

# PROPOSING A NEW MODEL OF KNOWLEDGE INNOVATION FOR RESEARCH UNIVERSITY BASED ON ENTREPRENEURIAL PARADIGM

RAMLEE B. MUSTAPHA

**ABSTRACT:** *The emergent entrepreneurial paradigm has led to the increasing role of the research university in knowledge innovation, hence making entrepreneurial research university a global phenomenon. Research universities are expected to provide intellectual innovations for the economic and societal advancement. It is argued that to ensure an effective achievement of research university's objectives, appropriate definition and model must be identified. This article attempts to propose a generic model of knowledge innovation for the research university. It identifies the definitions of the research university, knowledge innovation, and best practices of the established research universities. It then looks into the process of knowledge creation and innovation in research universities. Based on the review of literature, this article proposes a model of knowledge innovation for the research university by integrating knowledge innovation framework and the simplified Triple Helix Model. The focus of this article, however, is on the knowledge innovation. Knowledge innovation is most relevant in the context of research university. Literature also indicates that there are two forms of innovation, namely, incremental and radical innovations.*

**KEY WORDS:** *knowledge innovation, research university, Triple Helix Model, and entrepreneurial paradigm.*

## INTRODUCTION

Knowledge innovation in today's hyper competitive market could enhance organization's competitive edge (Drucker, 1993; and Tucker, 2002). This also applies to universities – institutions in the knowledge-intensive sector (OECD, 1998) – that need to respond to market demands just like any other business (Rowley, 2000). An academic revolution toward entrepreneurial paradigm is now a global phenomenon. Capitalization of knowledge in the increasingly recognized knowledge-based economy has called for a new mission and governance of research universities (Etzkowitz, Webster & Henley, 1998; and Etzkowitz, 2004). The entrepreneurial paradigm has permeated the elite ivory towers and gradually re-orienting the traditional roles of university from intellectual powerhouse to preparing students for job market and research “products” for sale in the knowledge

---

**Professor Dr. Ramlee B. Mustapha** is a Lecturer at the Faculty of Education UKM (National University of Malaysia); and also as the Director of the Centre of Excellence for Learner Diversity (CELD) at the Faculty of Education UKM, 43600 Bangi, Selangor Darul Ehsan, Malaysia. He can be reached at: [drmmustapha@yahoo.com](mailto:drmmustapha@yahoo.com)

economy. With the challenge for universities to consider the changing paradigm, university administrators and stakeholders should understand the new roles of entrepreneurial university.

As a hyper-research university, entrepreneurial university takes a strategic view of its own direction and priorities; engages an active role in capitalization (commercialization) of knowledge; and plays a proactive role in improving the efficacy of its regional innovation often with collaboration with industry and government agencies (Etzkowitz, 2004). The concept of entrepreneurial university is much discussed among the academic circles and there are some scholars who believe that the idea is a deviation from the previously accepted teaching and research mission (Lyotard, 1979; Pelikan, 1992; Readings, 1996; and Shumar, 1997). The idea was controversial: for some academics, the introduction of entrepreneurship as an academic mission is an antithesis to the philosophy of university itself.

The debates about entrepreneurial university require a separate forum and it is beyond the scope of this article. Based on the vast literature, we have accepted the assumption that the entrepreneurial paradigm has led to the increasing role of university in knowledge innovation. However, there was a lack of a working model for the research university to operationalize the process of knowledge innovation. The classic linear model of knowledge innovation is inadequate because the nature of innovation itself is inherently non-linear (Kline, 1985; and Kline & Rosenberg, 1986). Further, the standard linear model did not take into account the involvement of key stakeholders: university, industry and government as postulated by the Triple Helix Model (Etzkowitz & Leydesdorff eds., 1997). Despite the entrepreneurial interest of research universities, the gap between the knowledge innovation framework and the collaboration of the stakeholders signifies the knowledge *impasse* in the current literature. Thus, this article proposes a generic model of knowledge innovation for research university based on the critical review of the relevant literature.

Increased industry involvement in knowledge innovations augurs the global trend for applied research to address real world needs. In other words, knowledge innovation had spurred collaborative R&D (Research and Development) in industry, technology transfer from universities and government laboratories to the private sector, cooperative R&D agreements between government laboratories and industrial researchers, greater protection of Intellectual Property Right (IPR) to inventors and industrial researchers, provision of tax credit, SMEs innovative research grants and universities and government research and extension centers (Premus, 2002). Nevertheless, the disparity between university and industry is still wide due to philosophical differences.

### **PHILOSOPHICAL DIFFERENCES**

Historically, universities were founded on the principles of liberal arts, jurisprudence and theology, but eventually transformed into divisions; naturals and applied

sciences, and later further broadened into multiple disciplines, including the social sciences and humanities and the specific fields of knowledge and thoughts (Gray, 2001). The research functions took on a new dimension when scientific and technological knowledge is added to the curriculum hence challenging the relationship between research findings and their economic value. Originating as a medieval institution for the conservation and transmission of knowledge, university has evolved over the centuries into an institution in which knowledge is also created and put into use (Etzkowitz, 2004).

During the 20<sup>th</sup> century, modern universities have emerged with their institutional autonomy directed more at serving the broader community besides preserving academic tradition of teaching and research. When the students, government and industry are treated as potential clients, efficient and cost effective delivery of graduates and research activities is a primary value to the university systems. Many universities have added a third mission to the long-standing tandem of teaching and research, that is, service to the community. Such change urges universities to focus attention as centers for lifelong education and centers for scientific services to the community (OECD, 1998). Another distinguishing element that differentiates university from the rest of the world is the principle of academic freedom – notably the freedom of inquiry and research, freedom of teaching, and freedom of expression and publication. These freedoms enable the university to advance knowledge and transmit it effectively to the students and to the public (Atkinson, 2004).

In academia, there is no “secret” research. Researchers live by the *publish or perish* rule, and research is conducted for public benefit. In corporations, however, the rule is *publish and perish*; the goal is return on investment, and research is conducted for shareholder benefit (Wallenburg, 2004). Part of a university’s objective is to ensure the greatest public benefit is derived from university research. This sometimes involves commercialization of research discovery, because the public seldom use raw research findings; they use products.

The values and goals of a university are fundamentally different from those of a profit-seeking business. One of the greatest concerns of traditional academics is regarding those universities that compromise their academic integrity in an effort to suit the corporate interests. The more a university acts like a profit-seeking business, the bigger the risk that its core responsibilities – teaching and conducting basic research may become marginalized (Sample, 2002).

As a result of the philosophical differences, some quarters raised concern on the effect of university-industry partnership on fundamental research; challenging the basic responsibility of a public university – as an engager in basic research. While university research is directed by curiosity for knowledge, industry pays for research that benefits them and their shareholders. University gears for open communication for research results, while for companies, the protection of propriety information is necessary for the goal of financial return (Fassin, 1991; and Shenhar, 1993). University scientists’ responsibilities are often unclear – national normative policies are often not available. All these contradictions might

warrant a specific legislation if the public views negatively on the conflict of interests on the relationship between university scientists and industry. Therefore, an effective model of university-industry partnership with regards to knowledge innovation and propriety is needed.

