# THREE ESSAYS ON ASPECTS OF PATENT-RELATED INFORMATION AS MEASURES OF REVEALED TECHNOLOGICAL CAPABILITIES


By

**Yender Lee**

Faculty of Management

McGill University, Montreal, Canada.


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**THREE ESSAYS ON ASPECTS OF PATENT-RELATED INFORMATION AS MEASURES OF REVEALED TECHNOLOGICAL CAPABILITIES**

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# ABSTRACT

This dissertation consists of three papers on the theme of technological capabilities. Patent information can be viewed as *indicators* of inventive activities emanating from a certain underlying *technological capability. Cumulative patents may, therefore, be considered as the revealed manifestations of those technological capabilities* (hereafter abbreviated as RTC) Patent databases have stored a wealth of publicly-held and verified knowledge. Each of the papers in this thesis takes-up the challenge of examining some particular aspects of RTC based on patents; and will advance our knowledge of the subject modestly in a different direction, by taking advantage of invaluable competitive information contained in patent databases. In the sense of data-mining into knowledge, we formulate and introduce a series of concepts, measurements and a methodology under the title of *"patent calculation"* in the first paper to mine this invaluable information. We apply this methodology, with multiple indicators, to detect the existence of technological capabilities and examine it in relation to the pattern of global collaboration in patented inventions. In the second paper we study the over time, patterns of technological capabilities in a number of countries in relation to their market and industrial structure. In the third paper we search for potential patterns of selective concentration and specialization in the patent-intensive industries of newly industrializing countries by using the index of revealed technological advantage (RTA), which has been used as the conventional indicator in advanced countries since 1960s in technology-oriented studies. We also examine if the inherent complexities of this measure impacts the results. In summary, we develop concepts, measures and tools, in the three essays, to take advantage of patent information to characterize the patterns of revealed technological capabilities and its variations in relation to collaboration, industrial structure, concentration and specialization. Individuals and companies should make use of this invaluable competitive knowledge in their search for technological frontiers. [Abstract total 308 words / keywords: patent information, technological capability, patent calculation, international technological collaboration, technological concentration, and technological specialization]

# Trois rapports sur les aspects d'informations liées au brevet comme mesure de capacités technologiques découvertes

Par **Yender Lee**, Université de McGill, Montréal, Canada

## ABSTRAIT

Cette dissertation suit la thèse basée sur manuscrit. Le sujet principal porte sur des capacités technologiques. L'information de brevet peut-être visualisée comme *indicatrice* d'activités inventives émanant d'une certaine *capacité technologique* fondamentale.

*Des brevets cumulatifs peuvent, donc, être considérés comme des manifestations découvertes de ces capacités technologiques (CTD).* Les bases de données de brevet ont enregistré une richesse de connaissance verifiée. Chaque rapport de cette thèse relève le défi d'examiner quelques aspects particuliers du CTD basés sur des brevets, puis avancera l'état de notre connaissance du sujet dans une direction différente en tirant profit d'informations concurrentielles d'une valeur inestimable contenues dans les bases de données de brevet. Dans le sens de l'exploitation des données, il y a un besoin de créer des outils appropriés, des mesures et des concepts afin d'explorer ces informations d'une valeur inestimable. Nous formulons et présentons une série de concepts, de mesures et une méthodologie. Nous appliquons cette méthodologie, avec les indicateurs multiples, pour détecter l'existence des capacités technologiques et l'examiner par rapport à la configuration de la collaboration globale brevetée dans des inventions.

Dans le deuxième rapport nous étudions la configuration régnante dans un certain nombre de pays par rapport à leur marché et leur structure industrielle. Dans le troisième papierapport nous recherchons les configurations potentielles de la concentration et de la spécialisation sélective des industries fortement brevetées, dans les nouveaux pays industriels, en utilisant l'indice de l'avantage technologique découvert (ATD), qui a été utilisé comme indicateur conventionnel dans les pays avançés depuis les années 60 dans des études orientées vers la technologie. Nous examinerons également si les complexités inhérentes de cette mesure ont un effet sur lesrésultats. En résumé, nous créons les concepts dans les trois rapports, les mesures et les outils afin de tirer profit de l'information de brevet pour caractériser les configurations des capacités technologiques découvertes et de ses variations dans les relations à la collaboration, à la structure industrielle, à la concentration et à la spécialisation. Les individus et les compagnies ne devraient donc pas ignorer cette connaissance concurrentielle de valeur inestimable dans leur recherche des frontières technologiques.

347 mots / mots clé : information de brevet, capacité technologique, calcul de brevet, collaboration technologique internationale, concentration technologique, et spécialisation technologique

# ACKNOWLEDGEMENTS

"C'est ne pas facile pour moi...[1]." is my favorable slogan in introducing myself and my *management odyssey*[2] overseas in a scholarly wonderland known as the Management Doctoral Consortia run by the four-universities around holy Mont Royal in the holy city Montreal, including McGill[3]—an intellectual North American capital--after over long period of about 20 years of teaching at a large Taipei downtown business college with small campus in my homeland of Taiwan. Even though the completion of a Ph.D. dissertation represents a significant individual achievement, there are invariably others who must play key roles and deserve some recognition as well. First of all, I would like to thank my committee members, Professor Fernand Amesse, Shanling Li and McGill director Professor Jan Jorgensen for providing me with important feedback as I moved inexorably forward toward the ultimate completion of this endeavor.

My deepest appreciation must be reserved for my supervisor, Professor Hamid Etemad, a former associate dean at McGill, who has always been my best mentor, a guide and a lighthouse in this odyssey. Especially, his diligent research spirits of master-apprenticeship and the pursuit of perfection will always be my best scholarly paradigm. Besides academic life, all of his merits of careful consideration for my family, my health and like-mentor-like-friend, have earned my deep hearted respect and admiration. It is fortunate for me that I will hopefully have this McGill mentor throughout my lifetime career. Also, thanks to his health and agile mind, although he suffered a knee injury recently and rib-bone injury three years ago, I have made steady progress. I hope he is forever in good health.

At this story's right beginning, I need to thank MIS Professor Mike Wybo and Professor Allen Lee for accepting me into the McGill MIS area at the inception stage of this

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[1] This is French slogan that in English means 'it is not so easy for me....'

[2] The theme of ASAC 2001 that I just attended in May was *management odyssey*; where our essay no. 2 was honored with a Best Paper Award in ASAC 1999. This prize, that was not a best student award, looms larger now as so many mature professors in Canada and many from around the world competed for it. I will like to thank my co-author's good refining craft and apprenticeship besides my own good innovation of data-mining-into knowledge concept. Of course, we would like to thank the recommendation of ASAC1999 division leader of international business, Professor Brian Silverman as well as anonymous reviewers.

[3] In an issue of *Strategic Management Journal*, Professor Danny Miller denies his status of narrow 3M gang". On the opposite, I would happy to wish that I would be a new member of the broad definition of this 3M gang.

odyssey in 1995. This start-up owes its beginning to the long-urging of another lifetime mentor to get a PhD degree for minimum membership as a professor since 1976. He is Dr. Tinko Chen, an MBA mentor at National Taiwan University, co-supervising my masters thesis with Dr. Sweisen Liu. Next, particular thanks are directed to Professor Alex Whitemore and Professor Shanling Li for their kind consultation during a time period of my transition between MIS and the technology management area. Then, I am grateful for an initial encouragement and enlightenment in a course called "Seminar in Technology Management" by Professor Jorge Niosi, that stimulated my interest to shift from the MIS field to the fantastic field of technology management. During my odyssey I have learned that the nature of the two fields are close and complement each other as this dissertation's focus indicates very well. Data-mining into knowledge is indeed about the technology of knowledge. I feel that I have befriended many scholars in the two knowledge networks whose works are cited throughout this dissertation.

I am deeply indebted to my wife, Meinou Lin Lee, for accompanying me throughout this odyssey, and for her encouragements, tolerances as well as taking care of the most parts of our family affairs during my overseas recharging days. Although she is also on her own journey through an economics PhD degree at the same time, she has provided me with priceless help and support. Words are inadequate to express my profound love, respect, and genuine admiration that I feel for her. Meanwhile, it is always a good comfort for both of us to see our lovely children, Kong and Jade, grow and attain their education overseas with us. They have now reached a state to help their Ph.D. seeking parents. Thanks to Jade for her careful drawings of the Knowledge Network Maps. Finally, it is my sincere, obedient and happy duty to give my dear parents- Rulin and Chioushine, the approximate answer to their question of when I can finish; and my unlimited gratitude for their lifetime of support, care and attention for the health of their diligent old son forever.

Yender Lee -- an old overseas student
After a management odyssey
August 2001, la Lac aux Castors, Montreal

# CONTRIBUTIONS OF AUTHORS

## (Including publication status)

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Re: Certificate of Co-Authors' Contribution to Joint Research Works

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**Table: The Extent of Contribution of Each Author to the Joint Works**

| *Work Items* | *Candidate's contribution* | *Supervisor's contribution* |
|---|---|---|
| Generation of the Idea | X (2/3) | X (1/3) |
| Background analysis | X (2/3) | X (1/3) |
| Research design | X (2/3) | X (1/3) |
| Data Collection | X (3/3) | |
| Data analysis | X (3/3) | |
| First Rough Draft | X (3/3) | |
| Further Developments | X (1/4) | X (3/4) |
| Revised Drafts | X (1/4) | X (3/4) |
| Presentation at conferences | X (1/3) | X (2/3) |

Co-authors: Candidate-Yender Lee and Supervisor--Professor Hamid Etemad

Signatures: Yender Lee, Hamid Etemad

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# CHAPTER I:

# INTRODUCTION

## I. RESEARCH RATIONALE, OBJECTIVES AND RESEARCH QUESTIONS

### 1.1 Patent-Related Information as the Measures of Revealed Technological Capabilities

This dissertation is based on the "manuscript-based thesis" format. The main theme inherent in the three constituent manuscripts of the thesis is that technological capability is not fully understood; and, as a field of inquiry it remains understudied. Helfat (2000) maintains that the understanding of the so-called complex long-waves[1](Kondratieff, 1926) has attracted increasing interest[2]. As a proxy measure of such capabilities, we propose that patents could be viewed as a manifestation of technological capabilities at both micro and macro levels. Patent databases have stored a wealth of publicly-held and verified knowledge that have not received the full attention that they deserve. We propose to explore the information content of selected patent databases in order to shed further light on the technological capabilities that underlie an invention, which will eventually be certified by a patent(s).

Each of the manuscripts in this thesis will advance the state of our knowledge of the subject modestly in different directions by applying a set of tools, measures, concepts and procedures to take advantage of invaluable competitive information contained in patent databases. With respect to data mining, there is a need to create proper concepts, associated tools and measures to search the invaluable information so that one can develop a much richer

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[1] Kondratieff's long wave has been referred as technology cycle with about time period of 40-100 years.
[2] In a special issue on The Evolution of Firm Capabilities in *Strategic Management Journal*, Helfat (2000) introduced six papers examining the resources and capabilities needed for competitive advantage.

understanding of the underlying technological capabilities. Each of our manuscripts takes up the challenge of responding to some facets of this topic.

### 1.2 Basic Research Background

The term *invention* has been defined as an activity directed towards the discovery of new knowledge about product and process (Schmookler, 1957). A fair society should allocate substantial resources and offer strong incentives to inventors for its own economic welfare. In a landmark article, Arrow's simple model (1962) maintained directly that even an ideal system of patents might not provide an adequate incentive to invent. Generally speaking, the expected benefits received by an inventor are realistically far less than the gross social returns from his or her inventive efforts. This is unless a part of social costs (Coase, 1960 and 1937) are absorbed in some particular way(s). Patenting is the legal right to good ideas (Economist, 2001). Each patented invention certifies the existence of at least a new idea that can potentially be included, or used in the creation of product(s), process(es) or technology-related knowledge. The noteworthy point is that the innovative aspects of patent-related information (i.e., as stored in patent databases) are verified, well-documented, and also publicly available (with the legal protection[3] in lieu of, or in exchange for, public disclosure of the information).

The common proverb is: "Ideas come a dime a dozen." Invention seems to be the easy bit. Innovation, by contrast, is genuinely different (Economist Technology, 2001). However, innovation-related information, is less easily identified, certified and stored as public knowledge than is patent information.

*The concept of revealed technological capability (RTC).* We contend that patent information is a

[3] Only patent-related knowledge is explicitly protected by laws which guaranty it to remain imitation-free. This knowledge can be cost-effectively learned by any organization or individual within the patent period and be used as a knowledge platform on which to innovate again from its revealed knowledge as opposed to starting from zero

manifestation of inventive activities, which are in turn based on certain technological capabilities accumulated over time. They could be viewed as *the direct indicators* of the inventive activities that have emanated from the associated *technological capability.* As patenting cost is not trivial, each patent granted to an invention must point to the initial commercialization intentions. This particularly applies for cases with registered assignees(s) in the United States' Patent and Trademark Office (USPTO). Assignees are, by definition, those who are given the exclusive right to commercialize the patent, once granted (or deferred right once applied). Therefore *cumulative patents are manifestations of the underlying capabilities,* which can be potentially be exploited commercially at a later point. We term them *as revealed technological capabilities, or RTC for short, hereafter.* Such publicly verified and protected indicators are both visible and easily accessible for detecting their underlying intellectual capital (and property) in competitive environments. No individual or company should ignore this invaluable competitive knowledge in the search for research frontiers (Price, 1963 and 1965).

Due to the nature of patent databases (e.g., codified, externally certified, publicly accessible, etc.), a search on patent databases should *logically precede* any search for the existence of the relevant knowledge, whether it be tacit, embedded or embodied knowledge[4]. Knowledge may mean useful and competitive information made-up of unseen patterns and trends hidden in a mountain of data (Patterson, 2000).

Data mining is simple in theory, but it can become quite involved and not so easily

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knowledge.

[4] In discussing the organizational knowledge, Madhavan & Grover (1998) defined embedded knowledge as the potential knowledge resulting in a combination of the individual team member's store of tacit knowledge. The new knowledge always consists of explicit knowledge and tacit knowledge. Combining explicit knowledge is much easier than those of tacit knowledge. Therefore, we cannot ignore any explicit knowledge base, like patent bases.

accessible in practice (Patterson, 2000). Unlike older mathematical or statistical methods, which take a long time to yield constructive information, the current software and techniques for data-mining, or knowledge-discovery, with their increasingly scientific methods and specialized tools, help make mining mountains of data cost-effective. They can screen for golden opportunities and identify lucrative opportunities (hidden in data mountains) for most businesses to use (Patterson, 2000). Therefore, it would be a waste of time and effort, if such indicators of revealed technological knowledge, or capabilities, were not data-mined cost-effectively[5] before the start of any large-scale research. While research and development (R&D) is knowledge intensive, the engineers and scientists in the R&D process are typical knowledge workers (Laudon and Laudon, 1993). Needless to say, a technology manager in the R&D process, is far more than a technologist (Medcof, 1985). Ignoring the information stored in patent databases may prove costly to their knowledge-based work. Not only does it expose the research process to the risk of imitating what is already discovered (and patented), which may be costly and time consuming, it may also deprive the research process of the possibility of starting from a higher, pre-existing knowledge platform that is documented in patent databases. In sum, technological capabilities are understudied. We use the two perspectives of "data-mining-into-knowledge" and "knowledge work" to to synthesize this research problem.

### 1.3 The Justification of the Topic and the Connection of the Three Essays

The following will provide some clear answers to several critical research concerns:

[5] In PC Magazine special issue, Robert-Witt (2000) shows us that there is some new tools developed for text mining. For example, Notes R5 has text mining, instant messaging, and Web-collaboration built-in. Domino.com is a document and content management product. As for Lotus, the long waited Raven platform for knowledge management should be in beta by the time. At a high level, Raven is the "glue" that holds the Lotus' extensive line of knowledge management and collaboration products together. A PC Magazine's special issue on e-business essentials reports the above (www.pcmag.com accessed on Aug 6, 2000).

