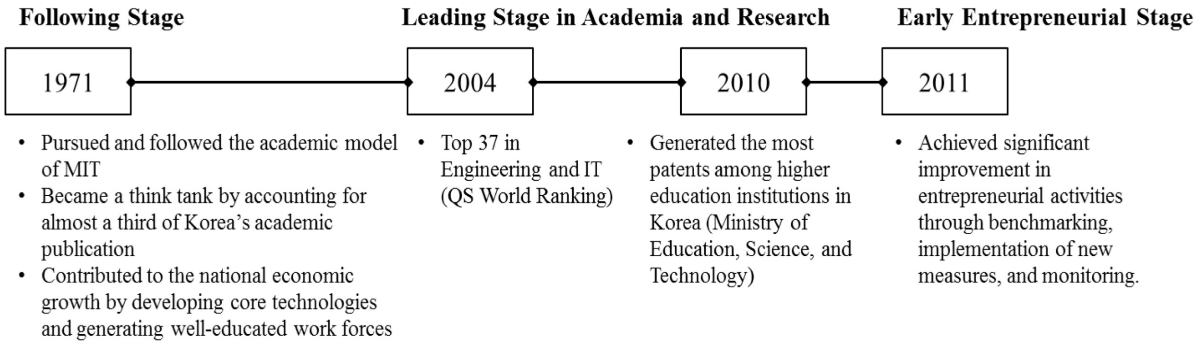


Fig. 1. Timeline of KAIST.

have been creating jobs for approximately 3.3 million people and generating annual world sales of $ 2 trillion which would be equivalent to seventeenth-largest economy in the world" [8]. With such eminent performance, MIT is the most benchmarked university in terms of start-up creation and technology commercialization [9–11]. Emulating successful private institutions such as MIT may not be the best strategy, due to differences in institutional and socio-economic contexts. Still, Etzkowitz [11] recommended to design entrepreneurial universities according to MIT prototype focusing on creating a more dynamic society, emphasizing entrepreneurship, firm-formation and risk-taking. Accordingly, KAIST has been implementing new measures by benchmarking MIT and the authors have been monitoring the improvement during the last few years. As a result, with the implementation of new measures, KAIST has entered the early entrepreneurial stage in 2011.

In addition, this research identifies strategic directions and develops catch-up strategies for engineering-oriented universities in late-comer countries, as the shift from universities' traditional educational model to the new entrepreneurial university model is expected to be even more crucial for late-comer countries. The policy makers in late-comer countries recognize the important role of university research in generating innovation for economic and societal development [12]. In this sense, the role is to lessen the negative impact of economic crisis and solve unemployment issues by commercializing the outcome of R&D and creating both business and job opportunities. In other words, the entrepreneurial model of university has a positive influence on employment structure and regional economic growth [2]. Accordingly, the late-comer economies such as the Dominican Republic and Ecuador in Latin America have initiated building and restructuring the higher education institutions, in order to foster indigenous innovation through the vitalization of university-industry linkage [13]. Therefore, such lessons learned from comparative case studies of KAIST and MIT have been applied to the cases of the late-comer countries including Dominican Republic and Ecuador. The status of these late-comer countries is similar to the situation of Korea, when KAIST laid the groundwork for a breakthrough in national innovation. These late-comers are striving to transform their industrial structure from low value added to high value-added by establishing a KAIST-like academic model. Korea was able to achieve its dramatic economic growth and industrialization by generating high quality technical human resources with the establishment of an engineering and research-oriented institution "KAIST" [4, 13]. However, on top of this academic model established by KAIST, the "later-comers" should consider exploiting their late arrival to advance toward entrepreneurial model of universities, rather than having to replicate the entire trajectory of universities including the stages of education and research-oriented model. Hence, the objectives of this research are as follows:

- Compare the entrepreneurial competitiveness of KAIST and MIT to identify strategic directions
- Monitor the impact of newly implemented measures at KAIST
- Develop catch-up strategies for engineering-oriented universities in late-comer countries

2. Methodology

For the purpose of the present study, the concept of entrepreneurial competitiveness is approached from entrepreneurship education and research commercialization standpoints. Previous studies addressed that universities contribute to entrepreneurship both through entrepreneurship education and research commercialization [14]. First, entrepreneurship education has an indirect impact on the vitalization of university entrepreneurship by significantly increasing the entrepreneurial intentions of students [15]. Since the number of start-ups created by KAIST students throughout late 1990s and early 2000s was extremely low, the status of entrepreneurship education was evaluated which plays an important role in positively changing the entrepreneurial intentions of students. The competitiveness of entrepreneurship education was measured by the number and composition of courses, composition of faculty members, outreach activities, and students' willingness to become entrepreneurs upon graduation [16, 17]. Secondly, research commercialization activities directly influence the technology transfer and entrepreneurial performance of universities by being the seedbed for new ventures [18]. In this sense, KAIST has increased its commercialization activities for the last decade with a more or less full range of support mechanisms for entrepreneurship and technology transfer. However, potential entrepreneurs including faculty members and students at KAIST have addressed that they are in the early stage of the development, requiring some improvement for better operations. Thus, the elements of research commercialization included such intermediaries as innovation centers, incubators, patenting offices, etc. In order to evaluate the competitiveness of research commercialization, productivity of technology transfer and licensing operations, self-sufficiency of human resources, and interactions among entrepreneurship-supporting organizations were taken into account [19].