In the post-capitalist and post-modernist era, knowledge innovation has become the industrial *religion* through which firms believe it could increase market share and profits (Valery, 1999). University, however, must be cautious not to go overboard. According to S.B. Sample (2002), research university funded by public fund is believed to be more suited to undertake a limited role in commercialization of research findings. If public university as a research university aggressively engages in commercialization, its teaching, basic research, social responsibility and community services agenda might get distorted. Nevertheless, the role and function of a university is evolving within an overall tradition. Innovation does not necessarily mean a break with tradition. Rather, it should mean incorporating new approaches within the academic tradition (Sample, 2002).

### **DEFINING RESEARCH UNIVERSITY**

So far, there is no universally accepted definition of a research university. Association of American Universities (AAU), which represents 60 leading public and private research universities in the US and Canada, states the AAU is an organization of research universities devoted to maintaining a strong system of academic research and education and to promote the improvement and advancement of graduate education, including best practices and procedures (<http://www.aau.edu/research/PHS9.21.00.html>, 10.11.2009). Carnegie Foundation used a classification of Doctoral-Granting Institution to characterize “Research University” which comprised institutions that award a substantial number of doctorates across a wide range of fields (<http://www.carnegiefoundation.org/Classification/CIHE2000/background.htm>, 10.11.2009). S.B. Sample (2002) defined research university as a research institution in which original research and scholarship are an integral part of the university’s mission. In essence, a research university emphasizes as its primary mission the conduct of research and the training of graduate students (Wisconsin Technology Council, 2004). In the United States, the first research University was Johns Hopkins University, established in 1876 modeled after the University of Gottingen in Germany (Wisconsin Technology Council, 2004).

Traditionally, research university emphasizes on teaching and conducting basic research. However, for the past three decades, many research universities have begun to aggressively involve in applied research. Entrepreneurial university takes one step further – to actively engage in knowledge capitalization and commercialization. Thus, a research university can be considered as a knowledge-based organization where the knowledge creation (*basic research*) and innovation (*applied research*) is the major part of the system. It is the epicenter for creating new knowledge.

Entrepreneurial university is a special type of research university which we called a hyper-research university. Hyper, because it did not fit the traditional

Humboltian model of a university. The 19<sup>th</sup> century Prussian scholar, Wilhelm Von Humbolt emphasized that a university should be based on the principle academic freedom. The freedom to explore research of the scholars' own choice: at whatever cost it is essential for society to have a group of researchers beyond any government control to explore scientific questions (Lotz, 2004). This model never envisions that "knowledge" should be commercialized. Entrepreneurial university transcends beyond the traditional realm by actively involved in the capitalization of knowledge that many traditional research universities shy from. H. Etzkowitz (2004) defined entrepreneurial university as a university that interacts closely with the industry and government and actively involves in capitalization of knowledge. Commercializing intellectual property is a norm in an entrepreneurial university. The proposed model of knowledge innovation in this article can be applied to both research and entrepreneurial universities.

### **BASIC VERSUS APPLIED RESEARCH**

Fundamental or basic research studies certain phenomena for the sake of advancement of knowledge. It is often exploratory and driven by researchers' curiosity. On the other hand, applied research is conducted to solve specific problems which often require urgent solutions. Nevertheless, the border between basic and applied research is not always clear. Basic research is still playing an important role in R&D, because it is a source of many new knowledge that has revolutionized contemporary civilization. Key channels through which university research impact industrial R&D include published papers and reports, public conferences and meetings, scholarly critiques, research exchange, and consulting (Cohen, Nelson & Walsh, 2002).

Proponents of basic research argue that in the long-run, universities contribute more effectively to the economic development of the state by focusing on education and basic research that support the subsequent effort of private sector research, rather than universities involve themselves in commercial research (Rolnick & Grunewald, 2001). This argument proposes that a mechanism to transfer universities research into commercial innovation is more resource effective than the resources consume in actually doing commercial research. This ideal is consistent with the Taylorist's classic principle of job specialization where productivity is competence-related. A. Rolnick and R. Grunewald (2001) also claim that the quality of graduates and scholarly journal articles overrides the number of patents produced as the final measure of how a university should be judged. This vantage point is linked to the separation of the real role of universities against the commercially oriented research undertaken by private sector.

In today's business environment, managing time-to-market and launch-to-maturity have become a key competitive advantage in delivering end products. Many studies have been conducted on the strengths and weaknesses of innovation speed (Lieberman & Montgomery, 1988; Crawford, 1992; Eisenhardt & Tabrizi, 1995; and Kessler & Bierly, 2002). In an ever-competitive world, the speed of

commercialization of an innovative idea might be far more important than perfecting the innovation. The importance of speed in high-tech markets is driven by increasing competition and the continually evolving expectations of customers (Doyle & Saunders, 1985).

Literature has also shown that radicalness of an innovation is critical for organizational survival (Christensen, 1997; Thomond & Lettice, 2002; and Veryzer, 2005). Both elements — radicalness and speed of innovation — seem to be equally important. If both forces were present in an organization, innovation culture would thrive in the long-term. Entrepreneurial initiators need commercializers while conversely; effective commercialization is greatly influenced by radicalness of entrepreneurial ideas to be successful. The dual-stage process are interactive and reinforcing each other. For example, the Cambridge phenomenon — high percentage of entrepreneurs living in surrounding the areas — suggests that the university and business relationship remains a cornerstone of entrepreneurial paradigm. People are basically like to stay in a place or work with an organization where their entrepreneurial ideas get translated into commercialized products.

In the context of university-originated innovation, the intensity of the innovation is contingent upon the extent of innovation-related activities promoted by the university. Not surprisingly that the number of universities in a region affects the intensity of research and innovations. For example, the number of patents produced in France is related to the corporate expenditure on R&D as well as university research in that territory (Piergiovanni & Santarelli, 2001). Accordingly, university research is the most crucial external source of knowledge for innovative activities of manufacturing firms in France. From the discussion, we can delineate that basic research, innovation and entrepreneurial activities are needed in a new knowledge construction. Therefore, it is important to strike a reasonable balance between basic and applied research.

### **UNIVERSITY-INDUSTRY COLLABORATION AND RESEARCH AND DEVELOPMENT (R&D)**

According to G. Holton and G. Sonnert (1999) and S. Chung (2001), the spirit of the university-industry cooperation has a common thread with the so-called *Jeffersonian research mode*. It has recently been argued that the confining dichotomy of basic research in academe (*Newtonian mode*) versus applied research in industry (*Baconian mode*) may be reconciled through a third form — the *Jeffersonian mode*. The Jeffersonian hybrid model suggests a research activity driven by fundamental, practical, and societal needs to be carried out under the condition of collaboration and partnerships. Jeffersonian approach to research would provide a strong *raison d'être* for future university-industry collaboration.