*The justification of the topics.* Popper (1963) states that there is an increasing need for knowledge to grow and progress continually, whether tacit or explicit[6]. Knowledge grows like organisms, with data serving as food to be assimilated rather than merely stored (Weiss, 1960). Knowledge increasingly serves as one of the two important bases of capabilities, with technology serving as the other (Kogut and Zander, 1992) . Given that the broad pool of knowledge external to a unit (e.g., an organization) grows much faster than the internal one for the most part, it logically follows that all knowledge workers, particularly R&D project managers (Hauschildt, Keim & Medcof, 2000), need to have easy access, and be able to search such external knowledge bases before initiating a new research stream internally. Patent databases store a wealth of *explicit* external knowledge. Basically, their roles are to present a documented and evaluated body of ever-advancing innovation-based or technology-related knowledge. Therefore, they can be viewed as a library or pool of knowledge from which both firm and knowledge workers can draw (or consult and explore) to further their own knowledge. Analysts may ignore this stored knowledge at such dangerously high costs as:

i) Information leading to patents are examined both internally (by company authorities prior to patent application) and externally (by patent examiners during patent review process) and are also open to further challenges in the public court systems once a patent is granted. They store highly reliable information[7].

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[6] The central theme is that organizational knowledge is created through a continual dialogue between tacit and explicit knowledge (Nonaka & Takeuchi, 1995). Meanwhile, there exists both the importance and the dilemma of this kind of knowledge conversion at the same time. During conversion process it has some risk of exposing knowledge to imitation by other competitors (Inkpen & Dinur, 1998).

[7] As the cost of patenting may be substantial and act as a barrier to patenting, many internal corporate authorities examine patent applications carefully, especially when the firm is applying from outside the U.S.

ii) They are publicly available and are among the best measures of inventions and technological knowledge embodied in, or to be exploited for, the new products or process resulting from the corresponding patent(s).

iii) Patents are the most reliable measure of the *inventive output* of research and development (R&D) activities, while R&D expenditure and the Number of Scientists and Engineers are both input measures.

In sum, patent data is therefore the most reliable evidence of the actual discovery of new ideas related to products and processes, while innovation data from trade journal reports (Acs, Audretsch & Feldman, 1994 and 1992) provide better evidence for R&D spillover. Especially when accumulated over time, they reveal (or portray) the accumulation of innovative technological capabilities. We suggest that no patented invention, documented in various patent databases, can be ignored by any competitor in a quest for generating (or accessing) similar intellectual capital or intellectual property. It is therefore imperative that the data-mining or text-mining (and their ever-refined versions) be utilized to reveal at least summary knowledge[8] about the technological opportunities related to one, or a family of revealed patents in a cost-effective manner; and also to identify the path of ever advancing technology frontiers (Price, 1963&1965b). Our research follows this philosophical stance and provides a methodology as well as examples for realizing this approach.

Toffler (1990) observed that a typical knowledge worker (i.e. all R&D scientists and engineers as well as technology managers as further defined, below) in the age of knowledge economy and knowledge society, must have some system (processes or methodology) at their disposal to *create, process and enhance their own technological knowledge, and in some cases*

[8] This summary knowledge about knowledge may be called meta-knowledge (or the knowledge of knowledge).

*also mange those of other co-workers* (especially in the case of technology managers). Laudon & Laudon (1993) stipulate the four generic attributes that characterize "knowledge work" (performed by knowledge workers) as:

i) "based on codified body of findings and results",

ii) "can be taught in schools as principles and procedures",

iii) "certified by the state and school", and

iv) "regulated by professional associations."(Laudon and Laudon, 1993)

The content of patent databases meet at least three of the above generic requirements. Furthermore, Laudon & Laudon (1993) also stipulated the four requirements of a general "Knowledge Work System" (KWS). A knowledge work system is defined as and *must*:

i) "provide an easy access to *external knowledge base",*

ii) "provide powerful analytical, graphic, document management, and communication software",

iii) "support computing-intense applications", and

iv) "offer a user-friendly interface" (Laudon and Laudon, 1993: 486-488).

Using Loudon and Loudon's framework for knowledge work and knowledge work systems, one can easily observe that patent databases are *certainly codified, certified, regulated and external* to the organization(s). Therefore they meet all the requirements of "knowledge Work". They also meet at least three (out of four) requirements of a "Knowledge Work System". Therefore, patent data-bases (particularly the recent electronically-stored versions, enhanced with search engines[9]) should be viewed as one of the most important external

[9] The term search engine refers to various type of search logic (mostly Boolean) on-the web or off-line data-mining (Instantis Inc., 2001). While the term "algorithm" usually refers to mathematical solution logic (flowchart) for programming through computation, in the recent search engine software companies have developed

knowledge databases on which to build competitive evaluation and interpretation of the pool of newly-created ideas (Laudon & Laudon, 1993: 488). Moreover, they should be used by all knowledge workers within a knowledge-creating organization (or knowledge work system), such as innovative companies in super-technology industries (Medcof, 1999) as envisioned by both Laudon and Laudon (1993) and Nonaka (1996; 1994 and 1991).

The concept of RTC allows us to also rely on both the resource-based and the knowledge based theories of firm as the theoretical basis for the above justification. However, we will review foundations of both the Resource-Based (Nelson & Winter[10], 1982) and Knowledge-Based theories (Kogut & Zander[11], 1992; Nonaka[12], 1994 and Nonaka & Takeuchi, 1995[13]) of the firm in order to argue that the study of *revealed* patents is analogous to the examination of the current frontier. If and when a firm is determined to push its knowledge frontier truly forward in order to increase its knowledge, or technology-based resources for increased competitiveness, it must examine the information inherent in the relevant family of patents in some effective manner. The three manuscripts in this thesis strive to provide new tools and methodologies to make such examination possible. This will be the common value-added contribution of each of the three manuscripts in this thesis.

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various technologies also called algorithms (Venkat, 2001) for determining the relevance and rankings for a given key word search. Search engines might be installed internally on the given website or externally all available websites around the Worldwide Web.

[10] Much organizational knowledge remains tacit, because it is not possible to describe all the aspects necessary for successful performance (Nelson & Winter, 1982).

[11] Kogut and Zander (1992) differentiate between information (e.g. facts) and know-how (e.g. how to organize factories). Recipes consist of information, but the description is imperfect representation of know-how. Explicit knowledge is transmittable in formal, systematic language, axiomatic propositions, and symbols. It can be codified or articulated in manuals, computer programs, training tools, and so on.

[12] For example Knowledge creation is a key competitive advantage, while inter-organizational knowledge creation has been underdeveloped (Nonaka, 1994).

[13] Nonaka and Takeuchi (1995) argue that a key challenge for organizations is the conversion of tacit knowledge into explicit. Knowledge is tacit and highly personal has little value until it can be converted into explicit knowledge that other organizational members can share.

*These three manuscripts / papers are connected by at least four common threads:* First, they are all based on the patent database of the U.S. Patent and Trademark Office (USPTO). They all use patent records as the basis for examining revealed technology based knowledge and its associated capability(ies).

Second, all of them utilize similar search logic(s) for on-line data-mining. In some cases, this search must be converted to "text mining"(Robert-Witt, 2000), as the associated texts (i.e.., the text of patent citations) must be also examined.

Third and most importantly, they clearly examine three related aspects of technology-based capability: i) technology specialization; ii) technology concentration, and iii) pattern of technology creation and collaboration globally. These are accomplished mainly by the use of a new generation of tools and techniques that analyze patent statistics mined by new information technology as indicators of revealed technological capability for a selected sample of countries.

Fourth, all of them include some members of the newly-industrializing countries (NICs) of Asia in the sample of countries studied. Although the actual sample of countries analyzed varies from one essay to the next, two criteria guided the selection of the sample throughout: i) As rapid industrialization in Asian NICs has compressed the cycle of technological development into less than three decades, thus allowing for the study of patterns that have taken much longer time in other countries, a select list of Asian NICs (mainly South Korea and Taiwan) were always included in the sample; ii) In addition to the Asian NICs, a carefully select list of the most appropriate countries, ranging from the most inventive to the most populous, are added to increase the sample's representativeness, to provide a basis for comparison of results, and to add richness to the findings.

Furthermore, during the emergence of the knowledge economy, it has been observed that new issue-driven (Leonard-Barton, 1992b) interdisciplinary sub-fields, such as knowledge management studies, are appearing with increasing frequency in conference themes. Consider for example INFORMS / KORMS 2000 (Theme: Information and Knowledge Management in the 21st Century) and PICMET 2001 (Theme: Technology Management in the Knowledge Era). Similarly, several special issues of management journals (e.g. *Strategic Management Journal* , Winter 1996 issue on Knowledge and the Firm; *California Management Review*, Spring 1998 issue on Knowledge and the Firm; and recent *Strategy Management Journal* (SMJ), 2000 special issue on The Evolution of Firm Capabilities) have published collections on closely-related themes. Particularly, Spender and Grant (1996) in the introductory overview to a special SMJ issue on Knowledge and the Firm, emphasize that patents are very satisfactory indicators of knowledge creation; and patenting is itself a strategic choice (p.7). In the last decade alone, the theory of the firm seems to have undergone a "paradigm shift" (Kuhn, 1962) from *capital-based* to *resource-based,* and is slowly moving toward *knowledge-based.* As stated earlier, our papers use patents as the revealed manifestations of the ever-advancing research frontier of technological knowledge and should certainly be able to shed some light on "the explicit" aspects of the emerging knowledge-based theory of the firm.

## II. AN OVERVIEW[14] OF PATENTING AND PATENT DATABASES

### 2.1 A Brief Discussion of The Patent Systems

The patent system is one of the oldest institutions of market-oriented societies designed to promote and diffuse innovation (Archibugi, 1992) dating back to 1474 in the Republic of

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[14] This part is an "overview" (Price, 1963 and 1965b) as opposed a conventional literature "Review". It is in addition, or complimentary, to the introductory materials and the literature Reviews attached to each manuscript. It is designed to avoid replicating the introductory or theoretical discussions of each manuscript.

Venice[15] (Scherer & Ross, 1990, 1980, 1970). Patents and patent statistics have *"fascinated"* economists for a long time as well as researchers of technology management in recent years by exploring questions, including economic growth, technological change, invention and innovation. The measurement of technological change is of increasing importance to business, research and policy (Archibugi and Pianta, 1996). Researchers have long desired a set of good measures and indicators in order to better understand those complex processes. We might first consider that the concepts of R&D, (invention, innovation and patenting) are somewhat different but they are all parts of interrelated, nonlinear and complex (Winter, 1989: 41) processes advancing the state of technology (i.e. new product or process). It is hoped that the effort of breaking down the process of technological advances into elements will eventually be more measurable (MacLaurin, 1953). Ideally, each of them should logically have had a distinct measure of its own.

However, direct measurements for three of them are not any easier or more reliable than the associated patents. In fact, Griliches (1990) wrote that we have "almost no" good measures for any of them -- except for patents as a measure of inventions -- (Griliches, 1990). Like sciences' [16] need to grow and progress (Popper, 1963) in order to avoid "infinite twin regress[17]" (Lakatos, 1978), technology cannot stay stagnant. Both science and technology need good indicators for better understandings and measurement of the direction of their trends, and the extent of their growth and progress; and even hopefully for managing their content. Since

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15 All of industrial organization book including three editions of this famous Scherer & Ross (1990/1980/1970) have a special chapter on patent system, innovation, R&D with economics. Scherer maintained that debate over the patent monopoly has continued ever since first practice by the Republic of Venice in 1474.

16 Here science means total sum of all fields not each specific field or a particular time period. For some field might dwindle, while some field grows (Price, 1963). Total science might be stagnate in some time period in the history.

17 In a theory of knowledge in philosophy of science, Lakatos (1978) demonstrated that science need firm foundations in avoid of infinite twin regress of meanings and truths.

there is a broad range of such indicators (e.g. R&D expenditure and innovation surveys), gone are the days when patent statistics were the only available indicators (Seguin-Dulude & Amesse, 1985). However, patent statistics are still seen as a *"valid indicator"* of some aspects of science and technology (Seguin-Dulude & Amesse, 1985)[18]. For example, papers by Mowery, Oxley & Silverman (1996) and Almeida (1996) in a special issue of *Strategic Management Journal* on Knowledge and Firm, utilize patent citation data to trace knowledge transfer between firms. In addition to the study of industry maturity measured by normal patenting activity (McGahan & Silverman, 2001), Silverman's (1998) study also uses patent citation data to measure technological overlap between firms before and after alliance formation.

**2.2 Possibilities of Continued Improvements**

We have seen several prototypical model problems and solutions[19] as major achievements that have later been viewed as an emerging research paradigm (Kuhn, 1963). Once these paradigms are identified, they should be considered as the early foundations of future research in patent and technology-related studies. As a part of our overview in Appendix V, this introductory chapter offers a list of the potentially emerging paradigms as identified by the contents of both the highly cited, and highly co-cited key-node authors. The major overview themes are presented along with their associated problems, improvements, advantages and / or disadvantages (limits and drawbacks).

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[18] Seguin-Dulude & Amesse (1985) observed that the developments in information technology and various data banks (databases) have been making information more readily available. Particularly, in the recent years the official web-site of the US Patent and Trademark Office (USPTO), driven by the state-of-the-arts internet technology, has offered the general publics around the world access to their comprehensive databases. These data bases can be readily examined through the associated search engine driven by Advanced Boolean Algebra. Such offerings might facilitate easier access and allows for extraction of more refined information for exploration of knowledge- and wisdom-rich information, which may otherwise remain hidden in the USPTO patent databases.

[19] In recent time the paradigm seems a terminological haze, the Kuhn (1962) formally defined it as universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners (p. v).

There are no good (perfect) measures (Griliches, 1990) for all of the interrelated concepts of economic change, technological change, R&D, innovation, and invention (as stated earlier), since all of them are overlapping, complex and nonlinear processes (Archibugi, 1992 and Archibugi & Pianta, 1996). With this chronic problem and historical view in mind, what can we do with these well-known problems in the context of our reflections on patent statistics as indicators of RTC?

Steiner wrote that *continual planning* should make managers better planners (Steiner, 1975: 66). His inspiration of continual improvement and "learning by doing", is borrowed from Piet Hein's: "the road to wisdom is plain and simple to express:"

> *"Err,*
>
> *and err,*
>
> *and err again;*
>
> *but less,*
>
> *and less,*
>
> *and less again. " (Piet Hein, 1966, cited in Steiner, 1975)*

Starting with Schmookler's path-breaking research,[20] (1950-1967) most, if not all, problems and debates surrounding patent studies seem to have already appeared. However, many small yet significant improvements have been offered along the development path of patenting and technology studies. This includes newer technology indicators such as new product trade reports as innovation (Acs & Audresch, 1988) and OECD standard surveys

[20] Schmookler's research seems to be viewed as the grand-opening of a new field called patenting and technology-related studies (PatStud) as all review papers, including Griliches' (1990) acknowledge. Schmookler's pioneering contributions are seen from his first three articles in the *Journal of Patent Office Society* (1950; 1953; 1953); first two articles in the *Review of Statistics and Economics* (1954; 1957); University of Penn dissertation in 1951 to his comprehensive book-- (1966) then a Schmookler's memorial book (1972) edited by Griliches & Hurwicz with a very strange title "...Data and..." referred to unused data and working papers .

(Archibugi & Pianta, 1996). In other words, patent statistics are not almighty technology indicators. However, for any set of valid technology indicators we cannot but include it and its improvements over time as suggested by Piet Hein.

### 2.3 Well-known Problems and Improvement Possibilities

Debates over the patent issues--monopoly, costs and benefits, alternatives--have continued ever since the first practice by the Republic of Venice in 1474 (Scherer & Ross, 1990/80/70). Meanwhile, the debate about patent statistics has not advanced very much since the 1960s when Schmookler published his series of seminal works. Similar pro and con arguments have been applied along this time period. Earlier studies often used successful patent applications as their output measure (Schmookler & Brownlee, 1962, Griliches & Schmookler, 1963). All of the major reviews[21] (e.g. Seguin.Dulude &Amesse 1985; Pavitt, 1985&1988; Dosi, 1988; Acs & Audretsch, 1989; Griliches, 1990; and Amesse et al., 1991) have well documented the positive arguments (uses, possibility, and advantages, strengths) as well as negative criticisms (misuse, disadvantage, limitation). However, there have been few advances (Basberg, 1987) in the ways in which patent statistics are presented and used. The associated analyses have not seen much improvement, so as to overcome the problems of validity. The detailed comparison between patent statistics is examined by Archibugi & Pianta (1996). The overall major disadvantages and advantages of patent statistics are briefly summarized in the following table.