This research has been carried out in three stages (see Table 1). First, the authors assess and compare the entrepreneurial competitiveness of KAIST with that of MIT, from which strategic directions for KAIST are identified. In the second stage, the actual measures implemented by KAIST for the improvement of its entrepreneurial competitiveness are monitored. In the last stage, the authors formulate catch-up strategies based on the key findings learned from the first two stages. Throughout the first two stages of our research, many interviews and surveys have been conducted. The authors used the entrepreneurial university framework provided by the Organization of Economic Co-operation and Development [19] in order to conduct interviews with key leadership of KAIST in a comprehensive manner. The interview framework for measuring the entrepreneurial competitiveness consists of six criteria including strategy, resources, support infrastructure, start-up support, evaluation, and entrepreneurship education. Our interview sample includes directors of KCI (KAIST Center for Innovation Initiatives), OUIC (Office of University-Industry Cooperation), CSE (Center for Science-based Entrepreneurship), and professors who have been actively engaged in entrepreneurship education and technology commercialization activities in KAIST. In addition, a nation-wide survey targeting university-based business incubators and technology licensing offices was conducted in order to grasp the status of entrepreneurship-supporting organizations in Korean universities. A survey on capturing KAIST students' willingness to pursue entrepreneurship upon graduation was conducted on students who took regular entrepreneurship courses at KAIST. Secondary data including organizational structure, technology transfer, and university policies of KAIST and MIT were collected through library research. Since KAIST has been implementing new measures to improve its entrepreneurial competitiveness, the annual performance report of KAIST provided its status compared to that of MIT. Lastly, in the stage of formulating catch-up strategies, data were collected by conducting interviews and surveys to engineering-oriented universities and entrepreneurship centers in the Dominican Republic and Ecuador. These proce-

Table 1. Methodological mapping

	Objectives	Primary Data	Secondary Data
Stage 1	– Weak points and strategic directions of KAIST have been identified by comparing the case of MIT	– A survey to measure the entrepreneurial willingness of KAIST students – A nation-wide survey sampling business incubators and technology licensing offices in Korea	– Government reports – Local Newspapers – KAIST annual performance report
Stage 2	– Based on the weak points of KAIST, actual measures taken by KAIST and their impact are explained	– Focus group interviews with key leadership of entrepreneurship supporting organizations and faculty members of KAIST – Open-ended interviews with KAIST students	– KAIST annual performance report – KAIST monthly newsletter
Stage 3	– With the lessons learned from new measures implemented at KAIST, catch-up strategies are formulated for late-comer countries	– Interviews with political leaders, public officers, CEOs, and educators in the Dominican Republic and Ecuador	– Project reports produced by Inter-American Development Bank

dures were critical in reflecting the needs of engineering-oriented universities in the late-comer countries.

3. Assessment of KAIST

3.1 Overview

At KAIST, there are currently five supporting organizations in pursuit of vitalizing university entrepreneurship (see Table 2). Other than OUIC which was established in 1994, CSE and KCI were recently established in 2004 and 2010 respectively. This recent strong initiatives in entrepreneurship started from 2004, when High-Tech Venture Center (HTVC) formerly known as Technology Innovation Center (TIC) & Technology Business Incubation (TBI) was enlarged and reorganized into the current OUIC. OUIC was able to expand the pool of their human resources for technology commercialization activities and extend their simple role as an incubator to technology licensing and project coordination through university-industry collaborations. In addition, business economics minor program under the School of Innovation was implemented in 2005. Although KAIST operated entrepreneurship education with the opening of College of Business in 1996, it provided limited number of courses with its weakness in geographical proximity between Seoul and Daejeon, where the main campus of KAIST is located.

MIT is the most important source of university technology creation in the U.S, as it was one of the earliest universities to establish a formal TTO (Technology Transfer Office) in 1932 with one of the most successful technology transfer functions in the U.S. [10, 11]. However, MIT does not have an internal incubator for ventures that lessens the early stage burdens of potential entrepreneurs. Rather, MIT focuses on growing faculty, student, and alumni initiatives with its proactive entrepreneurship education and vibrant ecosystem. All of these forces, in conjunction with supporting organizations that contributes to MIT entrepreneurial ecosystem, have been productive in creating new firms with impressive economic impacts [8].

3.2 Entrepreneurship education

Current entrepreneurship education curriculum at KAIST consists of 15 regular courses offered by both schools of engineering and business (see Table 3). Most of the courses focus on graduate level students rather than undergraduate students showing a similar trend with the U.S, where most uni-

Table 2. Entrepreneurship supporting organizations at KAIST and MIT

Entrepreneurial Activities	KAIST	MIT
Technology Licensing	– Office of University-Industry Cooperation (OUIC)	– Technology Licensing Office (TLO)
Entrepreneurship Education & Research	– School of Innovation – College of Business	– Sloan School of Management
Grant Program	– Office of University-Industry Cooperation – KAIST Center for Innovation Initiatives (KCI)	– Office of Sponsored Program (OSP) – Desphande Center – Industrial Liaison Program (ILP)
Mentoring	N/A	– Technology Licensing Office – Trust Center for MIT Entrepreneurship
Networking Activities	– Center for Science-based Entrepreneurship (CSE)	– Trust Center for MIT Entrepreneurship – Legatum Center for Development & Entrepreneurship
Incubation	– Office of University-Industry Cooperation	N/A

Table 3. Profile of regular entrepreneurship courses at KAIST and MIT

Category		KAIST	MIT
Number of Courses per Student Target	Undergraduate	3	2
	Graduate	12	46
	All	N/A	6
Number of Courses per Academic Unit	Engineering	10	5
	Business	5	49
Total Number of Courses		15	54

Source: KAIST Course Catalog, Martin Trust Center for MIT Entrepreneurship.