Numerous authors have argued that the industry's involvement in the university research agenda is important, not only for the firms and the university but also for national development and competitiveness (Bower, 1992; Atkinson, 1999; Santoro & Chakrabarti, 1999; and Etzkowitz, 2004). Due to the rapid change in knowledge

advancement, the nexus between universities and industries should be reinforced to sustain competitive edge. However, the partnership between university and industry can potentially pose a number of challenging problems (Chung, 2001). Thus, if the partnership is to be effective, several elements should be considered as follows: (1) universities must not lose sight of their ultimate aims of teaching students and performing basic research — unless universities retain their culture, base of fundamental research, and educational mission, they will not have a value to bring to the partnership; (2) university researchers should not be discouraged from publishing or disseminating their research results due to propriety claims to these results made by their industry partners; and (3) the private sector entities that partner with universities should not view their university partners as full-fledged substitutes for their own research programs.

The dynamism of globalization — in terms of international competitiveness — has forced many firms to rethink their global strategies. The viable way to survive in the future economic battlefield is to become actively involved and committed to an ongoing process of new knowledge creation and innovation. This may require the industry to rely on the research university as the center for knowledge generation and creative innovations to promote new technologies. In reciprocal, university is in need of private sector's support to sustain cutting-edge fundamental research. In sum, university-industry symbiotic collaboration has fast becoming the *sine qua non* of the 21<sup>st</sup> century.

Meanwhile, Research and Development (R&D) is considered as a major source of knowledge innovation. Economic theories (Schumpeter, 1911 and 1943; Solow, 1956 and 1957; and Romer, 1986 and 1990) seem to point to innovation as the major source of productivity in the long run. Although the relationship between R&D and innovation is complex and nonlinear, it is clear that substantial advances in knowledge innovation will not take place without rigorous and systematic R&D (Guellec & Van Pottelsberghe de la Potterie, 2004). OECD (1993) defined R&D as creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this stock of knowledge to develop new applications. Numerous empirical studies have been conducted to determine the effect of R&D on economic productivity and, in general, the findings show positive impact (Niininen, 2000; Guellec & Van Pottelsberghe de la Potterie, 2004; and Graversen & Mark, 2005).

The *corpus* of literature on R&D spillovers has developed significantly, as reviewed by Griliches (1992). Bayoumi *et al.* (1996) examined the roles of R&D, international R&D spillovers, and trade in enhancing economic productivity. The study found that a country can raise its total factor productivity by investing in R&D. Countries can also improve their productivity by trading with other countries that have large stocks of knowledge from their cumulative R&D activities. Empirical evidence also suggests that R&D increases a firm's "absorptive capacity" — its ability to absorb spillovers from other firms — as well as contributing directly to profitability (Leahy & Neary, 2004). This shows that inducing knowledge innovation through well-planned R&D is critical for productivity and economic growth.

Since the passage of Bayh-Dole Act in 1980, the number of patents issued to American research universities has risen dramatically. This US Federal Law gave universities the right to claim title to inventions made on their premises and to license their intellectual properties to clients. Before 1980, fewer than 250 patents were issued each year to universities in the United States. In 2002, the number had bloated to 3,673 patents issued to 219 filing institutions (Wisconsin Technology Council, 2004).

### **CASES ON UNIVERSITY RESEARCH SPIN-OFFS**

In business terms, “spin-off” means a new company that arises from a parent organization. A spin-off company is formed by individuals who were former employees of a parent organization and involves a core technology that is transferred from the parent company (Carayannis *et al.*, 1998). Hence, E.B. Roberts and D.E. Malone (1996) identified four principal entities involved in a spin-off process: (1) the technology originator; (2) the parent organization as licensing office; (3) the entrepreneur; and (4) the venture investor as the fund provider. University research plays a major role as the new knowledge originator to bring the “technology” from basic research through the stages of the innovation-development process to the point at which the transfer of technology can begin, and the new product can be successfully developed. Technology, Research or Science Parks associated with research universities are leading examples of “incubator environment” designed to nurture spin-offs (Davenport, Carr & Bibby, 2002).

The success story of Silicon Valley is a show case of a close relationship between university researchers and commercial investors. The role of Stanford University, and that of its visionary Vice-President, Frederick Terman, was critical to jump-start Silicon Valley. The rise of Stanford’s researchers to the forefront of academic excellence has enormous impact on the take-off of the Silicon Valley’s microelectronics industry. One of Terman’s most successful direct influences on the Silicon Valley performance was his role in launching Hewlett Packard. In 1954, Hewlett Packard built its company’s headquarters on one of the choicest pieces of land on the campus’s Stanford Industrial Park (Rogers & Larsen, 1984).

Like Stanford, Massachusetts Institute of Technology (MIT) is an elite research institution. The transformation at MIT was catalyzed by its research centers, which were originally funded by the federal government, and increasingly later by private companies (Roberts, 1991). A study by Bank of Boston (1997) identified 4,000 MIT’s spin-off companies that employed 1.1 million people, and generated \$ 232 billion in worldwide annual sales. The Bank of Boston’s study of spin-off from MIT points to the key role of university-based research centers in creating jobs and wealth through their spin-offs. Other names connected to MIT on academic spillover are General Electric and Siemens. Accordingly, H. Etzkowitz (2004) argues that MIT is a prime example of an entrepreneurial university even though it was regularly stated that MIT is an academic anomaly.



In the State of North Carolina, the Research Triangle Park supported by Duke University, University of North Carolina, and North Carolina State University is another success story. The business start-up rate in the Research Triangle Park is the highest in the state, the unemployment rate the lowest, and per capita income and average wages are above the state average. The Park housed more than 100 companies employing more than 36,000 people. Major companies such as IBM, Nortel, Motorola, DuPont, Harris Microelectronics, and SAS have operations in Research Park (O'Hare & Pitney, 2002).

Comparatively small university, the University of New Mexico (UNM) ranked 37<sup>th</sup> among all US public universities in R&D expenditure in 1996. The UNM's leaders hope to create a *technopolis* (center of a high-technology area) in Albuquerque, and UNM officials expect their university to be the key player in this process. Up to 1997, 19 new companies had spun out from 14 of the 55 research centers of UNM. Some of them are Asian Technology Infrastructure Program, Khoral Research, Nenopare, and SCB Technologies. An interesting finding on UNM that supports technology transfer is that most research centers are founded by the entrepreneurial faculty members who have the greater autonomy and ability to capitalize on a need for multi-disciplinary research (Steffensen, Rogers & Speakman, 2000).