**Table 1: A Summary of Overall Disadvantages and Advantages of Patent Statistics**

| *Disadvantages* | *Patents advantages over other measures*[22] |
|---|---|

[21] We referred and use some 18 comprehensive patent reviews in our references. In chronological order they arre: Carter and Williams (1958); Jewkes, Sawers and Stillerman (1958); Nelson (1959); Taylor and Silberston (1973); Pavitt (1978); Soete and Wyatte (1983); Seguin.Dulude and Amesse (1985); Pavitt (1985); Basberg (1987); Pavitt (1988); Dosi (1988); Acs and Audretsch (1989); Griliches (1990); Smith (1992); Granstrand (1994); Archibugi (1992); Brockhoff (1992) and Archibugi and Pianta (1996).

[22] OECD has developed standardized innovation survey since1992, which seem to have some potentially high

| | |
|---|---|
| Not all of innovations are patentable | Publicly-available |
| Not all of innovations are patented | Publicly-certified |
| Not all of patents are commercialised | Very up-to-dated |
| Mix degree of importance in terms of value and impact unless renewal or patent citation explored | Specific and detailed for time period, sectors and countries |
| Problem of flow or stock in short time | Overtime flow accumulates toward stocks |
| Propensity to patent across country, industry, large or small firm size. | Signals and noises absorbed in organizational capabilities (dummy variable) |
| Propensity to patent (and to patent abroad) | Less and lesser for other countries to patenting abroad in US |

### 2.4 A Summary of Patent Statistics' Advantages Over R&D Expenditure and Staff Statistics

The related concepts of economic change, technological change, innovation and invention, in a set of *complex but non-linear* processes are all waiting for some measures to detect and investigate them. Three sources of somewhat unrelated information have been frequently used to investigate the various aspects or phases of the above activities: i) Research and Development expenditure (R&D$); ii) Numbers of scientists, engineers and technicians (R&D-No); and iii) patent statistics (Patent-No.). Recently, OECD has been promoting standardized innovation surveys with a promise of potentially higher comparability: Time series comparability; International comparability; Comparability with R&D statistics and Comparability with industrial statistics including national accounts. Meanwhile, the problem of unit of analysis and aggregation, or lumpiness (Hall, Griliches & Hausman, 1986), still remains. Patent statistics are fundamentally based on one patent application document, while other measures, such as R&D$, R&D-Nos. or innovation surveys, pertain to a firm's efforts for a

comparabilities to complement patent statistics (Archibugi & Pianta, 1996).

series of products or processes. Then, depending on the context and usages, all of them have a somewhat different meaning based on whether they are used on an individual or aggregate basis.

**2.5 Overview of Various Propensities and Fraction of R&D Output**

High-tech industries (or super-technology) are highly dependent on innovation in science and technology (Medcof, 1999). It is a maintained assumption that patents are indicators of R&D output (or success) rather than only R&D input. However, each patent is not the only output of R&D, but only a fraction of it (Hall, Griliches & Hausman, 1986). The very use of information as an intangible good in any productive process is bound to reveal that process at least in part (Arrow, 1962). This part or fraction depends on the *degree of revealing,* as we termed it, which may vary considerably by industry, firm size, and over time based on their corresponding propensity to patent. Propensity to patent has been a difficult subject to study since the inception of the field of patenting and technology studies in 1950s and 1960s. While researchers at the qualitative end of the continuum tend to analyse by building theory first, the quantitative researchers insist on their belief in "no measure no science", whatever direct or indirect.

In the beginning, these studies Maclaurin (1953) intended to break down the process of technological advance into five hopefully measurable elements of propensities (without propensity to patent), including the propensity to: i) develop pure science, ii) invent, iii) innovate, iv) finance innovation and accept innovation. In a journal article published in *American Economic Review* Scherer (1965) tries to regress the firm size and patents by avoiding the inter-industry differences in propensity to patent through the use of dummy variables, while leaving these same differences within a given major industry to a random distribution. Another of Scherer's (1983) article in the *International Journal of Industrial Organization* with the clean title of "Propensity To Patent" also suggests that this must be measured in terms of the number of patents industrial corporations obtain per million dollars of company-financed R&D expenditure.

On the other hand, from a more qualitative view, the Yale group of Winter and his associates (Levin et al., 1987) have directed their research efforts and analysis toward R&D appropriation via a sampling questionnaire survey on a seven-point Likert Scale with 650 individual respondents from 130 line of the Federal Trade Commission (FTC lines[23]) in roughly 45 industries. Their survey data at level of the FTC line was chosen by them to facilitate merging with the disaggregate R&D data and Scherer's (1982) patent classification of the technology flow matrix. Winter (1989) also figured out a flowchart of logic-like decisions through five simple and linear questions called "conditions for strong individual patents" with slight difference from that of Levin et al. (1987). These strong conditions (Winter, 1989: 41) of patents in 'complex contexts' (p. 50) for incentives and effectiveness, include five stepwise questions: 1) whether the knowledge advance can be articulated or remain tacit? 2) if observable when in use? 3) if of enduring value? 4) if independent of other patented inventions? and 5) it discrete or basic?

Fortunately, the problem of propensity to patent abroad, particularly in a large country, such as the U.S., compared is much less to the propensity to patent domestically. Some analysts have suggested (Pavitt, 1985; 1988) that international differences in patenting in a given foreign country (particularly US) are more reflection of international differences in innovative activity rather than a difference in domestic patenting. There have been few reviews and studies on

[23] FTC lines provide the most disaggregated R&D expenditure data.

international comparisons using USPTO patent statistics in the existing literature. For example there are Paci, Sassu & Usai (1997); Soete (1980) and Soete & Waytte (1983). Fortunately, the application costs and expected benefits of patenting in the US being higher than those of patenting in any other domestic country, acts as a barrier to block sufficient number of patenting applications of marginal value. However, international dispersion of technology units (Medcof, 1997) of multinationals has attracted considerable attention, which could in large part be of multinationals' response to the globalization phenomenon. The propensity to patent abroad is significantly comparable for our three manuscripts among four major countries (Taiwan, South Korea, Canada and the Netherlands) as shown by the comparability analysis of countries' brief profiles in Essay No.2 and Essay No.3.

**2.6 Dataset Available At Unusually Long And Extremely Detail**

Actually, the most charming beauty of patent statistics are that they come in an "*unusually long and extremely detailed*" (Pakes, 1985), which means patent applications are, at least in principle, available for an unusually long time period with extremely detailed technological class breakdowns. De Solla Price (1983) argued that science and technology advances have been made as a result of the need to explain the new empirical data produced by improvements in measurement systems. Pavitt (1985; 1988) maintains that the scholars of science, technology and society should take recent improvements in quality and availability of patent statistics "rather seriously". Their richness and detail are likely to have a strong influence in future on the direction, nature, style and results of research, as well as the determinants and impacts of invention and innovation.

**2.7 Improvement Challenges in Generation by Generation after NBER Computer Age**

Patent statistics loom as a mirage of wonderful plenitude and objectivity. Some critiques often seem to insist that patents are "no good", but there has never been a best measure in the endless frontier of science (Bush, 1945) or the frontier of research (Price, 1963). What we need is always a balanced choice of 'second best" as the research paradigm (Kuhn, 1962) in the time period of each generation (Griliches, 1990). The most important feature of patents is that they have been available within a very slowly changing standard. No wonder that the idea of patent statistics as proxy measure has been learned and rediscovered from the research paradigm of quantitative studies of science and patenting generation after generation-- up to the "computer age" as mentioned in work of NBER group (Griliches, Hall, Huasman, Jaffe, Pakes, Schankerman and others). However, the opportunities for improvement for the current generation of "the Web age", along with the endless frontier of improvements for better technological measures, distinguishable from those of "the computer age", are not clear. We have, however, combined, the tools and facilities of both the web and computers to stand up to the challenges associated with generating data for our three essays, as discussed earlier.

Arrow (1962) noted that all of us as researchers in a field of patenting and technology studies are believers in learning by doing, and also learning by using (Rosenberg, 1982). We desire access to the best measures but keep using the second best ones and improve them. All problems of patent statistics have been well known for a long time and researchers have attempted to improve them generation-by-generation. The recent search engine technology has advanced dramatically since the Web became available in the 1990s. When the USPTO offered their internal search engine on the Web[24], called the *Advanced Boolean Logic*[25] or *Manual*

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[24] Search engines might be installed internally on the given website or externally all available websites around the Worldwide Web. In the present the Web grows by an estimated 6 million documents a day and with search engines indexing less than half of the Web (Instantis Inc, 2001). In effect, as a Webmaster you are creating tempting spider food for various arachnids-(spider-like) search engine to craw the Web.

[25] Canadian Intellectual Property Office (Industry Canada) also offers their search engine call Advanced Search in their website (CIPO, 2001).

*Search* (USPTO, 2001b), to access patent information, we made an early use of this kind of internal search engine on the website to construct and collect our dataset by fully downloading the total population, unlike the partial sampling of other previous and similar studies. A sample of our Advanced Boolean Logic formulation for extracting data from USPTO is shown in Table 2 below.

**Table 2: Selected Examples of Advanced Boolean Search Logic for Patent Calculation**

| | |
|---|---|
| In 1997 we used AS/*; in 2001 we cannot. But we used a combination of all state codes, instead. | AS/AK OR AS/AL OR AS/AR OR AS/AZ OR AS/CA OR AS/CO OR AS/CT OR AS/CZ OR AS/DC OR AS/DE OR AS/FL OR AS/GA OR AS/HI OR AS/IA OR AS/ID OR AS/IL OR AS/IN OR AS/KS OR AS/KY OR AS/LA OR AS/MA OR AS/MD OR AS/ME OR AS/MI OR AS/MN OR AS/MO OR AS/MS OR AS/MT OR AS/NE OR AS/NC OR AS/ND OR AS/NH OR AS/NJ OR AS/NM OR AS/NY OR AS/NV OR AS/OH OR AS/OK OR **AS/OR OR** AS/PA OR AS/PR OR AS/RI OR AS/SC OR AS/SD OR AS/TN OR AS/TX OR AS/UT OR AS/VA OR AS/VI OR AS/VT OR AS/WA OR AS/WI OR AS/WV OR AS/WY |
| For "No assignee" for Taiwan (1) in 2001 we must use logic: (ISD/1/1/2000->12/31/2000) and ICN/tw and not (ACN/tw) and not (AS/US*) as an approximation. (2) Compiling in 1997, we used the year for dataset and search logic with wildcard (*): ICN/tw and not ACN/* and not AS/* | (ISD/1/1/2000->12/31/2000) and ICN/tw and not ACN/tw and not (AS/AK OR AS/AL OR AS/AR OR AS/AZ OR AS/CA OR AS/CO OR AS/CT OR AS/CZ OR AS/DC OR AS/DE OR AS/FL OR AS/GA OR AS/HI OR AS/IA OR AS/ID OR AS/IL OR AS/IN OR AS/KS OR AS/KY OR AS/LA OR AS/MA OR AS/MD OR AS/ME OR AS/MI OR AS/MN OR AS/MO OR AS/MS OR AS/MT OR AS/NE OR AS/NC OR AS/ND OR AS/NH OR AS/NJ OR AS/NM OR AS/NY OR AS/NV OR AS/OH OR AS/OK OR AS/PA OR AS/PR OR AS/RI OR AS/SC OR AS/SD OR AS/TN OR AS/TX OR AS/UT OR AS/VA OR AS/VI OR AS/VT OR AS/WA OR AS/WI OR AS/WV OR AS/WY) |
| In 1997 ACN/* for all other countries outside US. In 2001 we use top 22 patent countries instead. | ISD/1/1/1996->12/31/1996 and ccl/327/$ and (AS/'OR' or ACN/jp or ACN/de or ACN/fr or ACN/tw or ACN/kr or ACN/ca or ACN/gb or ACN/it or ACN/ch or ACN/se or ACN/nl or ACN/au or ACN/be or ACN/at or ACN/dk or ACN/no or ACN/su or ACN/br or ACN/cn or ACN/in or ACN/id or ACN/pk) |

Remarks: 1. All abbreviations of search logics (e.g. IS, AS, ACN and ICN refers inventor state, assignee state, assignee country and inventor country, respectively) see USPTO as shown in Appendix V. 2. Unfortunately, IS/*, AS/*, ICN/* and ACN/* do not work at all at present. Therefore we try long combination of Boolean logics. IS/OR and AS/OR cause error in long logic due to interpretation of logic syntax, but if single AS/'OR" or IS/'OR', USPTO interpreter of search logic in short seems work.

Unlike previous and similar studies, in this research our major dataset was compiled directly by the on-line search engine on the USPTO Web site, which stores a wealth of patent-related information. These dynamic databases portray each granted patent's "application form" as published in the official publication-the *Patent Gazette*. Although we began our data collected in December 1997, these kinds of databases on the Web are only recently available on a broad basis for public use. It contains all the information of both patents granted since 1976 in full-text format, and those *"granted"* since 1790 in the format of full-page images. Furthermore, there is also information available about published patents *"applied"* for but not yet granted since March 15, 2001 (UPSTO, 2001a). This recent availability will open new windows to the application side of patenting activity in the world's largest patent system, for all researchers who have the desire to increase or supplement their data.

## III. AN OVERVIEW OF THE LITERATURE

### 3.1 An Overview of Technological Capability

What is capability? Seemingly, this is an exceedingly popular term. It should be helpful to begin with a clear attempt at a definition[26]. Literally, capability seems to represent a simple combination[27] of the word's capacity and ability. In the Random House dictionary[28] (Random House, 1993: 308) capability is defined as "(a) the quality of being capable, capacity, ability; (b) the ability to undergo or be affected; (c) usually, quality, abilities, features, etc., that can be used or developed, potential". Over the last century the distinction between production capacity and technological capability, has been the central feature of the process of technological accumulation in the industry (Bell and Pavitt, 1995). Production capacity seems narrow and short conceptually, and focuses on production efficiency for given input combinations. In contrast, technological capability means broader and richer in nature, and needs to generate

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[26] There are lengthy discussions on terminological problems of capability in the Introduction to *The Nature and Dynamics of Organizational Capabilities* (Dosi, Nelson and Winter, 2000). Winter (2000: 983) describes the fact that there is a booming terminological haze over the landscape of capability.

[27] In the other way, it is just a simple abbreviation of cap (main) plus ability similar to main (core) ability of all abilities.

[28] This dictionary published by Random House (1993) were edited by Flexner and Hausk.

higher technical efficiency (and change) that was not readily available in the system before. However, the required skills, knowledge, and experience needed to operate exceedingly more efficient technical systems due to technological change is becoming both slowly available, and impacting production capacity and hence the comparison.

Change in technology often goes hand in hand with the birth of, or changes in, organizational capability (Helfast, 2000:956). In fact, a highly cited technology theory was first called 'the theory of economic capability'[29] (Nelson and Winter, 1973) three decades ago. For our purposes, a country capability (Kogut, 1991) should include technological capability as well as organizational capability. Although the former can be assessed with some continuously-refined measures, the latter is very difficult to assess by effective measure. Various authors are using many similar terms in the scholarly and popular journals to refer to different aspects of capability. Teece, Pisano and Shuen (1997) and Helfat (1997) maintain that the learning for a business firm may in itself reflect a dynamic capability. Kogut and Zander (1992) and Zander and Kogut (1995) use combinative capability. Leonard-Barton (1992a) adds the concept of core capabilities. However, in all of our three essays, we abstract from the above distinctions and focus on the revealed aspects of technological capability (RTC), only to avoid the difficulties associated with measurements. Fundamentally, our thinking behind this word "revealed", is a manifestation that is explicit and quantifiable, which aligns with Nonaka's (1991) notion of knowledge creation as a process of *making tacit knowledge explicit,* as well as Winter's (2000) notion of capability as a matter of degree of achieving a desired output[30] result. Cumulative

[29] After that terminology was coined for the most conventional economic association proceedings--the American Economic Association, it was then called " theory of innovation" (Nelson and Winter, 1977) in newer technology-oriented journal-*Research Policy* and "....*Theory Of Economic Change*" in Nelson and Winter's (1982) book, thereafter. Form these documents, we can see how difficult it is a good theory acceptable within the convention boundary of the field for a good term-capability.

[30] Winter (2000) defines the state of capability that the state of an organization's ability to accomplish some

patents in databases reveal the explicit part of technological capabilities of a given company (or a given country when aggregated according to the law of large number) as a potential source for continued capability of knowledge creation for winning competitive patent races (Nordhaus, 1972 and Samuelson et al., 1994) in "the technology jungle" (Scotchmer, 1991 and Scotchmer & Green, 1990).