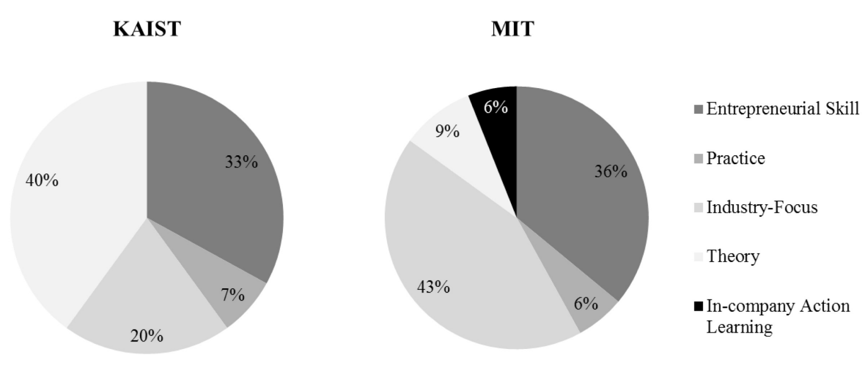
versities base their programs in graduate level [16]. Still, the professors from KAIST have commented that the number of entrepreneurship-focused courses offered to students is approximately one third of the curriculum in the U.S. This may have been due to the fact that KAIST does not operate an independent entrepreneurship-related program or academic track. In contrast, there are 54 regular entrepreneurship courses offered at MIT. Among them, 49 subjects are offered by the Entrepreneurship & Innovation Track (E&I) within MIT Sloan MBA Program established in 2008.

With the regular program at MIT, they have re-strengthened their monitoring system for measuring the number of companies started from their institutions and resulted in increasing their expectations. In this sense, opening a regular entrepreneurship program should be taken into considerations in order for universities to increase their focus on entrepreneurial activities as well as to increase the entrepreneurial intentions of students [20].

With regard to the composition of regular entrepreneurship courses at KAIST, the entrepreneurship courses focus on teaching basics and general knowledge on forming new ventures, rather than specialized topics related to emerging technologies focused on certain industries (see Fig. 2). This resulted in a failure to integrate the very important technical and engineering design aspects from which engineering students may find their entrepreneurial motivations [16]. In contrast, the majority of subjects at MIT are aiming to teach special topics in emerging technologies and new product development with its strong engineering background. Therefore, designing specialized programs targeted for each student group depending on their major, as well as utilizing synergy between engineering and business schools should be taken into consideration [16, 17]. Also, unlike the curriculum structure of KAIST, MIT provides courses that allow students to pursue "in-company action learning". These courses enable students to gain experiences by working with top managements of global start-ups. Consistent with this view, the entrepreneurship courses should be complemented with experiment and interaction-oriented environment through university-industry cooperation in educational setting.

In regard to faculty composition, the professors from College of Business and School of Innovation at KAIST raised their concerns on insufficient number of faculty members with entrepreneurial experiences. Entrepreneurial background of faculty members is critical in not only helping courses by providing real-world knowledge, but also with excellent networking opportunities for students. In the case of MIT, half of the professors in E&I track have made significant academic contributions in the field of entrepreneurship, and the rest are practitioners with managerial experiences in venture capital, law, sales, marketing, or consulting, i.e. This is a part of MIT's strategy to bring key actors of various fields into classes. Unlike traditional business education, entrepreneurship education should be experiment-oriented that demands interactions with the world. Therefore, the involvement of adjunct faculty should be maximized which is critical to the success of entrepreneurship education program [21].

In order to maximize the outcome of entrepreneurship education, networking activities such as business competitions, clubs, and conferences are good methods for gaining access to a wide range of networks, fostering interactions between and among various stakeholders in entrepreneurial activities. Between 2006 and 2010, conferences and competitions such as Business Economics Essay Competition, Business Plan Competition, and Pre-Star-Venture Competition have been organized by CSE (Center for Science-based Entrepreneurship) under the School of Innovation at KAIST. How-



Source: KAIST Course Catalog, Martin Trust Center for MIT Entrepreneurship

Fig. 2. Composition of regular entrepreneurship courses at KAIST and MIT.

ever, most of the conferences were sponsored and supported by Korean conglomerate companies, which made the deliverables to be retained by sponsoring companies. As a result, the conferences and competitions have failed to financially support potential student entrepreneurs to start their businesses; rather it was intended for sponsoring companies to utilize the ideas generated by university students. In the case of MIT, major networking events including $10k, $50k, and $100k are mainly organized by Trust Center for MIT Entrepreneurship which contributes to alumni networking and communications to stimulate entrepreneurial activities. In addition, in order to foster active participation of students in networking activities, MIT E&I track mandates their students to engage in at least one MIT $100K business plan team to build their own companies and fortunes with its alumni network of mentors, investors, and potential partners. As a result, MIT $100k has been so successful that 105 companies have been formed through active financing and mentoring provided by alumni entrepreneurs, venture capitalists, and others [8]. Thus, the main focus of organizing networking activities should be creating a "virtuous cycle" by maximizing the influence of successful alumni entrepreneurs on financing and mentoring of potential student entrepreneurs.