In Sweden, advanced engineering firms have established new technologies developed by university research. In the computer industry, SAAP (the Swedish Aircraft and Automobile Producer) through a strategic venture with Ericsson, obtained sophisticated digital mobile telephone technology from its military aircraft electronics and moved rapidly to become the big player in the market (Eliasson, 1996). The following generation spillover, Ericsson together with Hewlett-Packard successfully used the military aircraft technology for telephone system control and Volvo Aero in advanced aircraft engine components. The Swedish health care industry has also benefited from the university research. Both *Gambro* (now Incentive), specializing in dialysis equipment and treatment, and *Elekta*, specializing in radiation brain surgery, are making inroads into the care market by building specialized private clinics (Eliasson & Eliasson, 1996). *KoroBio* was founded by a university's business spin-off and a pharmaceutical company to screen potential substances in biotechnology and to identify promising candidates for resource-intensive clinical testing (OECD, 2000). A growing number of universities are willing to use small portion of their endowment funds to capitalize new firms often in association with other investors (Etzkowitz, 2004).

### **TECHNOLOGY TRANSFER AND TRIPLE-HELIX MODEL**

Another area in which universities, governments, and businesses should work together is technology transfer. Technology transfer from government labs and research universities serves to foster economic growth for metropolitan regions in the United States (Rogers, Takegami & Yin, 2001). In 1999, technology transfer

from universities to industry contributed \$ 38 billion to the economy, creating over 300,000 jobs and forming hundreds of new companies in the United States (Hall & Scott, 2001). Studies have shown that university research spillovers are subjected to geographical location and significant to certain industries such as in the electronic and instrumentation sectors (Anselin, Varga & Aes, 2000).

E.M. Rogers, S. Takegami and J. Yin (2001) identified five different technology transfer mechanisms from universities to business entities: spin-offs, licensing, meetings, publications, and cooperative R&D agreements. The two most common are spin-offs and technology licensing. Technology transfer is a sophisticated and often complex process. It needs significant resources and infrastructure to make it work well. There is a need to set up a technology-transfer infrastructure in universities that recognizes the realities of the business world. Much of the technology transfer involves working at the application stage – applications unforeseen by the researchers who originally developed the knowledge or technology (Sample, 2002). Great innovation needs to be championed and nurtured for a long period (Valery, 1999). These three classic examples epitomize the nature of technology transfer, as follows:

- Gottfried Wilhelm Leibniz, a German philosopher and mathematician, laid the foundation for the binary system of numeration in the late 17th century. Without his pioneering fundamental work, the great 20<sup>th</sup> century invention of a computer would never be materialized. Leibniz's advances in basic mathematical research had no direct economic pay-offs, neither to him nor to his employer (Hernes & Martin, 2000).
- Harry G. Steenbock, a Professor at the University of Wisconsin, discovered in 1925 that adding vitamin D to milk could prevent rickets. The Wisconsin Alumni Research Foundation (WARF), a non-profit foundation, was formed to commercialize his discovery. Since that time, WARF has grown and increased its grants to the University of Wisconsin through many innovative technologies developed by highly creative and respected on-campus researchers. Within seven decades since Professor Steenbock's breakthrough, over 3,000 discoveries have been disclosed to WARF. Based on these disclosures, WARF has obtained over 1,000 patents and over 1,500 foreign equivalents and has granted an excess of US \$ 450 million in university funds (Hernes & Martin, 2000).
- Researchers at NASA's jet Propulsion Laboratory invented a circuit board for space applications with unique properties – it could be subjected to high temperatures on one side and freezing temperatures on the other and still functioning electrically. The researchers tried to market this circuit board but there are no takers. Later it was discovered the fact that there was something else about the circuit board that could lead to commercial interest – it was the lightest circuit board ever made. The researchers initially didn't care about the weight, but the marketplace did (Sample, 2002).

Besides technology transfer, clustering and localization are crucial aspects. Anecdotal evidence shows that a number of countries and their policymakers are keen to adopt policies which will encourage clustering and create, for example, new "Silicon Valleys" in new places and in different industries (Cowan & Jonard, 1999).

The multiple reciprocal relationships generated by accelerating convergence of academic research, industrial sponsorship and governmental support have given rise to a new model for knowledge innovation process. A spiral model of University-Industry-Government (U-I-G), known as a Triple-Helix Model, was developed by H. Etzkowitz and L. Leydesdorff eds. (1997). This model transcends the previous modes of separation into a triple helix of overlapping, yet relatively autonomous sphere (Etzkowitz *et al.*, 2000).

This tri-lateral interaction is increasingly interwoven in a spiral pattern of linkages emerging at various stages of the innovation process. According to Etzkowitz *et al.* (2000), there are four processes involved: (1) the first is internal transformation in each of the helices; (2) the influence of one institutional sphere upon the others; (3) the creation of a new overlay or interfaces of the trilateral linkages; and (4) the recursive effect of these inter-institutional network of academia, industry, and government. Nevertheless, the Triple Helix Model, in our opinion, that drew from the idea of Double Helix of DNA is a complex structure to be applied in describing University-Industry-Government partnership. As admitted by L. Leydesdorff and H. Etzkowitz as follows:

In contrast to a biological double helix, a triple helix is by nature unstable. It remains an emerging construct on top of the underlying communications (Leydesdorff & Etzkowitz, 1996:4).

Thus, in our model, we used a simplified version of Triple Helix Model by simply hypothesizing that as long as there is a U-I-G entity (in what whatever forms or mechanisms) that supports and sustains research for knowledge innovation, we assume that knowledge innovation effort will move forward.

### **EPISTEMOLOGY OF INNOVATION AND WHAT IS KNOWLEDGE INNOVATION?**

According to B. Lundvall (1992), innovation is fundamental and inherent phenomenon of modern capitalism. Innovation is a process that is accumulative and it is surrounded by uncertainties (Lundvall, 1992). With the uncertainties, mapping the nature of innovation is a difficult task because the complexity of the idea (Mahdjoubi, 1997). Thus, innovation has diverse meanings depending on who is talking and in what contexts; akin to the classic metaphor of four blind men describing an elephant – each man conveys partial truths but not the whole truth. In the simplest term, E.M. Rogers (1995) defined innovation as an idea, practice, or object that is perceived as new by an individual or a unit of adoption.

Theory of innovation has evolved since the seminal work of J. Schumpeter (1911) in his book, *The Theory of Economic Development*. According to R. Cowan, N. Jonard and J. Zimmermann (2004), one of the long standing legacies of Schumpeter is the belief that innovation was a central aspect of a dynamic economy. Giving special emphasis to the role of technological competition and the entrepreneurial

function, Schumpeter is regarded as the founding father of innovation studies. Through his “creative destruction”, J. Schumpeter (1943) considers innovation as both creator and destroyer of corporations and entire industries. Many have followed in his wake, adding new understanding to the phenomena relevant to innovation and economic growth.