**3.2 The History or the Knowledge Network of Patenting and Technology-Related Studies.**

Garfield, Sher and Torpie (1964) maintained that a good question is to ask is whether a computer can write history[31]? The answer to this approximately forty-year old question today is perhaps negative, in that computers are not still able to write history; but computer-aided search of historical databases has been at least helpful to writing a well-organized and chronologically accurate history. In this introductory chapter, we will follow Garfield et al.'s (1964) old idea of making use of computer-aided searches on databases, such as that of Social Science Citation Index (SSCI) or Science Citation Index (SCI), which have stored a comprehensive record of past publications in their databases to provide an overview of the literature without losing site of broad trends due to attention for minute details.

Knowledge is simply the output of a learning (or knowing) process, just as plans are the output of the planning process. Gibbons, et al. (1994) held that terms of science and knowledge are often used interchangeably, or combined to form scientific knowledge. In his book *Science in Action*, Latour (1987) defined knowledge as "familiarity with events, places and people seen many times over...knowledge cannot be defined without understanding what [the process of] gaining knowledge means." (p.220). By extension then, familiarity with the knowledge

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desired result P could be represented by a dummy variable: either can do it (Xr=1) or cannot do it (Xr=0) and add necessity of a list of key criteria as performance measures.

[31] Garfield, Sher and Torpie (1964), *The Use of Citation Data in Writing the History of Science*, Philadelphia, PA:

generation system (Machup, 1980) of a given field, i.e., the knowledge network of that field, is equally necessary to the understanding of the nature, potential uses and the evolutionary process of that field over time. This knowledge can be alternatively stated as the "know what", "know where" and "know when" of a field.

The above discussion will help us to develop a chronological perspective and also a comprehensive understanding of the evolutionary path of patent- and technology-related studies. We have used the following procedure to develop that overview:

First, about 40 to 60 key authors (also called key-nodes) of about 100 highly-cited documents are identified and listed chronologically with full title (see Appendix I) by a search of ABI databases and then verified by the Amazon.com website. Second, a visual chart showing the associated Knowledge Network[32] (KN) with only about 15-20 highly co-cited key-nodes, using a co-citation matrix (McCain, 1989) (i.e., a 30 by 30 matrix of the most highly cited 30 authors from the above list of 40 to 60 key-authors) are intensively searched. Then, corresponding schematic linkages are drawn by hand to highlight, if not to characterize, the main landscape of this knowledge network in terms of its key-nodes and their associated connections. Finally, the respective works of these key-nodes are reviewed and overviewed in the next section. The concepts and model of Knowledge Network are examined in detail in Etemad and Lee (2001) and Lee and Etemad (2001b).

### 3.3 An Application of Data-Mining into the Knowledge Concept: The Abridged Map of the Overview

Could we capture, and then offer improvements to this rich existing patent information,

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ISI Inc.

[32] In another research projects, we have developed an operational model for the of Knowledge Network concept and have applied it to several emerging disciplines or sub-fields (see examples as Lee & Etemad (2000); Lee &

with the hope of advancing from data and statistics to information and knowledge? The easy-availability and cost-effectiveness, combined with the improvement offered by the recent information technology tools such as tools for knowledge discovery from databases (KDD) including data-mining and text-mining (Norton, 2000), are promising considerable advantages not seen since the inception of patent and technology-related studies. From the early paper version (e.g., monthly or yearly government publications of the *Patent Gazette* and other government Statistics) to the electronic database available through interactive CD-ROMs or their on-line counterparts (i.e., the web-sites with various search-engine or intelligent agents), we have seen many improvement opportunities for patents to become better technology indicators. Bohn (1994) asked: Is the difference between data, information, knowledge and wisdom a difference of level or stages of knowledge? Further to Bohn, we can ask: Are statistics that pertain to capture and the content of databases merely data, information, revealed knowledge or might they even point to wisdom wellsprings?

T. S. Eliot's interesting observation is very revealing: "Where is the wisdom, we have lost in knowledge? Where is the knowledge, we have lost in information" (T. S. Eliot (1888-1965) quoted in the Oxford's Dictionary of Quotations[33]). In the 1890s Lord Kelvin commented on the value of knowledge. His words were to the effect that when you can measure what you are speaking about, and express it in numbers, you know something about it. If not, you have scarcely advanced to the stage of science. In Bohn's framework (1994), Kelvin was advocating for the value of *stage three knowledge* (i.e., measured/measurable) over *stage two* (i.e., awareness[34]). Where do patents, as proxy measures of technological capabilities, fit into Bohn's

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Etemad (2001) and Etemad and Lee (2001b).

[33] This dictionary is edited by Partington (1997).

[34] Using the idea of a spectrum of knowledge "from art to science", Bohn (1994) identified 8 stages of knowledge,

scale of scientific knowledge? Are they just at the start of stage three knowledge, over stage two, or have we scarcely advanced to the earlier stage of science? Regardless of the debate as to where these proxy measures of technological capabilities actually fit, we hope that our analysis, housed in this three manuscript thesis, has advanced their stage of usefulness, has shed light on their content and pushed the state-of-the-art to a higher stage in Bohn's hierarchy.

### 3.4 Another Review or An Overview with a Map?

Like all other older scientific fields, patent and technology-related studies have their long history with firm research foundations. There is no lack of good literature surveys in the cumulative history of this field. A selected list of recent comprehensive surveys and reviews includes: Archibugi & Pianta (1996), Archibugi (1992), Granstrand (1994), Brockhoff (1992), Smith (1992), Griliches (1990), Acs and Audretesch (1989), Dosi (1988), Pavitt (1988;1985), Basberg(1987), Seguin-Dulude and Amesse (1985), Soete and Wyatte (1983), Pavitt (1978) and Taylor and Silberston (1973). Needless to mention, there are far earlier reviews such as Nelson (1959), Carter and Williams (1958), Jewkes, Sawers and Stillerman (1958) and the pioneer works of Schmookler's 13 publications[35] from 1950 to 1975.

This list of distinguished authors suggests that there is very little, and certainly no urgent, need for adding another new similar survey of our own to demonstrate a common understanding and satisfy partial requirements of this research. Instead, we will offer another

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ranging from complete ignore to complete understanding. Complete ignore; awareness; measure; control of the mean; process capability; process characterization (know-how); know why; complete knowledge. Given high potential technology opportunities, managing in high-tech industries requires both rapid learning and ability to manufacture with "immature" low stage of knowledge) technologies. High-tech process are those in which many of the important variables are stage four or below of knowledge.

[35] From the memorial book (Schmookler, 1972) of his collection of essays and data, we knew his wonderful belief is not ending with his not long life (1918-1967). In the Forward Kuznets (1972) emphasized that his selected challenge was 'not by imaginative leaps based on a few cases and resulting in essential untestable conjecture, but by the quantitative evidence… (p. vii).'

"list of key-nodes authors " by using the *knowledge network* approach,[36] to uncover both the identity and the content of the key-nodes and their associated linkages. This methodology will allow us to offer a brief but comprehensive review called *overview* by Price (1963 & 1965b). In the first stage of this approach, as stated earlier, all of the 40 to 60 key-nodes (i.e. a combination of influential authors and their works) with rich theory essentials and research resources, along a historical time scale are identified. The list of these key-authors and the content of their contribution are screened out with the analysis of a simple distribution of both the related journal articles (i.e., exceeding 1069 articles) documented in the SSCI database, from 1992 to 1999 and their associated citations (i.e. exceeding 29000 citations), with a heuristic cut-off frequency (citation fq >= 10) attached to it. The former will be referred to as the Source Sample, while the latter as the as the Citation Sample.

In the second stage, the top 30 key-authors are selected. Then, their representative contribution in central columns with subtotal frequency cited by source samples are listed in Appendix II both alphabetically in the left column and chronologically in the right column. The associated co-citation frequencies (total 29 x 30/2=435 pairs) of any two of them are searched directly from the 1991 to 2000 SSCI databases as shown in Appendix III. McCain had described a detailed procedure called a technical review (1990) on a raw co-citation matrix. For the purpose of seeing the paradigm shift (field dynamics) of patenting and technological studies, we divided a raw 30 x 30 co-citation matrix into two time periods: from 1991 to 1995, and from 1996 to 2000. In order to signifying the highly-co-cited key-nodes, we de-noised the low linkages to blanks if the co-citation frequency of that cell is below 60.

In the third stage, a visual chart of the knowledge network of patent studies with 15 to 20

[36] A knowledge network is an interlinked web of concepts, ideas, framework and theory essential (CIFTE)

key-nodes (i.e. highly influential authors), extracted from a 30 by 30 co-citation matrix, as mentioned above, are drawn schematically according their mutual co-citations. Each key-node (or star) in the figures of Appendix III refers to each key-author, which publication year denotes representative work. The width of the line connecting any two key-nodes is drawn according to the respective co-citation frequency of any two authors, whatever the publication.

Generally speaking, the left parts of two figures (including Arrow, Mansfield, Rosenberg and Nelson) seem to represent the old economic discipline interested in technology. Unlike this heavily linked part in the left, the right part constellation of four newer key-nodes (including Scherer, Griliches, Dosi and Pavitt) is becoming highly co-cited. Two superstars (Samuelson of Economics and Porter of Strategy field) are heavily co-cited but sparsely linked to other key-nodes. Comparing Figure 1 and Figure 2 of the Knowledge Network of Patenting and the Technological Studies Map, we can see there are new key-nodes. Jaffe and Cohen emerged with a co-citation larger than 80 in the time period of 1996 to 2000. Meanwhile, the linkages among key-nodes are interwoven much more densely than that last time period of 1991 to 1995.

Finally, the overview of all 30 key-nodes are briefly reviewed in a short paragraph in order to be summarized in alphabetic order with their citation frequency by source sample in Appendix IV. These are the related "insiders" of this field from 1992 to 1999.

**3.5 Summary**

In closing, we have proposed the concept of revealed technological capabilities as the over-arching topics in the chapter, of which, each of the three manuscripts are a part. We have discussed in some length the justification for the topics of research in the three-essays, the linkages between the three essays and the databases on which the three essays are based. We

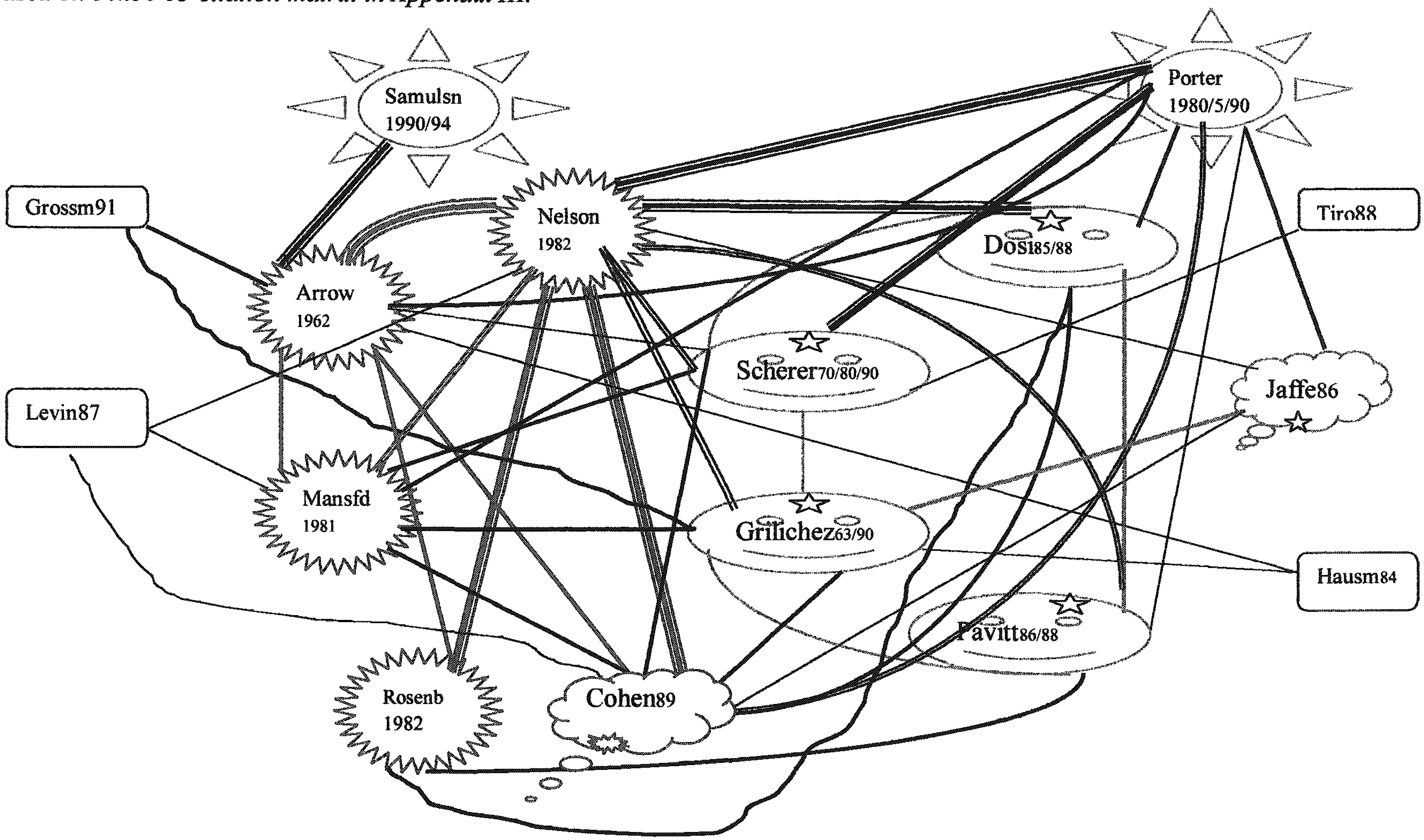
supporting a domain of inquiry, also see footnote 19.

have also summarized many of the arguments in favor and against the use of patent statistics as measures of our choice in this research. Although, each essay has its own pertinent literature review, we engaged in citation and co-citation analysis to chart-out the landscape of patenting and technology studies over the past 10 years in order to identify both the identity and the content of key contributors (in terms of citations) to this field. Borrowing from Price (1963 and 1965b), we have called this analysis an overview, although we have termed it as knowledge network of patenting and technology studies elsewhere (Etemad & Lee 2001a and 2001b). The length of analysis required for this overview forced us to put a part of them in the four appendices attached to this thesis. Although we have pointed out our contribution in terms of the development of a methodology, application and results in an earlier part of this chapter as well as each essay, we sincerely hope that the overview methodology results adds further value to this three-manuscript thesis as a whole.