As for the outcome of entrepreneurship education, a survey on KAIST students' willingness to pursue entrepreneurship was conducted. The survey result indicated that out of 100 students at KAIST, only 5 students are interested in opening their own businesses. This is consistent with KAIST official statistics which indicated that most of the students pursue advanced studies or their career in becoming researchers. This may have been due to the social consensus and expectations to grow these students into eminent scholars or researchers, rather than entrepreneurs. On top of this, scholarship policy of KAIST hindered students from being engaged in start-up activities. Most of KAIST students receive scholarship from the government and KAIST. According to its previous policy, KAIST did not allow students receiving scholarships to be engaged in opening a business entity. In contrast, the entrepreneurial environment and culture at MIT encourages its students and convince them that entrepreneurship is an attractive goal throughout their studies and upon graduation. In fact, many laboratories at MIT have created this entrepreneurship-friendly atmosphere for students by giving more weight on the impact of research, rather than producing a good quantity of papers and patents. Especially, the MIT Media Lab where the emerging technologies are made actively encourages students to apply unorthodox research approaches to real world problems. Their impacts have been great and according to their top 25 list of products and platforms spun out of media lab research over the past 25 years includes Amazon Kindle, Sony Reader, Barnes & Noble nook, LEGO Mindstorms, etc. In conclusion, setting up entrepreneurship-friendly environment and policies is one good way of promoting the student entrepreneurship.

3.3 Research commercialization

Research commercialization productivity was measured as the annual R&D expense divided by the annual technology licensing income. As indicated in Table 4, KAIST's 6 year average commercialization productivity was 0.7 percent, which is approximately 12 times lower than MIT's 6 year average 8.7 percent. This may have been due to the lack of technology licensing professional in quantity and quality hindering KAIST's technology licensing operations from securing self-sufficiency and economy scale. In fact, KAIST has problems with the size of the organization and professional level of staff in charge of technology licensing. KAIST TLO (Technology Licensing Office) is established in the form of a division under OUIC and consists of 11 staff. Among them, 73% of staff are not full-time and only 27% of the staff show their expertise in licensing operations with their relevant degrees or work experiences to the roles and responsibilities of TLO positions. In consistent with this fact, the

Table 4. Differences in the commercialization productivity between KAIST and MIT

Unit: Million US$

University	Performance Indicator	2005	2006	2007	2008	2009	2010
KAIST	Income from Technology Transfer (B)	0.6	0.9	1.6	1.0	0.8	1.8
	R&D Expenditure (A)	103.5	129.4	142.7	139.4	189.4	214.2
	Commercialization Productivity (B/A)	0.6%	0.7%	1.1%	0.7%	0.4%	0.8%
MIT	Income from Technology Transfer (B)	35.4	42.3	62.2	76.9	66.3	60.1
	R&D Expenditure (A)	580.7	600.7	614.4	659.6	736.1	677
	Commercialization Productivity (B/A)	6.1%	7.0%	10.1%	11.7%	9.0%	8.8%

Source: NSF (National Science Foundation), KAIST Annual Performance Report, MIT TLO.

survey conducted by Korean National Assembly in 2008 [22] indicated that university-based TLOs in Korea have 3.6 full-time staff members on average, which is distinctively lower than those of U.S and U.K with 7.8 and 6 full-time staff members respectively. In particular, the number of employees who specialize in actual technology licensing work is on average only 0.6 per office throughout the university TLOs in Korea. In the case of MIT TLO, there are currently 38 staff members with their relevant academic backgrounds including business, engineering, and law and work experiences on average of more than 10 years in various industries. This may have been due to the effect of setting the MIT TLO as a separate entity in 1985. As shown in Fig. 3, MIT had its TLO under the OSP (Office of Sponsored Program) before 1985, which is the same as the current structure of KAIST's TLO in the form of a division under OUIC. However, with the establishment of MIT's TLO as a separate entity in 1985, it dramatically reoriented itself toward playing a far more active role in technology transfer and pursued the economy of scale. As a result, the latest figures average 80 to 100 agreements and about 500 disclosures per year, which is a remarkable improvement in commercialization productivity compared to the initial TLO year which averaged 8 to 10 agreements and registered approximately 120 invention disclosures [8]. Therefore, universities should consider establishing TLO in the form of separate entity in order to enhance the commercialization productivity and benefit from the economy of scale.

Another factor resulting in the low commercialization productivity of KAIST is the income sharing policy occurred from technology transfer operations. Under the current law, even though the income from university technology transfer operation incurs, 20 to 60 percent of incurred income needs to be returned to the organization that funded the research projects and of the remaining amount, additional 50 percent is compensated to professors and researchers. In other words, after KAIST invests in patent and labor costs occurred from technology licensing operations, KAIST TLO cannot retain enough profits, effectively preventing them from making proactive investment decisions, due to the small amount left after deducting the royalties and compensations imposed by government regulations. On the other hand, MIT TLO takes 15 percent of the amount left, after deducting patent expense from technology transfer income. The remaining amount is equally allocated to inventors, academic departments and general fund. This may have been possible due to the basis of MIT's policy stating that "MIT owns inventions made with significant use of MIT administered funds or facilities". Thus, university policies should be designed for the intermediaries in charge of technology transfer to retain a proper amount of income for further investment in various entrepreneurial projects. Also, the government law confining the income model of university technology transfer should be deregulated.