Literature reveals that there are many types of innovation – knowledge innovation, technology innovation, organizational innovation, institutional innovation, social innovation, economic innovation, process innovation, and product innovation. The focus of this article is on the knowledge innovation. Knowledge innovation is most relevant in the context of research university. Literature also indicates that there are two forms of innovation, namely, incremental and radical innovations. Incremental innovation (Freeman, 1992) occurs more or less continually, in any industry or service activity, although at varying rate in different industries and at different times. Radical innovation, on the other hand, is a fundamental departure from previous production practices and involved discontinuity of the earlier technology (Utterback, 1994). Thus, radical innovations are much more risky than incremental innovations especially for established firms (Tushman & Anderson, 1986).

Before we can define what is knowledge innovation, one has to characterize what is knowledge? The complexity of defining knowledge is obvious, because it has multiple meanings depending on the contexts and perspectives. As G. Delanty argues as follows:

Knowledge can consist of professional knowledge; it can take the contrasting form of lay knowledge in which local or everyday knowledge confronts expertise. Knowledge can be equated with science or academic knowledge or can be seen as culture or praxis. There is also a sense of self-knowledge, that is, knowledge as *Bildung*, or self-cultivation. Knowledge, too, can take the elevated form of wisdom, in contrast to either *doxa*, the world opinion, or *logos*, the world of science (Delanty, 2003:71).

Since this study deals with knowledge innovation derived from research so the appropriate definition of knowledge, in this context, is a scientific knowledge that has gone through rigorous experimentation and validation process. Hence, H. Chuanqi (1988) defined knowledge innovation as the process of creating new scientific knowledge through R&D. It also involves the process of application, transmission (diffusion) and use of the new knowledge. This is an acceptable definition for our purpose. Since innovation is highly non-linear process; the model of knowledge innovation should exemplify non-linearity. It is more productive to view innovation as non-linear, where basic research problems can come out of practical issues as well as problems in a discipline and vice versa (Etzkowitz, 2004).

## **PROPOSING A NEW MODEL OF KNOWLEDGE INNOVATION**

The initial knowledge innovation model was a linear model developed by a group of MIT researchers (Etzkowitz, 2004). In the linear mode, innovation is assumed

to proceed sequentially from fundamental discovery (basic research) to applied research, and then to development and marketing. The classic linear model of knowledge innovation, however, is inadequate because the nature of innovation itself is inherently non-linear (Kline, 1985). Later, several non-linear models — including interactive, cyclic, systemic, and neural models of knowledge innovation have been published in literature such as Stephen Kline's chain-linked model (Kline & Rosenberg, 1986); Ralph Gomory's circle model (Gomory, 1992); Alic-Branscombe's model (Branscomb *et al.*, 1992); and the Neural Net model (Ziman, 1991).

The Stephen Kline's chain-linked model is the most cited non-linear innovation model. Kline argues that the inadequacy of the linear model necessitates the introduction of a more complex model in order to understand the nature of innovation. The chain-linked method emphasizes the socio-technical nature of industry and technology and the necessity view it as a complex system. In the model, the first path of innovation process — the central chain-of-innovation — begins with the design component and continuous through development and production to marketing components. The second path is a series of feedback loops (Mahdjoubi, 1997).

Cyclic model guru, Ralph Gomory introduced an alternative model to the linear model or what he called a ladder model. Ladder type of innovation refers to the sequential process on an innovation that descends from science downward “step by step” into practice. The cyclic model, on the other hand, refers to a repeated, continuous, and incremental improvement built into a series of dynamic design or manufacturing cycles.

Alic-Branscomb's model regards innovation as a social process involving the application of knowledge, together with other inputs, to design, develop, create, and market final products. The output of innovation can include intangible service products as well as physical objects and systems. The output of innovation can include intangible service products as well as physical objects and systems. The artifactual products should be viewed as derivative, the consequence of research, design, development, production, and marketing activities. But when coupled with design, development implies the steady refinement of concrete products, processes, and system through an iterative process of conceptualization, preliminary design, analysis, testing and redesign. This is basically an iterative process model — a derivative from the linear model.

Ziman's Neural Net model of innovation, mapped from brain analogy, introduced connectionist and parallel processing model. Both the cognitive space and the organizational space are self-organizing neural net patterns of the kind to be found in a living brain, where the nodes are neurons or nerve cells, connected both locally and over long distance by fibrous dendrites and axons, and are organized in layer structures. This connectionist model suggests that “*a layered system of many signal-processing units, interconnected and interacting in parallel within and between layers, has some remarkable properties*” (Ziman, 1991:74). By allowing each node to respond to incoming signals, a neural net can learn pattern recognition. The mind invents

and imposes patterns where none existed previously. The same may be said about the organizational network: “[...] *parallel regions in the network search for similar patterns, some of which can be combined to demonstrate the presence or absence of higher order patterns*” (Coward, 1990:59).

It is in the invention of those higher order patterns that creativity lies. Both in our cognitive and organizational spaces, different neural nets extract different patterns and combine them to produce and integrate recognizable wholes. To build the ability to analyze and respond to radically different types of experience requires a transformation of the patterns, a creation of new “regions”, the mobilization of “unused neurons” and the development of new connection sensitivities: (1) to support patterns-extraction experiences that are analogous to those the brain or organization has experienced but reframed somewhat, perceived in a slightly different way; and (2) to generate pattern cascades from previously disparate regions of experiences, to make new cascade patterns (Coward 1990; Ziman, 1991; and Paquet, 1997).

In a related concept, knowledge management has several models. Accordingly, T.H. Davenport, D.W. De Long and M. Beers (1998) examined corporate knowledge management initiatives. They identified knowledge management project involved in the creation of knowledge repositories, improve knowledge access, enhancement of knowledge environment and to manage knowledge as an asset to the organization. Hence, M. Damarest (1997) views knowledge management from a social environment perspective that has impact within the organization. His model identifies four phases of knowledge construction, knowledge dissemination, knowledge use, and knowledge embodiment, as a knowledge management project.

All these models have contributed, to some extent, in describing the process of knowledge innovation. Nevertheless, the complexity and heterogeneity of innovation make it difficult to formulate generalizations (Mahdjoubi, 1997). Previous linear and non-linear models were either too complex or too simplistic to be applied in practical terms. For example, Etzkowitz-Leydesdorff’s Triple Helix and Ziman’s Neural Net models are too complicated to map and the linear model is one-dimensional flow. Thus, the proposed model is to fill the gap by introducing dynamic yet generic model of knowledge innovation.

Based on M. Damarest (1997) and the simplified Triple Helix Model, we propose a knowledge innovation model comprising of five domains, i.e. (1) knowledge construction or basic research; (2) knowledge innovation or applied research; (3) knowledge diffusion or commercialization; (4) knowledge use or post-commercialization; and (5) feedback mechanism. For further description, see figure 1. We hypothesize that in order to support and sustain knowledge innovation process, a credible U-I-G support has been put in place and functioning at an effective level (the simplified Triple Helix hypothesis).