**Figure 1: KN-PatStud Map 1996-2000**

| Co-citations | Lines width | Pairs | | Co-citations | Line width | Pairs |
|---|---|---|---|---|---|---|
| 230+ | | 5 | | 100-150 | | 18 |
| 200-230 | | 2 | | 80-100 | | 17 |
| 150-200 | | 5 | | 0-80 | <blank> | 388 |

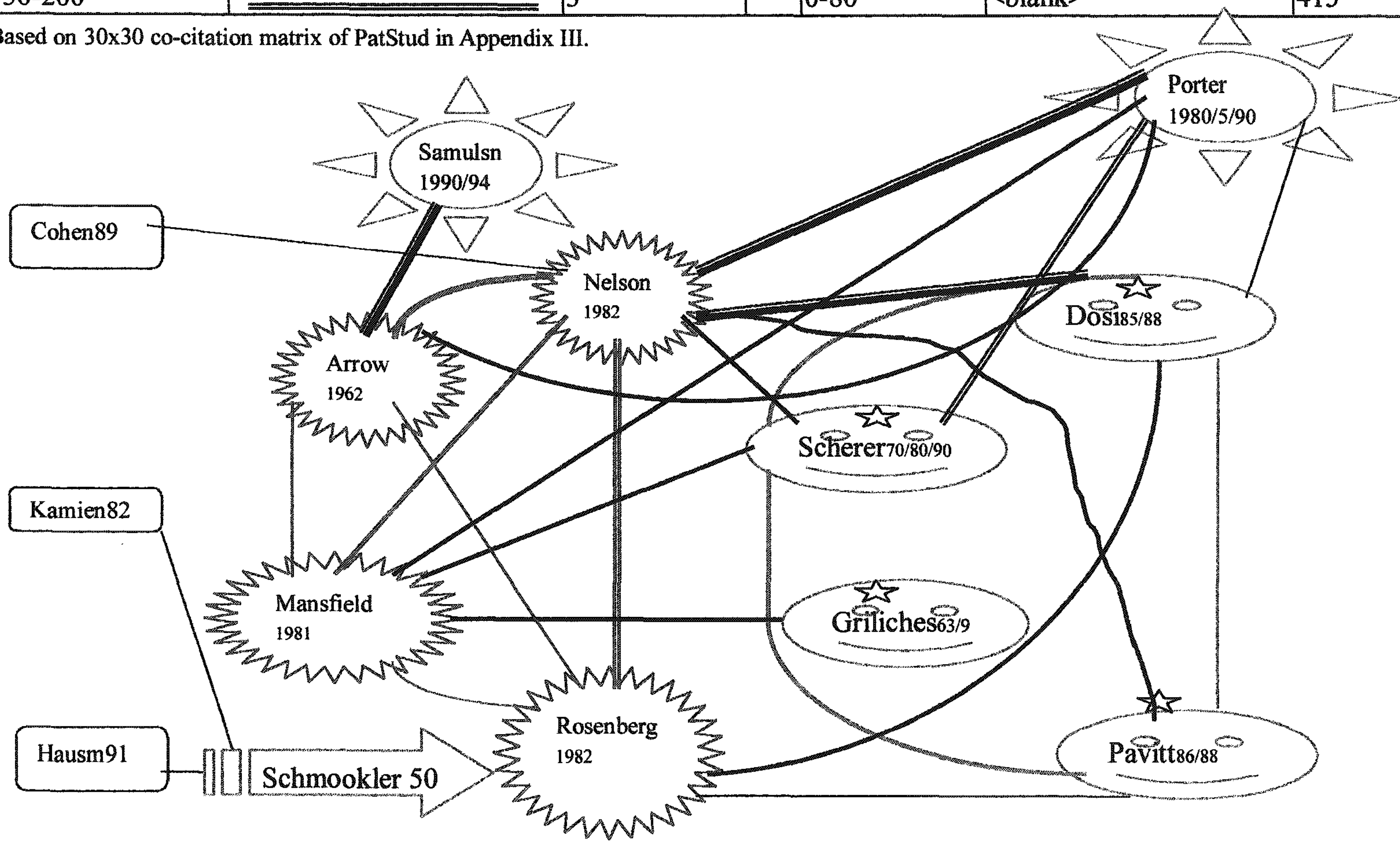
*Based on 30x30 co-citation matrix in Appendix III.*



## Figure 2: KN-PatStud Map 1991-1995

| Co-citations | Lines width | Pairs | | Co-citations | Line width | Pairs |
|---|---|---|---|---|---|---|
| 230+ | | 0 | | 100-150 | | 8 |
| 200-230 | | 3 | | 80-100 | | 8 |
| 150-200 | | 3 | | 0-80 | <blank> | 413 |

Based on 30x30 co-citation matrix of PatStud in Appendix III.



# CHAPTER 2: ESSAY NO.1

## PATENT CALCULATION AND TECHNOLOGICAL COLLABORATION IN INVENTIVE ACTIVITY

### ABSTRACT

Several information fields in a patent application can yield valuable insights to inventive activities of individuals, corporations and even countries. This paper examines the pattern of international collaboration in inventive activities of both inventors and assignees as defined by information supplied to the U.S. Patent and Trade Mark Office for both the "inventor(s)" and "assignee(s)." It develops a series of indices and evaluates them for patent information of USPTO databases for both fields of information on inventor(s) and assignee(s). This study covers the nine most inventive OECD countries and two Asian NICs (South Korea and Taiwan) for a span of 20 years, 1980 to 2000. Most of our findings, taken collectively, point to increasing pattern of cooperative, or collaborative, inventive activities worldwide over the past two decades. It appears that the world has already embraced the inceptive stage of "techno-globalism."

[Abstract 140 words/Key words: Collaborative inventions, Globalization of technology, Patent studies.]

### I: INTRODUCTION

This research is inspired by at least two complimentary developments: i) the documented astronomical increase in collaborative arrangements, leading to the potential emergence of globalization of technology, and ii) the interaction between this emerging global system and the national systems of innovation, which have been in place for some times. Deliberations, or debate, on the interaction between these opposing systems are still ongoing. One body of scholarship, complementary to collaborative efforts, views increased co-operative global inventive activities as extensions of the increased globalisation of trade and investment. On the opposite side however, another body of scholarship associates a nation's competitiveness with accumulation of technological capabilities and specialisation at the national, as opposed to global, level. This view may allow for higher co-operation nationally; but will logically oppose collaborative inventive efforts internationally, due to their obvious dissipation and leakage to, and through, partners.

This research aims to provide some fresh and empirically based evidence on the above debate and also to shed further light on these opposing perspectives on inventive activities. Specifically, this paper examines the incidents of collaboration *within and across* a select sample of the most inventive countries of the world (i.e., seven OECD countries and two fast developing NICs) over a period of 20 years, from 1980 to 2000, using patent records in the United States Patents and Trademark Office (USPTO). The paper consists of the followings. Immediately after this introductory note, followed by theoretical background in Section I, a new analytical methodology, leading to several new indices, is devised and presented in Section II to guide the research. This methodology is then applied to the patent information in Section III. Discussion of results and their implications are presented last.

## II: THEORETICAL BACKGROUND

### 2.1 Heightened Global Co-operation for Increased Competitiveness.

In an increasingly globalized world, where previously guarded national boundaries are "melting away" and inter-linked economies -- "ILE" -- are replacing them (Ohmae, 1990), technological frontiers may not remain immune for a long time (Amendola, Guerrieri, and Padaon, 1992; Amendola, Dosi, and Papagani, 1993; Chesnais, 1992). When the permeability of national borders (Kogut, 1991) is combined with co-operative scientific and commercial research (Sharp, 1989; Swan, 1988; Hughes, 1986; Ohmae, 1989) a creeping, if not full force, globalisation would soon embrace and national technology frontiers and transform them into what Archibugi and Michie termed as "Techno-globalism" (1995:121). Techno-globalism appears to run contrary to specialisation in the traditional national systems (Archibugi and Pianta, 1992). Grupp (1995) observed "In the face of techno-globalism, national technology and industrial policies are under pressure" (p. 213).

Some scholars have suggested that the oncoming of the increased technological diffusion (Grupp 1992, and 1995; Archibugi and Pianta, 1996) is inevitable. This is partly due to the co-operative efforts of the sister-subsidiary networks of multinational enterprises (MNE) straddling most countries of the world (Barré, 1995; Basberg, 1982; Cantwell, 1989; Chesnais, 1992; Dunning, 1992 and 1995; Kobrin, 1995; Kogut, 1991; Ostry, 1990; Serapio and Dalton, 1993; Etemad and Seguin-Dulude, 1988; Wyatte, Bertin and Pavitt, 1985)[1] ;and is partly due to increased and deliberate intra- and inter-industry (as well as cross-boarder) co-operative and collaborative efforts in quest for increased world-wide competitiveness (Contractor and Lorange, 1988; Hergert and Morris, 1988; Gomes-Cassares and Soete, 1990; Yoshino and Rangan, 1995, Mowery, 1992; Ohmae, 1989; Schmoch, 1995). The globalisation of technology is neither the sole reason for, nor is the only outcome of collaborative efforts. The qualitative change in the nature of global competition is both necessitating and reinforcing the pursuit of such co-operative strategies because of global competition's escalating risks, increased capital requirements, shrinking cycle time (i.e., time compression) all at the same time (Hergert and Morris, 1988; Grupp, 1995; Cusumano, 1985; Okimoto, 1989; Ohmae, 1989; Moxon, Roehl and Truit, 1988; Stalk and Hout, 1990; Stalk, 1988). These combined with a rapid evolution of the traditional cost structure toward increasing fixed costs, diminishing variable costs and shrinking payback periods, mainly due to rapid technological obsolescence, further necessitates a more co-operative and collaborative strategy world-wide (Yip, 1992; Bower and Hout, 1988). Any of the changes listed above *alone* would have constituted sufficient grounds to call for a re-examination of the corporate strategy; including the value chain activities, starting with R&D and inventive activities.

The cross-border alliance movement en-masse was in full swing well before the 1980s. Although, most cases escaped public attention, examples of publicised cases covered various industries and countries in typical network of alliances. By the mid 1980s, the Japanese company Toshiba had, for example, allied with the following enterprises; Olivetti of Italy (1984), AT&T (1985), LSI Logic (1985), Siemense of Germany (1985), Hewlett-Packard (1985), Siemense and General Electric (1986). The *shift in business operating paradigms had taken an early, but pervasive turn -- from self-reliance to partner-depe*ndence -- by the late 1980s and early 1990s.

IBM, as another example, had breached its own past tradition of self-reliance and formed some 20,000 alliance-style relationships world-wide by 1992, including some 400 equity investments. General Motors' strategic partners included Fuji Heavy Industries, Hitachi, Honda, Isuzu, Mitsubishi, Nissan, Suzuki, Toyota (Japan), Daewoo (South Korea), Renault (France), Mercedes-Benz (Germany), Saab and Volvo (Sweden), Rover (U.K.), Fiat (Italy) and some others (Yoshino and Rangan, 1995:10). In GM's network of international alliances, at least six were formed with technology mandates (Hitachi, Honda, Isuzu, Suzuki and Toyota). GM was *not* alone in the auto industry. Practically, *all* members of the industry had formed a large network of alliance, including those for collaboration in inventive activities.[2]

Thus, the inescapable conclusion from the above is that: i) the most fundamental of value-chain activities -- the inventive/innovative activities -- could not have possibly been excluded from the global alliance frenzy of the past two decades, and similarly, ii) not all the results of such inventive activities could have been declared as "industrial secrets" without much formal trace in the public world-wide inventive/technological regimes, especially in light of some incestuous relations and raucous, if not rancorous, departures such as that of Hitachi from the Motorola Network in 1990.[3]

**2.2 Research Questions.**

Fundamental research questions emanating from the above discussions are:

i) What is the observed *pattern of collaboration* in inventive activities for a selected list of countries with known incidences of co-operation and collaboration?

ii) Do these patterns *vary* across countries *over time*?

iii) In the conflicting paradigm of co-operation-competition, which countries seem to have facilitated relative coopertion?

**2.3 Patent Time-Series As Measures Of Inventive Activities.**

Three source of somewhat unrelated information have been frequently used in the past to investigate the various aspects of inventive activities: i) Research and development expenditures (R& D), ii) Number of scientists, engineers, and technicians, and iii) Patent statistics.

i) <u>R&D expenditures.</u> Research and development expenditures are known to be an imprecise, non-specific and highly aggregated *input measure* of inventive activities (Chakrabarti, 1991; Griliches, 1990). R&D expenditure is just one of the inputs to the inventive process; and as such, it can *not* possibly be considered as the most reliable measure. Smith (1992) argues that "R&D is an input measure at best, the importance of which varies significantly across firms and industries" (1992:383). Dunning observes that "all the usual cautions apply to these data [R&D expenditures]. They are fragmentary and rarely directly comparable" (1992:20). Additionally, the serious biases of this measure in favour of certain technologies and industries and larger enterprises with higher propensities to innovate (Scherer, 1983; Cockburn, 1989) are well-documented (Smith, 1992; Griliches 1990).

ii) The number of scientists, engineers and technicians. These measures also suffer form some of the above qualitative ills. Educational backgrounds, productivity, and work ethics, among other factors impacting the reliability and comparability of these measures, further add to the above inconsistencies. Furthermore, the R&D expenditure may include many soft, and at time unclassifiable, expenditures conveniently financed by the R&D funds (and then charged as such expenditures). Scherer (1984) reports that the expenditures for developing prototype(s)--i.e., some 50% of total developmental costs--in some industries are included in R&D expenditures, adding to the inherent inconsistencies. iii)

Patent statistics. In contrast to the above measures, patent statistics are used as measures of inventive activities' *output* (Chakrabarti, 1991; Grupp, Maital, Koschatzkty and Frenkel, 1992; Griliches, 1990; Kodama, 1991), innovative activity (Acs and Audretesch, 1989), technological change (Basberg, 1987), technological strength (Narine, Noma and Perry, 1987), accumulated capabilities (Etemad and Lee, 1999a), and specialization (Archibugi and Pianta, 1992). Patent statistics are publicly available, remain up-to-date and provide both very specific and detailed information for tracing inventive activities over time. Furthermore, patent statistics are the *only* formally and publicly verified output measure of inventive activities (the previous two are both unverified input measures) [4]. These advantages have led researchers in the past to favour patent statistics and use patents exclusively as measures of inventive and innovative activities (Acs and Audretesch, 1989; Soete and Wyatte, 1983; Tong and Frame, 1994; Sirili, 1987; Narine, Noma, and Perry, 1987; Etemad and Seguin-Dulude, 1987, Etemad and Lee 1999b). One is therefore compelled to favour patent statistics, if only *one* measure of inventive activities is to be examined.[5] That is indeed the case in this paper.

**2.4 Data: The USPTO Patent Time Series.**

Given the "non-linear" nature of inventive and innovative activities (Archigibugi and Pianta, 1996; Barré, 1995), researchers in these fields must be sensitive to at least four problems in selecting their measurements: i) the lumpiness nature of inventive activities, ii) interactions between the various component of these activities over time, iii) representativeness of such activities. The selection of a given set of measures, as opposed to another, may heighten some of the above problems to varying degrees. A reasonably long time-series of patent statistics avoids the first two problems to a great extent. But the others (i.e., unevenness and representativeness) may need explicit remedies.

The patent data bases of the United States Patent and Trade Mark Offices (USPTO) *suffer the least from all biases inherent in patent statistics,* especially if a long period of time and sufficient number of technological classes are included as Scherer suggested by his "law of large numbers" (Scherer 1984 quoted in Griliches, 1990, p. 1670). Griliches and associates have shown that some two-thirds of all applications submitted annually (e.g., 104,000 applications in 1980) are granted a patent in less than 10 years: i.e., 65,000 "utility" patents were granted by 1984, 1,400 at the end of 1988, and 300 in the next three years (Griliches, 1990:1663). Another aspect of representativeness in USPTO is the proportion of patents granted to foreign applicants. This ratio has increased consistently as the rest of the world increased the level of its inventive activities: i.e., 19% in 1960, 39% in 1980, and 48% in 1988 (Griliches, 1990: 1663). In this research we use a longitudinal USPTO database nearly 20 years long (1980 to 2000). The top nine most inventive countries of the world (i.e., Seven members of the OECD and two Asian NICs) form the sample.

## III: METHODOLOGICAL DEVELOPMENTS: TOWARDS COLLABORATION INDICES IN PATENTING ACTIVITIES

Several information fields in a patent application can yield valuable insights to inventive activities of individuals, corporations and even countries. Under the most simplistic scenario, and for the most part, the identity of the *inventor (i)* and the *inventor's* stated *country of residence (ic)* establish, the location of inventive activity for which the patent is sought. This is not, however, a universal case as residents or citizens of a country may be engaged in inventive activities in another country. Another field, called *assignee (a)* and the *assignee's* stated address in a country *(ac)* point to the intended agent and the location for deployment, including commercialization, of the intellectual property rights accruing to the patent at the *time of filing the application.* It is not required of either the inventor or the assignees to declare their country of citizenship in the patent application.[6] Unfortunately, not all patent applications are as simple as the above case. Many possibilities arise and complex cases are readily observable. Several of these possibilities, germane to this research, are reviewed below.

***Case 1: Multiple Inventors***. This is where several inventors *cooperate* to complete the invention for which the application for a patent is filed. At least two possible variants can give rise to interesting situations.

*Case 1a: All Inventors Share the Same Country of Residents.* In this case, inventors' stated country of residence could be assumed to be the location of inventive activity with high degree of certainty for most cases. But this is not the universal case.

*Case 1b: Members of the Inventive Team Declare Different Countries of Residence.*

Under this variant, it is not a-priori clear as to where the location for inventive activity has been; and the presumption of the country of residence, as a proxy for location of inventive activity, does not clearly hold. Regardless of attribution problems associated with both of the above cases, the presence of multiple inventors is a clear indicative of *collaborative inventive activities*. Thus, the comparison of the total number of inventions -- i.e., patents counts -- and the total number of inventors involved in those patents can reveal the incidents of *cooperation in inventing activities leading to co-invention*. The co-inventor index for a given country can be then simply stated as formulus below.