Lastly, the interaction between and among internal entrepreneurship-supporting organizations which is a key enabler of research commercialization has risen to be an important issue among the key actors of KAIST. In particular, for supporting organization in the early stage of development, forming an interactive atmosphere is a good way to receive feedbacks from various sources, thereby facilitating viable collaboration and cooperation in complementing competences that one lacks. Still, the collaborations among the relevant organizations at KAIST are in need of vitalization. According to interviews with the representatives of each organization at KAIST, the horizontal collaboration between and among internal organizations was rare, as the culture formed within the organizations emphasized information security rather than information sharing. In contrast, many types of interaction are shown at MIT. First, OSP dispatches its representatives called Grant/Contract Administrator or a Senior Contract Administrator to each academic department at MIT. This individual is responsible for providing services to the department for the entire life-cycle of the project. Secondly, technology licensing officers actively contribute to MIT classes and student activities with their personal expertise. These include participation in sponsorship and judging of the $100K Business Plan Competition, active involvement with the MIT

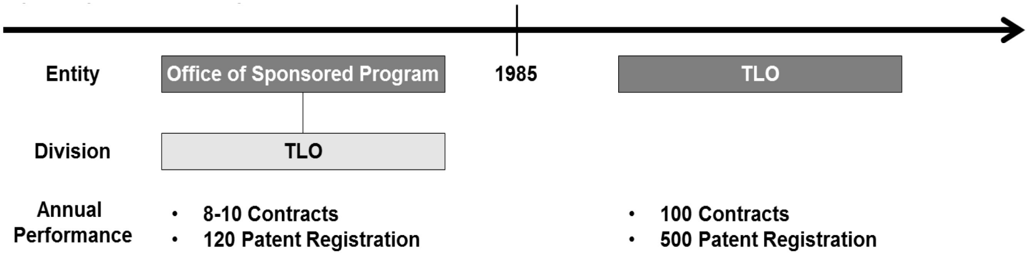


Fig. 3. Organizational change of MIT TLO.

Enterprise Forum, and giving guest lectures on patents and licensing in a number of courses, both undergraduate and graduate, and clubs. Lastly, Desphande Center under school of engineering focuses on interacting with faculty members by offering catalyst programs. As a result, over 250 faculty members have submitted their proposals and in return the center has supported more than 300 faculty members from a diverse array of academic departments since 2002. Therefore, when forming the support infrastructure, promoting interactions between and among professors, academic departments, and entrepreneurship relevant organizations is necessary to create synergy effect.

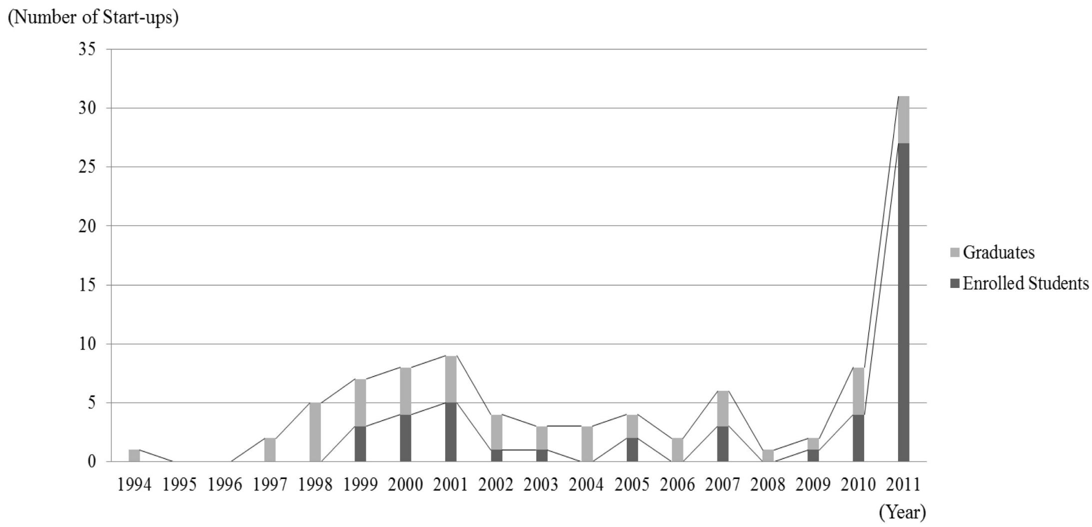
4. Implementation of new measures at KAIST and their impact

With the assessment results identifying weaknesses and strategic directions of KAIST, actual measures have been implemented. Although the assessment results have directed KAIST to many weak points, not all weak points have been dealt with new measures, due to financial and administrative constraints at KAIST. In this section, the new measures implemented by KAIST and their impact on the entrepreneurial performance of KAIST are explained.

4.1 Entrepreneurship education

The number of start-ups created by KAIST students throughout late 1990s and early 2000s was 9. Since then, the number has dramatically declined to 1 in 2008 and 2 in 2009 including the number of start-ups created by enrolled students and graduates (see Fig. 4). Even though KAIST has been producing the best quality engineers in Korea with its reputation of being the best university in Korea according Joongang Daily's Korean University Ranking from 2008 to 2011 [23], the entrepreneurship education and university policies have been impeding the vitalization of students' entrepreneurship. In order to solve the problems, KAIST has been implementing new measures by improving entrepreneurship education and university policies. KAIST recently has announced to open a regular undergraduate-level entrepreneurship program for minor degree which will be implemented soon. KAIST abolished its scholarship policies that prevented students to be engaged in entrepreneurship activities, so that students could freely pursue their entrepreneurial activities without any disadvantages on their scholarship. In order to foster university-industry cooperation in education, School of Innovation has been hiring professors who have managerial and entrepreneurial experiences in various industries.

Among the new measures implemented at KAIST, several educational and research programs have been beneficiary for potential entrepreneurs at KAIST. A program called "E5-KAIST" aiming at providing education and start-up support for students has contributed to the vitalization of university entrepreneurship among students. The program has supported students with a free office for start-up planning, a space for manufacturing, alumni mentoring, and courses focusing on improving the competences required for start-up companies. Entrepreneurship courses, as well as the research programs including "Entrepreneurship for Student Researchers" and "Customized Entrepreneurship Support" were implemented to promote student entrepreneurship depending on their academic background and research field. Research programs



Source: KAIST Annual Performance Report

Fig. 4. Number of start-ups created by KAIST students.

supported students' research in a practical way through research funding with the guidance of relevant lecturers and assistants.