**First, Knowledge Construction (Basic Research).** Based on figure 1, the model begins with the knowledge construction phase which usually happens in university or government laboratories. Basic research is also critical to firms in

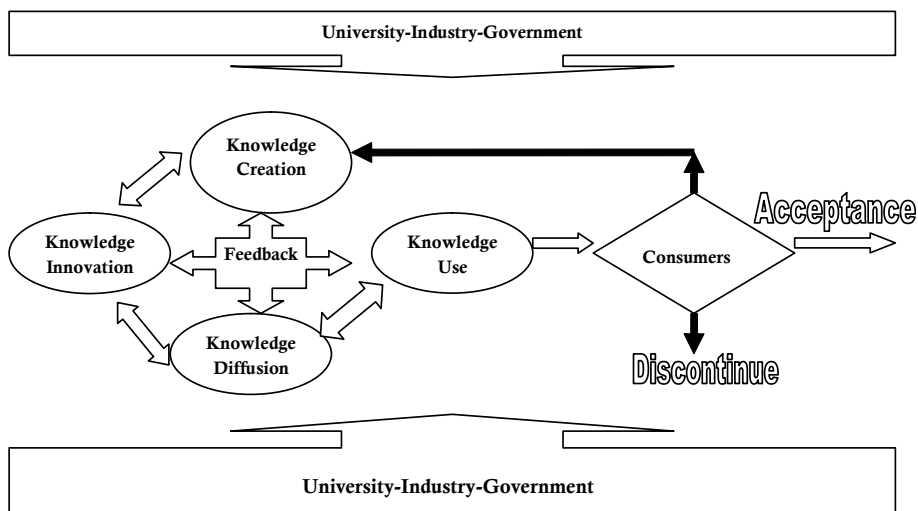


Figure 1:  
Generic Model of Knowledge Innovation

certain industries particularly the manufacturing sector. The interactive model brings interaction between basic research and applied research, vice versa. The phase of basic research can move to applied level (knowledge innovation level) if there is a sufficient knowledge base and if there is a need or demand to transform the basic research findings to a more practical and usable “product”. The flow between knowledge creation and knowledge innovation is not static. It may go back and forth depending on the feedback received regarding the new discovery and how it could be improvised to a more sophisticated and real-life functional level. In every stage of the model there is a feedback mechanism. In this model, feedback is central to the process; and that is why the feedback loop is placed in the center of the model.

*Second, Knowledge Innovation (Applied Research).* In most of the cases, the knowledge innovation phase is context-specific. Knowledge innovation can be carried out in a joint applied research between university and industry (or government) in order to produce viable results that can benefit the clients and other stakeholders. It is also an interactive process. For instance, the potential of an interactive model became apparent during the Second World War (1939-1945), when scientists working on strategic problems in wartime research projects such as radar and surveillance systems for the military, who believed that they had put aside their academic pursuit (basic research). Later, they found that the project has spawn new theoretical derivatives that they have to revert back to basic fundamental research.

As mentioned earlier, in order for this model to work, cooperation among all parties (U-I-G) must be put in place to ensure the process of knowledge creation

and innovation is going at the appropriate pace. Mechanisms to assess or evaluate knowledge flow must be rigorous enough to enhance knowledge innovation. New knowledge may be created at each stage but this on its own will not necessarily drive the project to the next stage.

*Third, Knowledge Diffusion (Commercialization).* The production and diffusion of knowledge has long viewed as a vital component of economic growth (Cowan & Jonard, 1999). Knowledge, when created, is not globally available. That is why dissemination or diffusion of new knowledge is important. Hence, E.M. Rogers (1995:5) defined diffusion as “*the process by which an innovation is communicated through certain channels over time among the members of a social system*”. Further, the diffusion process involves the spread of a new knowledge or technology from its source to potential adopters.

The commercialization of research findings is expected to occur at the end of the knowledge innovation phase (applied research). The process operates in tandem, often through the university’s technology transfer office, moving relevant knowledge and technology out of the university and its liaison office and bringing problems in — an interactive process is generated in which each phase interacts with the other. In order to generate and refine the new knowledge, evaluation mechanism is needed to diagnose the weaknesses and drawbacks of the “knowledge” (usually in the forms of technologies and products).

*Fourth, Knowledge Use (Post-Commercialization).* Final stage is the knowledge use or post-commercialization phase. This is the real litmus test for the final “product”. If the “product” is accepted by the users then it will circulate in the market but if it was found “defective” or useless then it will be either discarded (discontinued) or recycled back for improvement. This interactive-cyclic process of knowledge innovation exemplifies Charles Darwin’s classic theory of the “survival of the fittest”. The plethora of new artifacts that are invented and put on the market, only the superior few that eventually survive (Ziman, 2000).

## CONCLUSION

Knowledge innovation in a contemporary hyper competitive market could enhance an organization’s competitive edge. An academic revolution toward entrepreneurial paradigm is now an emerging phenomenon. Capitalization of knowledge in the increasingly recognized knowledge-based economy has called for new mission and governance of research universities. With the challenge for universities to consider the changing paradigm, university administrators and stakeholders should understand the new roles of entrepreneurial university. Knowledge innovation is critical in an entrepreneurial university. This article proposed a generic model of knowledge innovation based on knowledge innovation framework and the simplified Triple Helix Model. This model hypothesizes that sustainable support and collaboration from industries and government are needed to facilitate research universities to actively involved in knowledge innovation. Research has shown that universities with a long tradition of ties with industry and having high quality



research tend to generate more knowledge innovations. This means that synergistic and sustainable partnership and adequate funding improve quality of university research thus make it easier to transform universities into innovators.