*Co-invention (or co-inventor) index* = total number of inventors as a ratio of total number of corresponding patents. The information recorded in patent databases allows for two alternative operationalization of this index: i) counting the total numbers of inventors for a patent, or ii) counting inventors' countries of residence.[7] While the former point to the mere incident of cooperation (or collaboration) in inventive activities, the latter provides additional information on their declared location of residence. Therefore the use of the latter provides both more information and more reliability. We have used the country of residence as the preferred measure throughout this study.

***Case 2: Multiple Assignees***. It is possible to assign a given patent to multiple "assignees." Similar to Case 1, multiple assignees may or may not share the same country of residence. There is evidence to suggest that some inventions carried out at MNC's subsidiary locations are either jointly (with the subsidiary) or exclusively assigned to the MNC's headquarters for strategic reasons (Etemad and Seguin-Dulude, 1987). The former gives rise to co-assignment, while the latter results in non-matching countries of residence for inventor(s) and assignee(s). The important point here is that the intellectual property rights attached to a single patent may be assigned, for further exploitation, to a single or multiple entities, including the inventor(s). As assignees are generally associated with commercial, as opposed to inventive, aspects of patents, this cooperation should be viewed qualitatively different from cooperation (or collaboration) between inventors for inventive activities.

$$Co\_inventor\ Index = \frac{\sum_{j}^{J} total\ number\ of\ inventor's\ countries\ of\ residence\ for\ patent\ j}{total\ number\ of\ associated\ patents} = \frac{1}{J}\sum_{j}^{J}\sum_{k} ic_k \geq 1.00$$

Where: j is the patent counter indicator

J is the total number of Patents in the index

$ic_k$ is the inventor k's country of residence for a given patent (j)

The *lower bound value of unity* for the co-inventor index points to a single individual inventor(s) applying for a single patent. When there is more than one inventor per patent, the index naturally assumes greater values than unity. There is *no theoretical upper bound* for this index.

*Case 2a: Multiple Assignees Share the Same Stated Country of Residence.* This case points to a potential intra-country cooperation for realizing the patents' commercial benefits. Intra-country cooperation, collaboration, or alliances, between two or more individuals (or enterprises) are examples of this case.

*Case 2b: Assignees Declare Multiple Countries of Residence.* In this case multiple assignees, with their associated (different) countries of residence, are stated on the patent application at the time of filing. Although the *initial* intent at the time of filling for a patent may have been to commercialize the patent *cooperatively* and perhaps in *multi locations* (i.e., in multi countries--consistent with both time compression and rapid technological change, discussed earlier), whether or not this is followed cannot be assessed. Disregarding this minor complication, an index of co-assignee, reflecting on intentions to utilize a patent *jointly*, can be easily formulated as follows:

Co-assignee index = total number of assignees' stated countries of residence as a ratio of total number of corresponding patents.

$$Co-assignee\ Index = \frac{1}{J}\sum_{j}^{J}\sum_{k} ac_k$$

Where: j is the patent counter indicator

J is the total number of patents in the index

$ac_k$ is the assignee k's stated country of residence associated with a particular patent j

This index can capture collaboration on the "assignee" side of patents. Its theoretical lower bound is one (or zero, see below for no-assignee cases), while there is no theoretical upper bound.

*Case 2c: No Assignee is declared in the patent application.* This case simply means that "assignee" information field was left blank on the patent application. Unlike Case 1, whereby the index of co-inventors is always equal or greater than unity, the co-assignee index can assume positive quantities smaller and larger than one, including zero. This is due to the fact that patent offices allow the field of assignee to be left blank (i.e., "no assignee"). Thus when a single patent, regardless of the number of its inventors, is assigned to *no one, only one, or more than one assignee(s),* the index can correspondingly assume values of zero, 1.00 and figures larger than unity. When a large number of patent with different numbers of assignees are considered (including cases with no assignees), the index can theoretically take the entire range of *positive numbers* both smaller and larger than unity. However, patent, with no assignees, corresponding with a co-assignee index = 0.0, can be easily identified and excluded from the rest for a separate analysis. For the remaining patents, the co-assignee index would then assume a lower bound of 1.00 (i.e., at least one assignee per patented invention).

***Case 3: The Combination of Co-inventors and Co-assignees.*** Case 3 is indeed more realistic than the previous simple cases. This is the case when a team of inventors cooperates to complete an invention in order to attain a patent(s) for potential multiple track (and multi-location) utilization through multiple assignments once the patent is obtained. Similar to previous cases, the inventor or assignee fields of information may contain identical countries of residence or different lists. Unlike the previous cases, a single and simple index fails to capture the inherent complexities completely.

*The Formulation of Hypothesis, Application of Methodology and Data Analysis.* The overriding concern of this paper, as stated earlier, is the incidence of inventive and innovative collaboration. Three hypotheses are formulated to examine the phenomenon from the various perspectives reflected in this paper's data set. Specifically, they are as follow:

i) That, increased joint-invention is a manifestation of, and associated with, increased globalization of *inventive* activities *over time* ($H_1$);

ii) That, increased joint-assignment is also a manifestation of, and associated with, increased globalization of *innovative* activities *over time* ($H_2$); and

iii) That, the simultaneous increases in incidents of co-invention and/or co-assignments are the inevitable results of, and associated with, increased *technological globalization over time* ($H_3$).

In fact, three of joint invention, joint assignment and joint invention as well as joint assignment across the border line imply the different degree of globalization of technological capabilities in technological generation revealed to some extent in patent databases. In sum, globalization of technology could be revealed in partial by the above indicators. In reverse logics, what all above indicators reveal point to a very obvious trend of the globalization of technology generation "revealed" in US patent databases.

*The Data.* The data analyzed below is reflective of inventive activities of nine countries over a span of more than 20 years. The selected countries are: Canada, France, Germany, Great Britain (with UK or GB designations), Japan, the Netherlands, the United States (which are the top OECD inventive countries) and two NICs who have recently embarked on *intensive* inventive activity and technological development: South Korea and Taiwan. In the interest of space only the analysis for five time-periods -- i.e., years 1980, 1985, 1990, 1995, and the most current[8], 2000 -- are reported here. The data analyses presented bellow closely follows the analytical framework developed in Part II. Corresponding links will be also pointed out as the analysis progresses. Exhibit 1, below, summarizes various cases of Part II in order to facilitate linkages to the corresponding data analysis in this section as the following analysis unfolds.

**Exhibit 1: Summary of Specific Cases in Part II in Relation to Corresponding Hypotheses**

| **Category** | **Intended Research Objectives & Questions** | **Proposed Indicators** |
|---|---|---|
| *i) Multiple Inventors:*<br>Case 1a: Uni-national Inventors<br>Case 1b: Multi-national Inventors | To examine collaborative activities at the *inventive* levels of intra- or inter-nationally ($H_1$). | Co-inventor Index >1 and increasing over time |
| *ii) Multiple Assignees:*<br>Case 2a: Uni-national Assignees<br>Case 2b: Multi-national Assignees<br>Case 2c: No Assignees[9] | To examine intended collaboration at the *innovative and commercial* end. both intra- and inter-nationally ($H_2$). | Co-assignee index increasing over time |
| *iii) Combination of Co-inventors and/or Co-assignees*<br>Case 3: Joint Inventions and Assignments between U.S. and Other Countries | To examine the extent of comprehensive collaboration in inventive activities ($H_3$). | Both the co-inventor index >1 and the co-assignee index increasing over time |

## IV: DISCUSSION OF RESULTS

### 4.1 The Co-inventor Index and $H_1$.

Co-inventor index for the above countries as well as the entire world, excluding U.S., is reported in Table 1a. An entry for a given country and a given year, as defined earlier, is the total number of inventors (declaring that particular country as their place of resident) as a ratio of total number of associated patents. The construction of Table 1a corresponds to Case 1a in

Exhibit 2. Table 1a shows remarkably consistent upward trends in collaborative inventive activities for all countries and the world as a whole, excluding U.S. (see the row entitled: Others-US), over all time periods. The size of "Japanese" inventive teams appears to be the largest (e.g., average of 2.75 inventors per patented invention in 1996/1997) and "Taiwanese" to be the smallest (e.g., an average of 1.32 inventors per patented invention in 1996/1997).

Although figures reported in Table 1a are both conservative and underestimate[10] the true figures, the size of inventive national (as opposed to international) teams are increasing consistently. This may be partly due to the increasing complexity of patented inventions over time. It may also be due in part to rising incidents of co-operations and alliances in organizing inventive activities as discussed in Part I. In Table 1a, the row entitled "Others-U.S." represents the average overall case of all countries combined, excluding US. It portrays the reality of the worldwide cooperative inventive activities (excluding U.S.) between inventors. These highly aggregated figures (e.g., 237,173 inventors for 101,254 patents in 96/97) average out many larger and smaller variations within countries as well as time periods. Yet on the whole, the average size of inventive team(s) has consistently increased from the low of 2.06 in 1980 to 2.34 persons in 1996/97. This is clearly indicative of worldwide inventive activities moving away from their traditional characterization centered on individuals and carried out in virtual secrecy. In sharp contrast to this larger and increasing trend in team sizes worldwide, Taiwan's inventive activities have remained, for the most part, an individual activity. The inventive activities of individual inventor/entrepreneur and relatively small size of Taiwanese firms may have impacted the smaller reported team sizes in that country. As shown in Table 1a, Taiwan co-inventor index remains close to unity (i.e., ranging from 1.09 in 1980 to 1.31 in 1996/97).

To illustrate a specific example of joint invention between inventors with different countries of residence, as envisioned by $H_1$ and captured by Case 1b, the phenomenon of joint invention between the U.S. and other inventors is investigated and reported in Table 1b. On the whole, as can be seen in the top row entitled "Others-U.S." in Table 1b, there is a consistent upward trend over time. Just about 5% (4.64%) of *worldwide* inventive activities in 2000 are carried out with U.S. co-inventors. While some figures for the decade of the 80s in Table 1b do not adhere to the consistent upward trends for years 1990 to 1995 and 2000 figures, Canadian, French, Dutch and German figures show a very consistent and upward trend over time. The large figures for both Taiwan and S. Korea in the 1980s are due to the dominant position of US-based MNEs in inventive activities. This upward trend for others could be partly attributed to the relatively large and increasing presence of U.S.-based subsidiaries (of MNEs) in these countries in general, and in Canada and the U.K. in particular. In a parallel fashion, this upward trend is indicative of an exceedingly increasing cross-border cooperation in inventive activities. *These trends clearly confirm $H_1$.* The micro details of these cases, however, merit further investigation to shed light on the true mechanisms that lead to, or caused by, the increased collaborative activities envisioned by $H_1$.

**Insert Tables 1a and 1b About Here**

### 4.2 The Co-assignee Index and $H_2$

As discussed earlier, the "assignee" information field of patent application is more reflective of ownership and *ex-ante commercial intentions* at the time of application as opposed to the ex-post reporting of *innovative* activities (as contrasted to the "inventor" information field). Similar to entries in Table 1a, an entry for a given country and time period is the total number of assignees (stating a particular country as their place of residence) as a ratio of total number of associated patented inventions. Again, Japan shows the largest multiple assignee incidents (e.g., 6.26% of patented invention have multiple assignees in 1996/97) and Taiwan the smallest. As for the former, this combined with high co-invention figures may be reflective of Japan's Keiretsu-based inventive structure.

Although, the incident of multiple assignments, as shown in Table 2a, is on the rise world wide, it does not seem to be a relatively popular activity. Even in Japan less than 6% of patents report multiple assignees in 1980. But, there is a consistent upward trend across all countries and time periods. Again, the row entitled: "Others-U.S.," which reports assignment activities for the entire countries of the world excluding U.S., shows a consistently rising trend, but on average that stands at less than 5% in 1996/1997 (i.e., less than 5% of patents have multiple assignees-- also see Table 2a). This rising trend, as hypothesized in $H_2$, must be viewed as a reflection of increased globalization of inventive activities.

A specific example of Case 2b (i.e., multiple assignees with multiple countries of residence) is the case of joint assignment between a United States assignee(s) and a counterpart(s) in another country (ies) in the sample. The results of data analysis are reported in Table 2b. Joint assignment with the U.S, as can be seen in Table 2b, is also a relatively minor event. Less than 1% of patents in the world are co- assigned, with at least an U.S. resident as an assignee. It is note worthy that the actual patent counts is also small by any comparison. Only 3337 patents for major patenting countries in the world as a whole, (from the total of some 80,000 patents with 66,000 have at least on assignee) in 2000 have a joint assignment with at least one U.S. assignee. Consistent with Case 2a, co-assignment with U.S. for Canada, Germany, Great Britain and the Netherlands show figures of larger magnitude than the average. A cursory comparison of results in Tables 2a and 2b indicates that collaboration as indicated by co-invention and co-assignee is on the rise as a whole; but with a much stronger emphasis on inventive activities. *The consistent upward trends in both Tables 2a and 2b are clearly indicative of internationalization, or globalization, of worldwide inventive and innovative activities over time.*

**Insert Tables 2a and 2b About Here**

The case of "no assignee", corresponding to Case 2c, is reported in Table 2c. Although consistently decreasing over time for all countries, there are large differences in the calculated figures for various countries. For Taiwan, for example, close to 42% of patents declared no assignee on their patent application at the time of filling for patent in U.S. in 2000 (i.e., the assignee field of information was left blank). Although this is the largest ratio for all countries in the sample for 2000, it is the smallest for Taiwan over times from 1980 to 2000. Since no assignee is commonly viewed as an indicator of individual inventors' and small enterprises' involvement, individuals and SMEs appears to have the largest share of inventive activities in Taiwan. In contrast to Taiwan, South Korea's no assignee rate stands at 7.41% in 2000 with a declining trend; while for Japan, it is the lowest at 2.38%, which are both reflective of a difference in inventive structure of Taiwan as compared to the latter two countries.[11] That is, the bulk of inventive activities in Taiwan are carried out by individual inventors or small firms in contrast to high concentrations in larger firms in Korea and Japan[12]. For the world as a whole, excluding U.S., some one-tenth (10% in 1995) of patents on average do not declare assignees. Two observations are also noteworthy; i) in spite of the increasing number of patented inventions (e.g., 25,773 patents in 1980 versus 78766 patent in 2000 for the world excluding U.S.), the no assignee proportion has consistently fallen (i.e., from 15.49% to

10.36% in 1995) over time and across almost all countries in the sample; ii) the no assignee rates in the Taiwan and Canada show higher ratios over time than other industrializing countries, which may be reflective of the vibrant and inventive individuals and small firms in these countries. In another side, higher no assignee in US also reflect same phenomenon, while the patenting costs might be slight lower than other countries to patenting abroad in U.S. The figures and their trends in Tables 2a, 2b, and 2c combined show a clearly increasing trend in "Co-Assignment" on one hand and decreasing trend on "no-Assignee" other hand, which are both confirm $H_1$. Although, these trends certainly merit further follow-up and micro investigation, they collectively point to increased collaborative activities at all levels for all countries over time.

**4.3 Multiple Inventors and Multiple Assignees and $H_3$.**

Due to the potential complexities and also potentially large combination of multiple inventions and assignment, only one specific case is presented as an example and analyzed here. This is the case of *simultaneous co-invention and co-assignment* involving agents with *U.S. residence* and presented in Table 3. The low theoretical probability of simultaneous co-invention and co-assignment involving agent(s) with U.S. residence is confirmed with the small magnitude of the raw patent count numbers, which have given rise to the small figures in Table 3. For Taiwan and South Korea, for example, the total corresponding patent counts are each less than five in 2000. The largest patent counts are for Japan and Canada that are still resulting in very small figures in Table 3 (0.2% and 0.7%, as ratio of total inventions by the residents of Japan and Canada, respectively). These low figures indicate that cooperative activities do *not* generally *span over all* facets of inventive, innovative and commercial activities. This implication is consistent with observed practice of collaboration often focused on one part of the inventive-innovative-commercialized activities (Gomes-Cassares, 1996) as opposed to the entire span. Full and expansive cooperation appears therefore to be more of an exception than the rule. In the absence of additional information, it is therefore clear that $H_3$ can not be accepted.