In addition, courses covering special topics including venture capital and IT business have been set up by academic units through university-industry collaboration in education. Guest lectures and project mentoring were carried out by incumbent consultants and venture capitalists. Through these courses, students were able to define and solve real business problems of incumbent high-tech start-ups. The solutions provided by students have been quite effective for incumbent high-tech start-ups to reconsider their position and strategies in the market, thereby improving their firm performance. With the implementation of such policies and programs, the number of start-up companies has sky-rocketed to 31 in 2011 which are 15 times higher than that of 2009. Among 31 companies, 27 companies which take 90% of the whole portion have been created by enrolled students. This record hit KAIST's 18 year high.

4.2 Research commercialization

In 2011, KAIST OUIC recorded US$ 11 million of profits earned from technology licensing (US$ 5 million), stock selling of companies graduating from business incubation programs (US$ 3 million), and securing the shares of subsidiaries (US$ 3 million). This outstanding performance was backed by diversifying its profit structure (see Table 5). Among these profit-earning models, more than half of the profits have been generated by securing the shares through establishment of subsidiaries.

Among the subsidiaries, Dongwon OLEV (Online Electric Vehicle) Corporation and OLEV Technologies have been a part of KAIST's key initiatives on university technology transfer since 2010. Both the companies stemmed from KAIST's OLEV project. In the initial stage of this project, key leadership of KAIST have played important roles in securing the investment from the government and fostering a collaborative atmosphere for participating academic units. KAIST secured US$ 25 million in the first year and US$ 15 million in the second year from the government which resulted in the proactive engagement of Korean government agencies in the project. By motivating the government, KAIST also benefited from the government which helped in changing regulations and developing the infrastructure for the operation of OLEV. Since the technology required a paradigm shift among its potential customers, the proactive initiative of Korean government contributed to the development and pilot test of the technology. In addition, with the top-down support of KAIST's key leadership, multiple academic departments have been able to collaborate and complete the R&D process within a relative short period of time [24].

Nevertheless, the project stumbled due to the hardships arising from commercialization of the technology. During this phase, KCI and OUIC have overcome the problem by establishing a systematic triangular network with industries and the government (see Fig. 5). These two key intermedi-

Table 5. Profile of subsidiaries established by KAIST

	i-KAIST	**Dongwon OLEV Corporation**	**OLEV Technologies**
Product	Education contents and IT device	Online electronic vehicle	Online electronic vehicle
Investment Amount	US$ 300,000	US$ 10,000,000	US$ 1,500,000
Share of KAIST	49%	30%	30%

Source: KAIST Annual Performance Report.

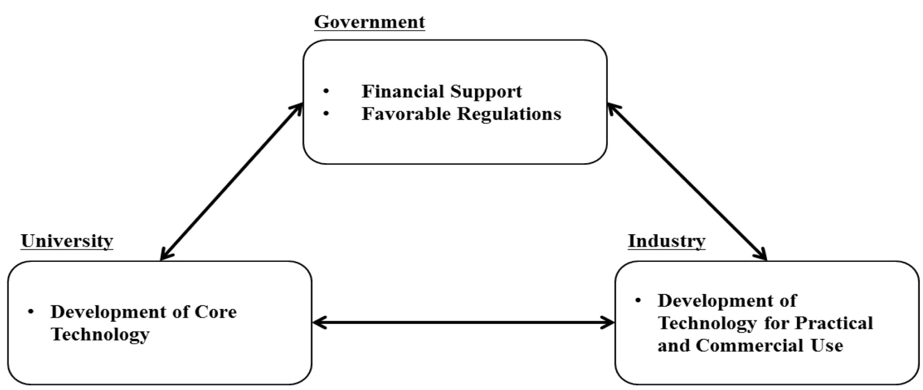


Fig. 5. Triangular network.

Table 6. Summary of key findings

Diagnostics	Implemented Measures
– Focus only on delivering general knowledge on entrepreneurship	– Set implementation plans to run a minor program in entrepreneurship – Organized special topics course on venture capital in the department of industrial engineering
– Fail to integrate various aspects of engineering for designing new products	– Designed specialized research programs targeting engineering-major students Ex) "Entrepreneurship for Student Researcher", "Customized Entrepreneurship Support"
– Insufficient number of faculty members with entrepreneurial experiences	– Recruited professors from various backgrounds including law, business, venture capital, etc.
– Networking events that only focus on benefitting sponsors	Not Observed
– Absence of incentives for entrepreneurship hindering student entrepreneurship	– Set entrepreneurship-friendly environment for students to freely engage in start-up activities Ex) Abolished the restrictions on scholarship recipients' engagement in start-up activities
– Lack of self-sufficiency in human resources for technology transfer operations	Not Observed
– Narrow sources of income from technology transfer operations	– Diversified the business model of technology transfer intermediaries
– Absence of collaborative culture among entrepreneurship supporting organizations	– Initiated university-based entrepreneurial projects with top-down planning and support to induce the participation of multiple academic departments

aries have played a major role by forming a solid partnership with the regional government in order to implement the OLEV for the purpose of pilot test. Also, since OLEV required a number of technologies and platforms for the development of the final product, these two key intermediaries contributed to forming partnerships with the key players in required technological field. In addition, OUIC and KCI played important roles dealing with Korean conglomerates and investors in the U.S to establish subsidiaries. As a result, although OLEV technologies are yet to be released and used by consumers, it has been successfully turned into business entities as Dongwon OLEV for Korea and OLEV Technologies for U.S [24].