## REFERENCES

- Anselin, L., A. Varga & Z. Acs. (2000). "Geographic and Sectoral Characteristics of Academic Knowledge Externalities" in *Papers in Regional Science*, Vol.79, pp.435-443.
- Atkinson, R.C. (1999). "The Future Arrives First in California" in *Issues in Science and Technology*, Winter [1999-2000]. Available also at <http://www.ucop.edu/pres/comments/fuarriive.htm> [accessed in Bangi: 10 November 2009].
- Atkinson, R.C. (2004). "Academic Freedom and the Research University" in *Proceedings of the American Philosophical Society*, Vol.148, No.2, pp.195-204.
- Bank Boston. (1997). *MIT: The Impact of Innovation*. Boston: Bank Boston.
- Bayoumi, T., D.T. Coe & E. Helpman. (1996). *R&D Spillovers and Global Growth*. Cambridge: NBER, MA.
- Bower, D.J. (1992). *Company and Campus Partnership*. London: Routledge.
- Branscomb, L. et al. (1992). *Beyond Spin-off: Military and Commercial Technologies in a Changing World*. Boston: Harvard Business School Press.
- Carayannis, E.G. et al. (1998). "High-Technology Spin-offs from Government R&D Laboratories and Research Universities" in *Technovation*, Vol.1, pp.1-11.
- Christensen, C.M. (1997). *The Innovators Dilemma: When New Technologies Cause Great Firms to Fail*. Boston: Harvard Business School Press.
- Chuanqi, H. (1998). "From Innovation to Knowledge Innovation". Available also at <http://www.modernization.com.cn/innovation.htm> [accessed in Bangi: 10 November 2009].
- Chung, S. (2001). "Forum on the Roles of Research University in Knowledge-based Economy". Paper presented in Tsinghua University, Beijing, China: April, 28-29.
- Cohen, W., R. Nelson & J. Walsh. (2002). "Links and Impacts: The Influence of Public Research on Industrial R&D" in *Management Science*, Vol.48, No.1, pp.1-23.
- Cowan, R. & N. Jonard. (1999). "Network Structure and the Diffusion of Knowledge". Available also at <http://www.merit.unimaas.nl/publications/> [accessed in Bangi: 10 November 2009].
- Cowan, R., N. Jonard & J. Zimmermann. (2004). *Evolving Networks of Inventors*. Maastricht: MERIT-Infonomics Research Memorandum Series.
- Coward, L.A. (1990). *Pattern Thinking*. Westport, CT: Praeger.
- Crawford, C. (1992). "The Hidden Costs of Accelerated Product Development" in *Journal of Product Innovation Management*, Vol.9, pp.188-199.
- Damarest, M. (1997). "Understanding Knowledge Management" in *Journal of Long Range Planning*, Vol.30, No.3, pp.374-384.
- Davenport, S., A. Carr & D. Bibby. (2002). "Leveraging Talent: Spin-off Strategy at Industrial Research" in *R&D Management*, Vol.32, No.3, pp.241-254.
- Davenport, T.H., D.W. De Long & M. Beers. (1998). "Successful Knowledge Management Prospects" in *Sloan Management Review*, Vol.39, No.2, pp.43-57.
- Delanty, G. (2003). "Ideologies of the Knowledge Society and the Cultural Contradictions of Higher Education" in *Policy Futures in Education*, Vol.1, No.1, pp.71-82.
- Doyle, P. & J. Saunders. (1985). "The Lead Effect of Marketing Decisions" in *Journal of Marketing Research*, Vol.22, pp.54-65.
- Drucker, P. (1993). *Post Capitalist Society*. New York: Harper Row.

- Eisenhardt, K. & B. Tabrizi. (1995). "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry" in *Administrative Science Quarterly*, Vol.40, pp.84-110.
- Eliasson, G. (1996). *Firm Objectives, Control and Organization: The Use of Information and the Transfer of Knowledge within the Firm*. Dordrecht/London: Kluwer Academic Publisher.
- Eliasson, G. & A. Eliasson. (1996). "The Biotechnological Competence Block" in *Revue d'Economie Industrielle*, Vol.78, No.4, pp.7-26.
- Etzkowitz, H. (2004). "The Evolution of Entrepreneurial University" in *International Journal of Technology and Globalisation*, Vol.1, No.1, pp.64-77.
- Etzkowitz, H. & L. Leydesdorff [eds]. (1997). *Universities in the Global Economy: A Triple Helix of University Industry Government Relations*. London: Cassell.
- Etzkowitz, H. et al. (2000). "The Future of the University and the University of the Future: Evolution of Ivory tower to Entrepreneurial Paradigm" in *Research Policy*, Vol.29, pp.313-330.
- Etzkowitz, H., A. Webster & P. Henley. (1998). *Capitalizing Knowledge: New Intersections of Industry and Academia*. Albany: State University of New York Press.
- Fassin, Y. (1991). "Academic Ethos versus Business Ethics" in *International Journal of Technology Management*, Vol. 6, No. 5/6, pp.533-546.
- Freeman, C. (1992). "Innovation, Changes of Techno-economic Paradigm and Biology Analogies in Economics" in Christopher Freeman [ed]. *The Economics of Hope: Essays on Technical Change, Economic Growth and the Environment*. New York: Pinter Publishers.
- Gomory, R. (1992). "The Technology-product Relationship: Early and Late Stages" in Nathan Rosenberg, Ralph Landau & David Mowery [eds]. *Technology and the Wealth of Nations*. Stanford: Stanford University Press.
- Graversen, E.K. & M. Mark. (2005). "The Effect of R&D Capital on Firm Productivity". *Working paper for the Danish Centre for Studies in Research and Research Policy*.
- Gray, H.H. (2001). "The University in History: 1088 and All That". *Paper presented at the Idea of the University Colloquium, University of Chicago [17 January]*.
- Griliches, Z. (1992). "The Search for R&D Spillovers" in *Scandinavian Journal of Economics*, Vol.94, pp.29-47.
- Guellec, D. & B. Van Pottelsberghe de la Potterie. (2004). "From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter?" in *Oxford Bulletin of Economics and Statistics*, Vol.66, No.3, pp.353-378.
- Hall, Z. & C. Scott. (2001). "University-Industry Partnership" in *Science*, Vol.291, No.5504, pp.531-553.
- Hernes, G. & M. Martin. (2000). *Management of University-Industry Linkages*. Paris: International Institute of Educational Planning.
- Holton, G. & G. Sonnert. (1999). "A Vision of Jeffersonian Science" in *Issues in Science and Technology Online*. Available also at <http://www.issues.org/issues/16.1/Holton.htm> [accessed in Bangi: 10 November 2009].
- <http://www.aau.edu/research/PHS9.21.00.html> [accessed in Bangi: 10 November 2009].
- <http://www.carnegiefoundation.org/Classification/CIHE2000/background.htm> [accessed in Bangi: 10 November 2009].
- Kessler, E. & P. Bierly. (2002). "Is Faster Really Better? An Empirical Test of the Implications of Innovation Speed" in *IEEE Transactions on Engineering Management*, Vol.49, No.1, pp.2-12.
- Kline, S. (1985). "Innovation is Not a Linear Process" in *Research Management*, Vol.28 [July-August], pp.36-45.
- Kline, S. & N. Rosenberg. (1986). "An Overview of Innovation" in Ralph Landau & Nathan Rosenberg [eds]. *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington, DC: National Academy Press.
- Leahy, D. & J.P. Neary. (2004). "Absorptive Capacity, R&D Spillovers, and Public Policy". Available also at <http://www.ucd.ie/economic/staff/pneary/pdf/absorptv.pdf> [accessed in Bangi: 10 November 2009].
- Leydesdorff, L. & H. Etzkowitz. (1996). "The Future Location of Research: A Triple Helix of University-Industry-Government Relations II" in *EASST Review*, Vol.15, No.4, pp.1-8.
- Lieberman, M. & D. Montgomery. (1988). "First Mover Advantages" in *Strategic Management Journal*, Vol.9, pp.41-58.