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Insert Tables 2c and 3 About Here

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## V: CONCLUSION AND STRATEGIC IMPLICATIONS

An overall re-examination and the analysis of information presented in Part III point toward a consistent upward trend in collaboration on various aspects of inventive activities. For example, Table 1a on co-inventive activities documents clearly that the size of inventive teams have been increasing across all countries in the sample over the past 20 years. Although the increasing inventive activities of *individual inventors,* with potentially smaller sized teams in entrepreneurial and small enterprises (Etemad and Lee 1999a), have undoubtedly had a downward impact on all entries in Table 1a, these highly aggregated average figures (for size of inventive teams) are *consistently larger than unity in all* cases, about 2.00 for most cases, and approaching 2.70 for Japan. The most revealing fact is that the *average size of teams* for the world as a whole has gradually increased and is approaching 2.4 inventors per patented invention. The more interesting observation is, however, that the average size of inventive teams has *grown steadily* by some 25% to 30% over the time period (especially for the two NICs) of this study. As stated earlier, this increase in the size of inventive teams may be attributed to a combination of factors, prominent amongst which are increased collaborative arrangements. Other contributing factors may include, but not limited, to: i) the increasing complexity of inventions requiring additional expertise (i.e., multi disciplinary teams), ii) the greater time pressure forcing a shorter completion cycle, iii) the higher competitive pressures to enter market sooner than other rivals, and iv) the increasing competitive need to keep or develop a technological lead in exceedingly shrinking technological life cycles. Although patent information does not offer a direct evidence for the cause, our analysis clearly supports the hypothesis of increasing collaborative inventive and inventive-based commercial activities. Almost all manifestations of such increased collaborative activities are observable, though indirectly. Disregarding the cause, the inescapable consequence of these increased joint activities across nations must be an increased globalization of inventive activities over time.

Entries in Table 1b, documenting the joint inventive activities of U.S. residents and the residents of the rest of the world, also confirms the above trend. On the whole, close to 3% of the worldwide patents report an U.S. co-inventor. In light of the fact that a great majority of inventive activities takes place in the highly industrialized countries of OECD, the above figure underestimates the reality of US participation in these highly inventive countries. Yet it further points to the importance and the increasing collaborative efforts between the U.S.

inventors and those of the other OECD countries over time. For Canada, for example, the incident of joint inventions between Canadian and U.S. inventors is approaching 12%.

For the two NICs in the study, however, there is some evidence to suggest (Etemad and Lee 1999a and b, also see Tables 1a, 2b and 2c) that not only have these NICs established a solid level of inventive activities, but also each has adopted a developmental course of their own. While individuals and SMEs seem to be the primary sources of inventive activities in Taiwan (based on high no assignee statistics in Table 2c and low co-assignments in Table 2b) South Korea's chaebols (similar to Japan's Keiretsus) have become powerful engines in that field (based on low co-assignee rates in Table 2b and high co-invention rates in Table 2a). This information also provides support for Dunning's (1992) observation that South Korea and Japan (to a lesser extent) have had restrictive policies affecting cross-border collaboration adversely.

If one accepts that the reason for multiple assignees (similar to the case of multiple inventors for expediting inventive process) is broadening and deepening the market reach of a commercialized patented invention globally, Table 2b (reporting co-assignee incidents) is also confirmatory evidence for this increasing worldwide collaborative trends on the innovative and commercial side. An approximate average of one-twentith (0.5%) of non-U.S. patents, report multiple assignees (see the row entitled "Others - U.S." in Table 2b). Other specific examples of these phenomena are shown in Table 2b, where the incidents of joint assignment with U.S. are reported. Since the figures for most countries in Table 2b are reasonably stable across the time period, the steady (but small) increase for co-assignment in the world (excluding U.S.) must necessarily come from other countries not in the sample, which points to the *broader expanse* of the phenomenon than that of the countries present in the sample. In other words, collaboration in inventive activities is inclusive of a larger number of countries than our sample.

This paper attempted to portray a reasonably accurate picture of the reality by developing a simple calculation to shed discriminating light on inventive activities. Although information fields of patent application provide limited, and at times only indirect, input data for drawing definitive and direct conclusions, the multi-faceted capabilities of our proposed approach, though in its early stages of development, show very promising signs. Most of these signs, especially when taken collectively point to increased level of co-operative (or collaborative) inventive activities worldwide over the past two decades. It appears that the world has already embraced the inceptive stages of the globalization of technology resulting from the increased cooperative and collaborative inventive activities of individuals and enterprises. Collaboration in inventive activities does not, however, show as equally strong presence in the developing world as those in the highly industrialized countries, and future research must confirm the true trends of these early signals.

## VI: FINAL REMARKS

- **Team Size or Co-Inventor Index?**

In Essay No.1 we fond that the average inventors per patent case is increasing. Given the large presence of single inventor in all population of USTPO patent database, the team size should even increase more rapidly than our numbers. In other words, the average team size after subtraction of single inventor will be far larger and increase at a faster rate, based on the more precise formulas:

*Modified Team Size= (Number of Occurrences in Same Country-Number of Patent Case with Single Inventor) / (Number of All Patent Cases- Number of Patent Case with Single Inventor)

Unfortunately, the present USPTO does not offer a field for the number of inventor per patent case and even our re-designed Advanced Boolean search logic cannot detect and isolate statistics for this purpose. Instead, we estimated approximate average team size by average inventors of given country per patent case and then divided by total patent cases for a given country (called co-inventor index). By the same logic, co-assignee index is for the number of assignee per patent case. For verification and confirmation, we have examined a small sample of about 120 cases from 5978 cases in year 2000; 79 cases from 3912 cases in year 1998 and 43 cases from 2143 cases in 1995 issued to Taiwan by USPTO, in order to count (by hand) their numbers of inventor and assignee distribution. As shown the table 4, the respective calculated co-inventor index of Taiwan sample is 1.40, 1.66 and 1.23 but with sample team size 2.7, 2.14 and 2.38 in 2000, 1998 and 1995. On the other side, the calculated co-assignee index in 2000, 1998 and 1995 of Taiwan sample is 70/69=1.0014, 1.000 and 1.000 but with a sample including one case of team size 2.000 (co-assignment) in 2000 while no case in 1998 and 1995. Therefore, we can point that the actual team size is definitely larger and increasing faster than our estimated numbers previously are presented in the Table 1a and 2a in Essay

No.1.

Insert Table 4 About Here

## ENDNOTES

[1] For the contrary evidence of non-globalization, see Patel and Pavitt (1991).

[2] See Yoshino and Rangan (1995) particularly Figure 1.2 with an exhaustive coverage of automobile industries' alliances worldwide.

[3] The court proceeding were covered extensively; see, for example, *Wall Street Journal* of January March, April, May June 1990.

[4] USPTO has 119 Established broad classifications that currently cover all inventive activities, but critics of the patent system argue that neither USPTO nor the European patent system (EUPTO) create new categories fast enough to accommodate the rapid pace of Technological development underway.

[5] For extensive comparison of measure of inventive and innovative activities, see reviews by Griliches (1990); Smith (1992); and Acs and Audretesch (1989). For advantage and disadvantage of patents, see also Archibugi and Pianta (1996: 452-454).

[6] Although the distinction between the country of citizenship and residents is an important one, for the purposes of this paper and due to the lack of further information, they are used interchangeably. But, every effort is made to be as specific as possible.

[7] The information field of country of residence, for both the inventor (ic) and assignee (ac) are more clearly listed and searchable, because of related information such as city of residence, postal code, etc, than the identity of either the inventor or assignee. Another benefit of this operationalization is a much easier identification of international co-invention than searching inventor's name/identity field.

[8] We have updated all tables to 2000. Since the function of occurrence hits is not offered in USPTO search pages (USPTO, 2001), the co-inventor index in Table 1a and the co-assignee index in Table 2a are remained 1996-1997

[9] Patent offices, including USPTO, do not accept patent applications with no inventor. Therefore the case of"no inventor" will never arise.

[10] Co-inventor index is always underestimated team size involved in R&D process, since not all R&D team members are listed in inventors field in patent application form.

[11] Etemad and Lee (1998a & b) have shown that inventive activities are reflective of industrial concentration in South Korea and Taiwan. Some 60% of inventive activities in South Korea are performed by the top four large Korean chaebols. While the top 20 largest Taiwanese firms can accourt for no more than 5-10% of Taiwanese inventive activities for the past 20 years.

[12] Archibugi, Evangelista, and Simonetti (1995) have examined the impact of industrial concentration on inventive activities. Etemad and Lee (1999a) find similar impact.

**Figures and Table 1a: Co-Invention Index**

| year | Taiwan | Korea | Canada | N'lands | Italy | year | Japan | Germany | France | UK | US | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980# | 1.09 | 1.15 | 1.40 | 1.57 | 1.70 | 80# | 2.48 | 2.06 | 1.71 | 1.60 | 1.50 | 2.06 |
| 1985# | 1.12 | 1.22 | 1.47 | 1.53 | 1.68 | 85# | 2.44 | 2.06 | 1.81 | 1.63 | 1.57 | 2.08 |
| 1990# | 1.14 | 1.47 | 1.52 | 1.64 | 1.73 | 90# | 2.63 | 2.20 | 1.90 | 1.71 | 1.72 | 2.23 |
| 1995# | 1.31 | 1.74 | 1.68 | 1.76 | 1.89 | 95# | 2.69 | 2.38 | 2.01 | 1.77 | 1.91 | 2.30 |
| *2000# | 1.33 | 1.86 | 1.72 | 1.86 | 1.99 | 00# | 2.81 | 2.38 | 2.11 | 1.85 | 2.03 | 2.38 |
| 96-97# | 1.32 | 1.80 | 1.70 | 1.80 | 1.94 | 96-7# | 2.75 | 2.38 | 2.06 | 1.83 | 2.01 | 2.34 |

Remarks: 1. Each cell is calculated by hit occurrences divided by patent counts.

2. *2000 cannot easily be updated at present USPTO logic. We estimated it on the basis of 95 to 97 figures.

3. An entry, e.g. **2.34**, implies the inventor number per patent case, if all cases are only single inventor, then that numbe

**Figure 1 of Table 1a: Co-invention Index for the 5 Listed Countries**

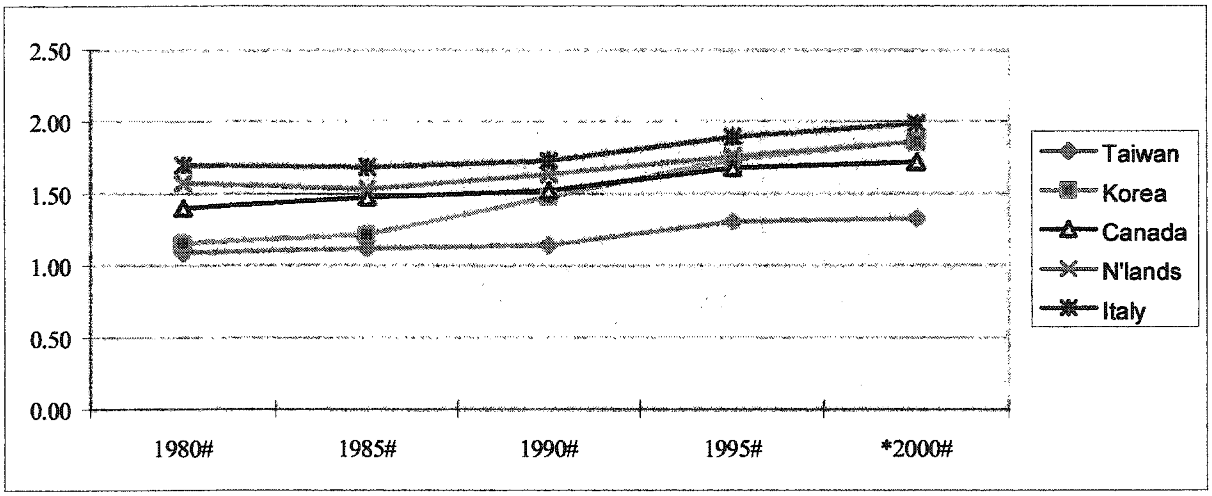
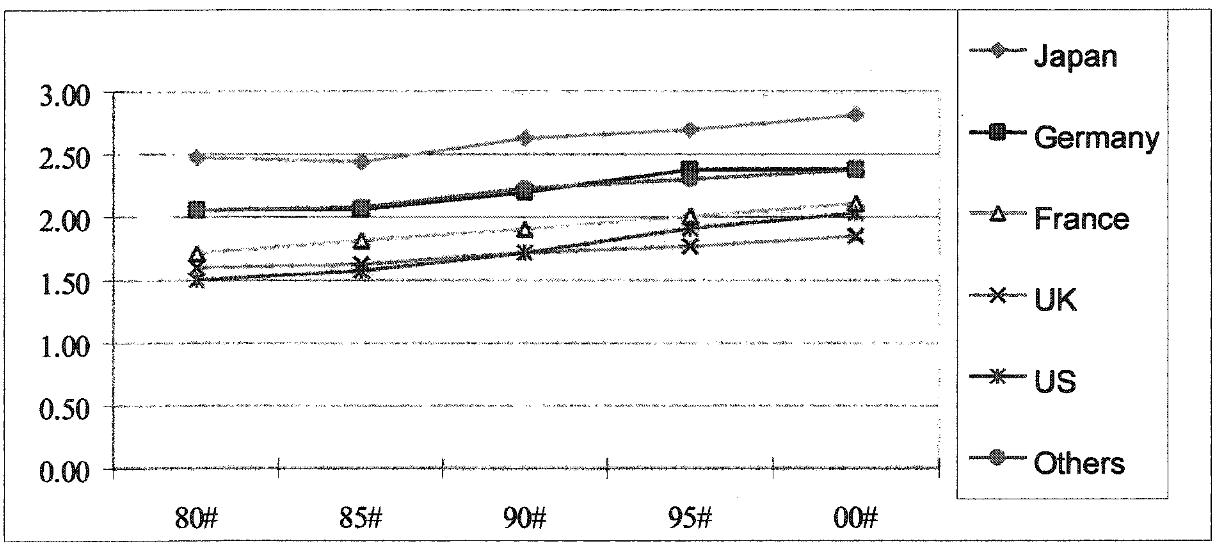



**Figure 2 of Table1a: Co-invention Index for the Five Listed Countries and Others**



**The Figures and Table 1b: Joint Invention Between US and Other Countri**

| x | Taiwan | Skorea | Canada | Nland | Japan | Germany | France | UK(gb*) | Italy | sub | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 80jt% | * | * | 5.00% | 1.55% | 0.51% | 0.89% | 1.27% | 2.18% | 0.46% | 1.25% | 1.38% |
| 85jt% | 4.46% | 0.00% | 5.06% | 2.07% | 0.50% | 1.16% | 1.09% | 3.61% | 1.36% | 1.33% | 1.62% |
| 90jt% | 1.72% | 2.37% | 6.56% | 3.20% | 0.79% | 1.84% | 2.04% | 4.82% | 1.86% | 1.84% | 2.21% |
| 95jt% | 3.97% | 2.21% | 9.23% | 6.83% | 1.53% | 3.26% | 4.06% | 10.13% | 6.22% | 3.40% | 4.08% |
| 2000jt% | 3.21% | 2.70% | 13.85% | 9.63% | 1.69% | 5.49% | 6.92% | 13.69% | 5.83% | **4.64%** | n.a. |
| x | Taiwan | Skorea | Canada | Nland | Japan | Germany | France | UK(gb*) | Italy | sub | Others |
| 80jt# | 7 | 4 | 63 | 11 | 38 | 53 | 28 | 56 | 4 | 264 | 356 |
| 85jt# | 9 | 0 | 76 | 18 | 67 | 81 | 28 | 98 | 14 | 391 | 553 |
| 90jt# | 15 | 7 | 144 | 36 | 164 | 148 | 65 | 153 | 29 | 761 | 1038 |
| 95jt# | 85 | 28 | 239 | 68 | 355 | 235 | 130 | 302 | 83 | 1525 | 2068 |
| 2000# | 192 | 96 | 596 | 160 | 563 | 637 | 320 | 650 | 123 | 3337 | n.a. |

Remarks: 1. For significant charting, Taiwan and S.Korea 1980 cells (8.97% and 30.77%) are viewed as outliers.