5. Conclusions and policy recommendations

To demonstrate the key findings more precisely, the summary table explains the weaknesses drawn from the assessment and the actual measures taken, which have been quite effective in improving the entrepreneurial performance of KAIST (see Table 6). The lessons learned from case studies of KAIST and MIT have been applied to the cases of the late-comer countries including Dominican Republic and Ecuador, in order to develop catch-up strategies and draw policy recommendations (see Fig. 6).

In order to establish a sound transition into entrepreneurial approach, a long-term strategic intent should first be set in place for key leadership at universities in order to secure proactive support from the government. Although the government of these late-comer countries recognizes the importance of R&D, their research funding is still increasing slowly and are often not sufficient to stimulate universities [25]. As learned from the case of OLEV, KAIST would not have been able to successfully develop the core technologies in the early stage of R&D without the proactive support of the Korean government, which resulted from the strong strategic intent of KAIST's key leadership. On top of this financial support, the pilot test agreements between KAIST OLEV and regional governments may not have been formed without the government's willingness to take risks, even after knowing that OLEV

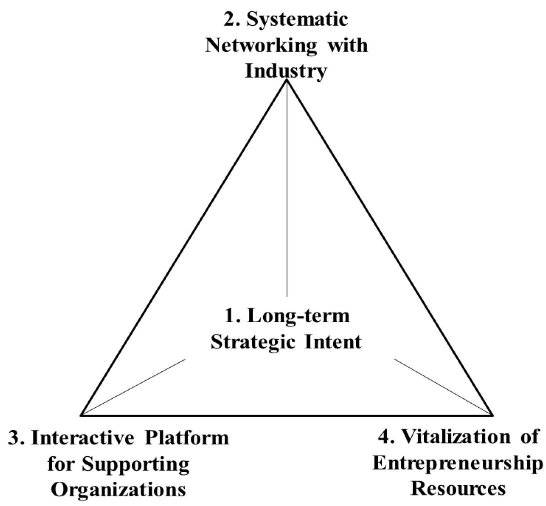


Fig. 6. Catch-up strategies for late-comer countries.

lacked economic efficiency. Therefore, a long-term strategic intent along with activities creating and maintaining an enterprising culture on the whole at government and university should be formulated to serve as an integrated part of all courses, research, and external activity [26].

Secondly, systematic networking with industry should be established by collaborating with alumni entrepreneurs and venture capitalists, in order to vitalize mentoring services, networking, and financing activities. These late-comer countries show their weaknesses in low degree of outreach activities such as internships and networking events, due to weak linkage formed between universities and industries. Involving external parties into the curriculum by organizing guest lectures or other networking events is rarely shown which could provide access to mentoring and financing opportunities to prospective entrepreneurs. Therefore, various opportunities for potential entrepreneurs in universities to receive seed money and operating assistance should be in place. In addition, universities in the late-comer countries do not have any special mechanism that manages agreements, thereby hindering universities from having self-sufficient internal entrepreneurship support. Due to its absence, individual faculty members personally and informally contact firms and some research results are often transferred without any formal contract on intellectual property rights [25]. As learned from the case of KAIST, the intermediaries such as KCI and OUIC showed their proactive engagement not only in the commercialization stage, but also in the research and development phase. In order fulfill these roles, the intermediaries in charge of technology transfer should be granted with the ownership and disposition of technology.

Thirdly, an interactive platform for supporting organizations should be established, in order to promote interactions between and amongst professors, academic departments, and relevant organizations for synergy effect. Many universities in these late-comer countries do not have enough entrepreneurship infrastructures. When new supporting organizations are established in these universities, there may be conflicts between the interests of the existing and newly established organizations. As learned from the research and development stage of KAIST's OLEV, the collaborations among multiple engineering departments have been backed by top leadership and resulted in the development of the core technology within a year. Therefore, building an interactive platform should be in place to promote networking among the stakeholders with the support of top leadership. Also, sufficient shared space and discussions for interactive occasions should be in place [25].

Lastly, vitalizing entrepreneurship resources should be achieved by designing university policies to motivate students and faculty to pursue their entrepreneurial activities. Current entrepreneurship education in the late-comer countries lags behind in terms of offering incomplete curricula only focusing on teaching business plan development. To be more specific, it has relatively lower proportion of new product development, new venture finance, new venture growth, and new venture marketing, as the country lags behind in technology and industrial development [25]. Therefore, as learned from the case of KAIST, regular entrepreneurship program and various entrepreneurship-supporting programs should be designed and implemented to increase the willingness of students to pursue entrepreneurial activities. By establishing regular entrepreneurship programs, the students majoring in the program will have higher chance to start new businesses with their strong entrepreneurial intentions [20]. In addition, establishing executive programs for students by hiring faculty members who are practitioners with managerial experiences capable of providing networking opportunities is a viable option to improve the quality of entrepreneurship education. Not only entrepreneurship courses, but also research programs relevant to students' major should be offered at all levels in order to secure enough resources for research commercialization.

Universities in late-comer countries have aimed their contributions toward economic growth by fostering entrepreneurship education and research commercialization activities. This study contributes by presenting catch-up strategies for the successful university-based entrepreneurship in late-comer countries. The catch-up strategies for the engineering-oriented universities in late-comer countries will pave the way for the forthcoming industrial upgrading to reach its status as the engine of growth.

Acknowledgements—The authors wish to acknowledge the research grant supports from Korea Advanced Institute of Science and Technology and Korea Institute of Science and Technology Evaluation and Planning (N04120053). We also would like to thank Inter-American Development Bank (DR-T1023).