- Lotz, P. (2004). "Limits to Control?". Paper presented at the DRUID Summer Conference on Industrial Dynamics, Innovation and Development. Denmark: Elsinore [June, 14-16].
- Lundvall, B. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter.
- Lyotard, J. (1979). *The Postmodern Condition: A Report on Knowledge*. Translated by Bennington & Massumi [1984]. Manchester: Manchester University Press.
- Mahdjoubi, D. (1997). "Non-linear Models of Technology Innovation". Available also at [http://www.gslis.utexas.edu/~darius/non\\_md1/non\\_md1.html](http://www.gslis.utexas.edu/~darius/non_md1/non_md1.html) [accessed in Bangi: 10 November 2009].
- Niininen, P. (2000). "Effect of Publicly and Privately Financed R&D on Total Factor Productivity Growth" in *Finish Economic Papers*, Vol.13, No.1, pp.56-68.
- OECD. (1993). *The Measurement of Scientific and Technological Activities: Standard Practice for Surveys of Research and Experimental Development*. Paris: OECD.
- OECD. (1998). *University Research in Transition*. Paris: OECD.
- OECD. (2000). *Knowledge Management in the Learning Society: Education and Skills*. Paris: OECD.
- O'Hare, R. & P. Pitney. (2002). "The Economic Impact of Higher Education". A White Paper presented to review the economic impact of higher education and the University of Alaska System, [July 16], University of Alaska, Fairbanks.
- Paquet, G. (1997). "Evolutionary Cognitive Economics". *Unpublished Paper*. Available also at <http://www.gouvernance.ca/index.php?page=embed&lang=ce&embed=publications/97-52.pdf> [accessed in Bangi: 10 November 2009].
- Pelikan, J. (1992). *The Idea of the University: A Re-Examination*. New Haven: Yale University Press.
- Piergiorganni, R. & E. Santarelli. (2001). "Patents and the Geographic Localization of R&D Spillovers in French Manufacturing" in *Regional Studies*, Vol.35, No.8, pp.697-702.
- Premus, R. (2002). "Moving Technology from Labs to Market: A Policy Perspective" in *International Journal of Technology Transfer and Commercialisation*, Vol.1, No.1/2, pp.22-39.
- Readings, B. (1996). *The University in Ruin*. Cambridge, MA: Harvard University Press.
- Roberts, E.B. (1991). *Entrepreneurs in High Technology: Lessons from MIT and Beyond*. New York: Oxford University Press.
- Roberts, E.B. & D.E. Malone. (1996). "Policies and Structures for Spinning-off New Companies from Research and Development Organizations" in *R&D Management*, Vol.26, Issue 1, pp.17-48.
- Rogers, E.M. (1995). *Diffusion of Innovations*. New York: The Free Press, 4<sup>th</sup> edition.
- Rogers, E.M. & J.K. Larsen. (1984). *Silicon Valley Fever*. New York: Basic Books.
- Rogers, E.M., S. Takegami & J. Yin. (2001). "Lessons Learned about Technology Transfer" in *Technovation*, Vol.21, No.4, pp.253-261.
- Rolnick, A. & R. Grunewald. (2001). "The University of Minnesota as a Public Good". Paper presented at the University's Contribution to Minnesota's Economic, Social and Cultural Vitality [August, 23]. Available also at <http://minneapolisfed.org/pubs/fedgaz/01-11/public.cfm> [accessed in Bangi: 10 November 2009].
- Romer, P. (1986). "Increasing Returns and Long Run Growth" in *Journal of Political Economy*, Vol.94, pp.1002-1037.
- Romer, P. (1990). "Endogenous Technological Change" in *Journal of Political Economy*, Vol.98, pp.71-102.
- Rowley, J. (2000). "Is Higher Education Ready for Knowledge Management?" in *International Journal of Education Management*, Vol.14, No.7, pp.325-333.
- Sample, S.B. (2002). "The Research University of the 21<sup>st</sup> Century: What will it Look Like?". Keynote Address to the 23<sup>rd</sup> Army Science Conference, Orlando, Florida [December, 2].
- Santoro, M. & A. Chakrabarti. (1999). "Building Industry-University Research Centers: Some Strategic Considerations" in *International Journal of Management Reviews*, Vol.1, No.3, pp.225-244.
- Schumpeter, J. (1911). *Theorie der Wirtschaftlichen Entwicklung*. Translated in 1934 by Duncker & Humblot become *The Theory of Economic Development*. Cambridge, MA: Harvard University Press.
- Schumpeter, J. (1943). *Capitalism, Socialism and Democracy*. London: Allen & Unwin.
- Shenhar, A.J. (1993). "The PROMIS Project: Industry and University Learning Together" in *International Journal of Technology Management*, Vol.8, No.6/7/8, pp.611-621.
- Shumar, W. (1997). *College for Sale: A Critique of the Commodification of Higher Education*. Washington, DC: The Falmer Press.

- Solow, R. (1956). "A Contribution to the Theory of Economic Growth" in *Quarterly Journal of Economics*, Vol.70, pp.65-94.
- Solow, R. (1957). "Technical Change and the Aggregate Production Function" in *Review of Economics and Statistics*, Vol.39, pp.312-320.
- Steffensen, M., E.M. Rogers & K. Speakman. (2000). "Spin-offs from Research Centers at a Research University: A Communication Perspective" in *Journal of Business Venturing*, Vol.15, No.1, pp.93-111.
- Thomond, P. & F. Lettice. (2002). "Disruptive Innovation Explored". Paper presented at the 9<sup>th</sup> IPSE International Conference on Concurrent Engineering: Research and Applications, at the Cranfield University, UK.
- Tucker, R.B. (2002). *Driving Growth Through Innovation*. San Francisco, CA: Berrett-Koehler.
- Tushman, M. & P. Anderson. (1986). "Technological Discontinuities and Organizational Environments" in *Administrative Science Quarterly*, Vol.31, pp.439-465.
- Utterback, J. (1994). *Mastering: The Dynamics of Innovation*. Boston, MA: Harvard Business School Press.
- Valery, N. (1999). "Survey of Innovation in Industry: Industry Gets Religion" in *The Economist*, February, 20.
- Veryzer, R.W. (2005). "The Roles of Marketing and Industrial Design in Discontinuous New Product Development" in *The Journal of Product Innovation Management*, Vol.22, pp.22-41.
- Wallenburg, J. (2004). *Genomics, Health and Society: Emerging Issues for Public Policy*. Canada: Symposium Report, Policy Research Initiative.
- Wisconsin Technology Council. (2004). "The Economic Value of Academic Research and Development in Wisconsin". Available also at [http://www.wisconsintechcouncil.com/uploads/documents/academic\\_r&d\\_report\\_2004.pdf](http://www.wisconsintechcouncil.com/uploads/documents/academic_r&d_report_2004.pdf) [accessed in Bangi: 10 November 2009].
- Ziman, J. (1991). "A Neural Net Model of Innovation" in *Science and Public Policy*, Vol.18, No.1, pp.65-75.
- Ziman, J. (2000). *Technological Innovation as an Evolutionary Process*. Cambridge, UK: Cambridge University Press.