References

1. M. Yemini and J. Haddad, Engineer-entrepreneur: Combining technical knowledge with entrepreneurship education—The Israeli case study, *International Journal of Engineering Education*, **26**, 2010, pp. 1220–1229.
2. H. Etzkowitz, Research groups as 'quasi-firms': The invention of the entrepreneurial university, *Research Policy*, **32**, 2003, pp. 109–121.
3. P. K. Wong, Commercializing biomedical science in a rapidly changing "triple-helix" nexus: The experience of the National University of Singapore, *The Journal of Technology Transfer*, **32**, 2007, pp. 367–395.
4. D. W. Kim and S. W. Leslie, *Beyond Joseph Needham: Science, technology, and medicine in East and Southeast*

Asia, The University of Chicago Press, USA, 1998, pp. 154–185.
5. A. T. Bernardes, Cross-over, thresholds, and interactions between science and technology: Lessons for less-developed countries, *Research Policy*, **32**, 2003, pp. 865–885.
6. Ministry of Education, Science, and Technology (MEST), *White book on university-industry collaboration in Korea*, MEST, Korea, 2010.
7. N. P. Suh, *Theory of Innovation*, Korea Advanced Institute of Science and Technology (KAIST), Korea, 2009.
8. E. B. Roberts and C. E. Eesley, *Entrepreneurial impact: The role of MIT*, now Publishers,2011, USA.
9. H. Etzkowitz, A. Webster, C. Gebhardt and B. R. C. Terra, The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm, *Research Policy*, **29**, 2000, pp. 313–330.
10. S. Shane, Selling university technology: Patterns from MIT, *Management Science*, **48**, 2002, pp. 122–137.
11. R. P. O'Shea, T. J. Allen, K. P. Morse, C. O'Gorman and F. Roche, Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience, *R&D Management*, **37**, 2007, pp. 1–16.
12. C. Zhou and X. Peng, The entrepreneurial university in China: Non-linear paths, *Science and Public Policy*, **35**, 2008, pp. 637–646.
13. W. J. Kim, J. S. Lee and J. T. Hwang, *Strengthening of institutional capacity to promote technological innovation in Dominican Republic: Diagnosis, evaluation and curricular redesign for engineering careers*, Inter-American Development Bank, Dominican Republic, 2011.
14. E. A. Rasmussen and R. Sørheim, Action-based entrepreneurship education, *Technovation*, **26**, 2006, pp. 185–194.
15. N. E. Peterman and J. Kennedy, Enterprise education: Influencing students' perceptions of entrepreneurship, *Entrepreneurship Theory and Practice*, **28**, 2003, pp. 129–144.
16. C. Hamilton, G. P. Crawford and E. M. Suuberg, A technology-based entrepreneurship course, *International Journal of Engineering Education*, **21**, 2005, pp. 239–256.
17. Z. T. Bae, Technology entrepreneurship teaching programs in Korea: The KAIST experience, *Proceedings of Rountable on Entrepreneurship Education (REE) Asia*, Singapore, 2004.
18. W. E. McMullan and L. M. Gillin, Industrial view points – Entrepreneurship education—Developing technological start-up entrepreneurs: A case study of a graduate entrepreneurship programme at Swinburne University, *Technovation*, **18**, 1998, pp. 275–286.
19. A. R. Hofer and J. Potter, Universities, innovation and entrepreneurship: Criteria and examples of good practice, *OECD Local Economic and Employment Development (LEED) Working Paper*, 2010.
20. L. Kolvereid and Ø. Moen, Entrepreneurship among business graduates: Does a major in entrepreneurship make a difference?, *Journal of European Industrial Training*, **21**, 1997, pp. 154.
21. G. E. Hills, Variations in university entrepreneurship education: An empirical study of an evolving field, *Journal of Business Venturing*, **3**, 1988, pp. 109–122.
22. National Assembly of the Republic of Korea, *Innovation plan for engineering colleges in the age of knowledge and information society*, National Assembly of the Republic of Korea, 2008.
23. Joongang Daily's Korean University Ranking, http://www.jedi.re.kr/, Accessed 10 September 2012.
24. J. S. Lee, S. Y. Yoon, H. S. Yoon and B. J. Kim, *Research on entrepreneurial environment and policies for the vitalization of university entrepreneurship*, Korea Institute of S&T Evaluation and Planning (KISTEP), Korea, 2012.
25. W. J. Kim, B. H. Lee and J. T. Hwang, *Strengthening of institutional capacity to promote technological innovation in Dominican Republic: Creation and strengthening of technology based entrepreneurship centers in engineering faculties*, Inter-American Development Bank, Dominican Republic, 2011.
26. M. Klofsten and D. Jones-Evans, Comparing academic entrepreneurship in Europe—The case of Sweden and Ireland, *Small Business Economic*, **14**, 2000, pp. 299–309.

Hyungseok Yoon is a Ph.D. candidate in Business and Technology Management at Korea Advanced Institute of Science and Technology (KAIST). His research interests include engineering and entrepreneurship education in developing countries and industrial policies of emerging countries in Latin America. He earned his Bachelor of Arts in Spanish Literature from Hankuk University of Foreign Studies and Master of Science in Industrial Engineering from Yonsei University in Republic of Korea.

Joosung J. Lee is an associate professor at the Department of Business and Technology Managment at Korea Advanced Institute of Science and Technology (KAIST). He has expertise in sustainable innovation and entrepreneurship research and university-industry collaborative education. He is actively involved in advancing engineering education for developing countries. Dr. Lee received his Bachelor of Science in Mechanical and Industrial Engineering from University of Illinois at Urbana-Champaign and earned Master of Science and Ph.D. in Technology Policy and Aerospace Systems from Massachusetts Institute of Technology.