2. An entry refers cases/country sum, e.g. **4.64%**, implies the 4.64% of total patents are joint invention with at least one US in

3. The Joint Invention Cases make sense themselves;The number of cases is steadily increasing worth further field study.

**Figure 1 of Table 1b: Percentage of Joint Inventions with US for the Nine Countries Listed**

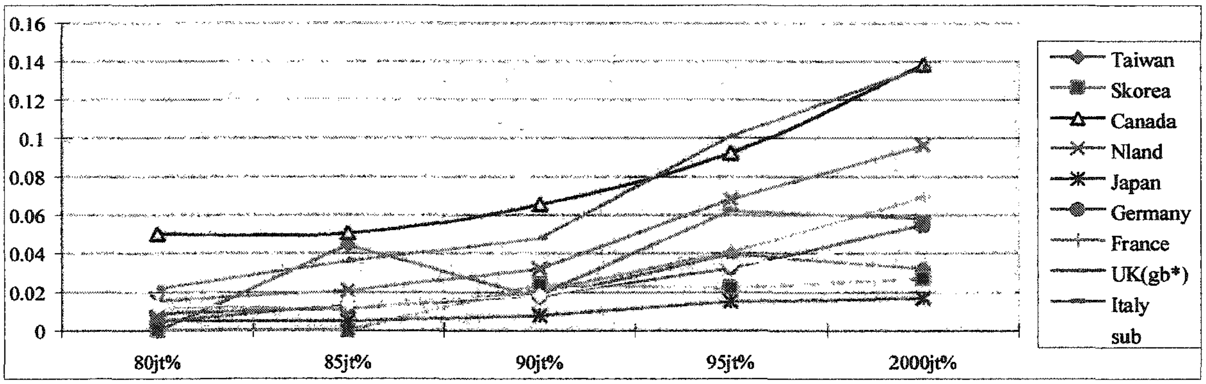
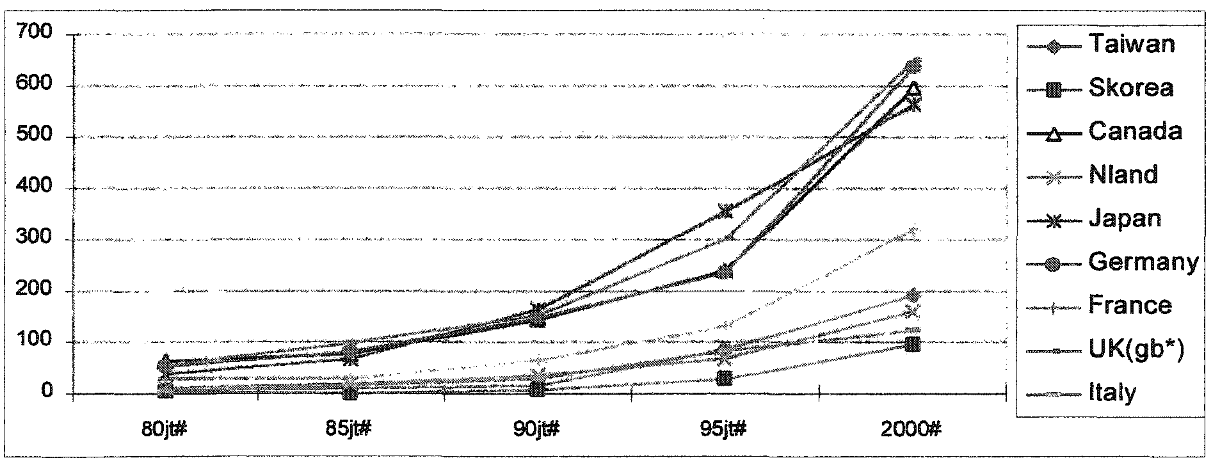



**Figure 2 of Table 1b :Number of Joint Inventions with US for the Seven Countries Listed**



**Figures and Table 2a: Co-Assignment Index**

| year | Taiwan | Korea | Canada | Nlands | Italy | year | Germn | France | UK | Japan | US | others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 1.000 | 1.000 | 1.054 | 1.014 | 1.016 | 80# | 1.010 | 1.040 | 1.044 | 1.058 | 1.007 | 1.034 |
| 1985 | 1.000 | 1.000 | 1.027 | 1.019 | 1.012 | 85# | 1.015 | 1.037 | 1.005 | 1.061 | 1.006 | 1.039 |
| 1990 | 1.031 | 1.019 | 1.013 | 1.005 | 1.026 | 90# | 1.013 | 1.036 | 1.009 | 1.063 | 1.010 | 1.043 |
| 1995 | 1.039 | 1.024 | 1.023 | 1.011 | 1.042 | 95# | 1.011 | 1.027 | 1.015 | 1.062 | 1.011 | 1.045 |
| *2000 | 1.006 | 1.028 | 1.027 | 1.017 | 1.034 | *00# | 1.017 | 1.043 | 1.013 | 1.064 | 1.019 | 1.047 |
| 96-97 | 1.008 | 1.026 | 1.025 | 1.014 | 1.038 | 967# | 1.014 | 1.035 | 1.014 | 1.063 | 1.015 | 1.046 |

Remarks: 1. Each cell is calculated by hit occurrences divided by patent counts.

2. 2000* cannot easily be updatedat present USPTO logic. We estimated it on the basis of 95 to 97 figures.

3. An entry, e.g. **1.046**, implies the inventor number per patent case, if all cases are only single inventor, then that number will be 1.00.

**Figure 1 of Table 2a: Co-Assignee Index for the Five Countries Listed**

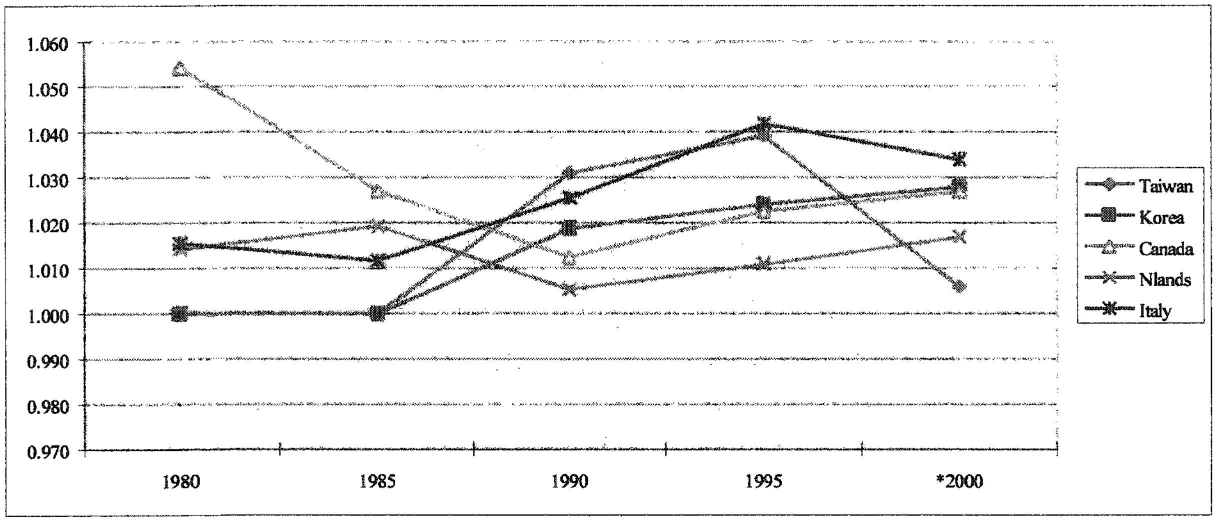
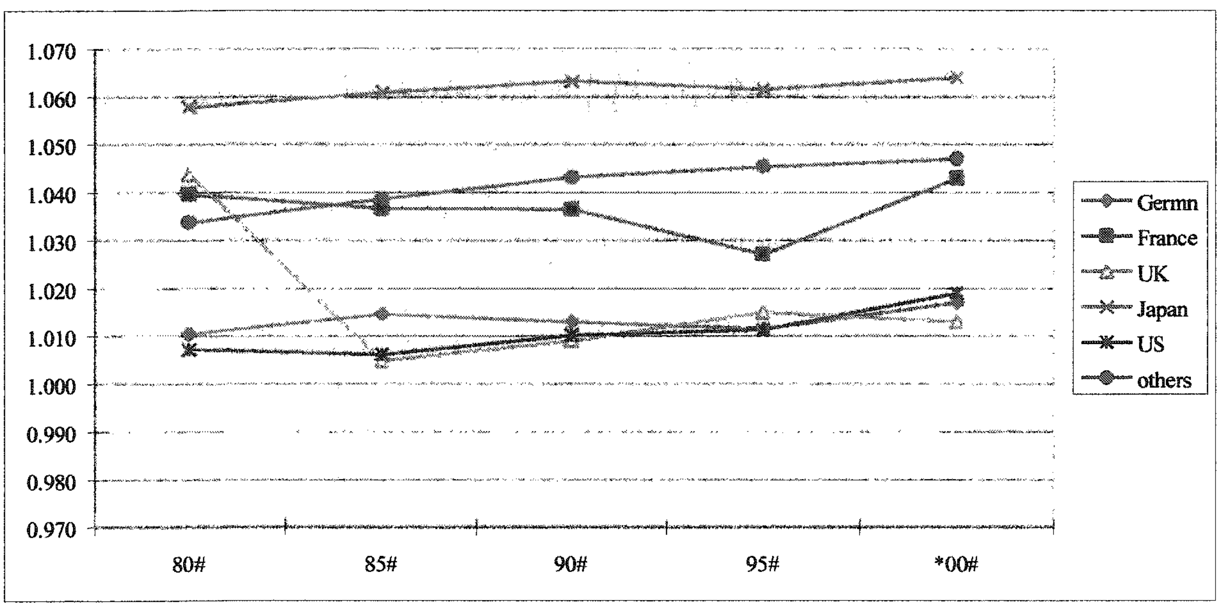



**Figure 2 of Table 2a: Co-Assignee Index for the Five Countries Listed and Others**



**Figures and Table 2b: Joint Assignement Between US and Other Cou**

| year | Taiwan | Korea | Canada | Nlands | Japan | Germ | French | UK | Italy | others |
|---|---|---|---|---|---|---|---|---|---|---|
| 80no% | 0.00% | 0.00% | 0.51% | 0.35% | 0.13% | 0.12% | 0.11% | 0.27% | 0.00% | 0.15% |
| 85no% | * | 0.00% | 0.37% | 0.00% | 0.10% | 0.11% | 0.10% | 0.43% | 0.52% | 0.16% |
| 90no% | 1.24% | 0.00% | 1.07% | 0.00% | 0.13% | 0.20% | 0.12% | 0.18% | 0.00% | 0.18% |
| 95no% | 0.42% | 0.26% | 1.13% | 1.09% | 0.61% | 0.32% | 0.24% | 0.45% | 0.52% | 0.54% |
| 00no% | 0.11% | 0.52% | **1.74%** | 1.68% | 1.29% | 0.79% | 0.86% | 2.66% | 0.40% | *n.a. |

| year | Taiwan | S Korea | Canada | Nlands | Japan | Germany | French | UK | Italy | Others |
|---|---|---|---|---|---|---|---|---|---|---|
| 80no | 0 | 0 | 3 | 1 | 9 | 6 | 2 | 5 | 0 | 30 |
| 85no | 1 | 0 | 3 | 0 | 13 | 6 | 2 | 8 | 4 | 45 |
| 90no | 2 | 0 | 12 | 0 | 26 | 13 | 3 | 4 | 0 | 70 |
| 95no | 3 | 3 | 15 | 7 | 136 | 19 | 6 | 8 | 5 | 226 |
| 00no | 4 | 17 | 45 | 16 | 425 | 75 | 32 | 69 | 6 | * |

Remarks: 1. For significant charting, Taiwan 1985 cells (6.25%) are viewed as outliers.

2. An entry refers cases/country sum, e.g. **1.74%**, implies the 1.74% of total patents are joint invention with at least one US inventor.

3. The Joint Assignee Cases make sense themselves;The number of cases is steadily increasing worth further field study.

**Figure 1 of Table 2b: % of Joint Assignments between US and the Countries Listed**

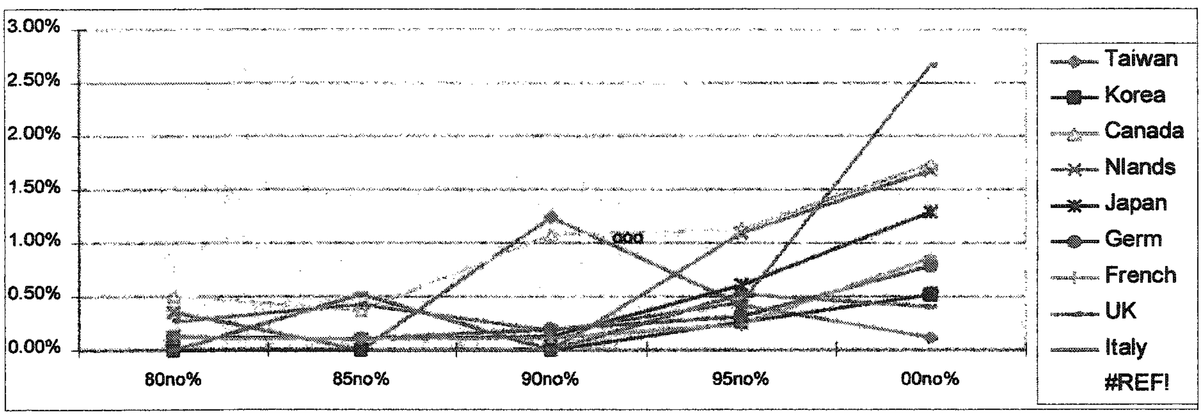



**Figure 2 of Table 2b: Number of Joint Assignments Between US and the Countries Listed**

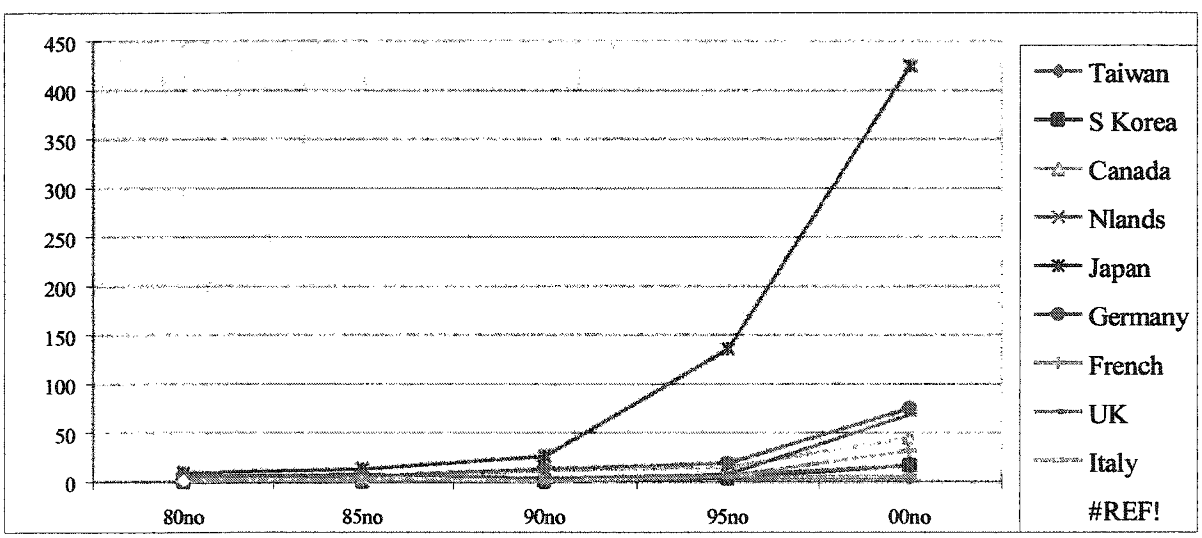


**Table 2c: No Assignee Rate**

| year | Taiwan | Korea | Canada | Nlands | Italy | year | Japan | Germn | French | UK | US | others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80no% | 87.2% | 76.9% | 39.2% | 9.9% | 23.6% | 80' | 5.8% | 10.8% | 13.6% | 11.6% | 27.6% | 15.5% |
| 85no% | 89.1% | 54.0% | 33.0% | 9.0% | 16.1% | 85' | 3.5% | 10.2% | 11.4% | 10.8% | 23.7% | 11.2% |
| 90no% | 79.4% | 22.4% | 37.7% | 8.0% | 13.8% | 90' | 2.8% | 10.2% | 9.9% | 10.3% | 27.3% | 11.2% |
| 95 no% | 61.8% | 9.4% | 36.1% | 7.2% | 10.2% | 95' | 1.9% | 7.2% | 7.0% | 10.0% | 25.0% | 10.4% |
| 00no% | **42.0%** | 7.4% | 30.4% | 16.3% | 20.7% | 00' | 2.4% | 12.6% | 12.9% | 23.1% | n.a. | n.a. |
| year | Taiwan | Korea | Canada | Nlands | Italy | year | Japan | Germn | French | UK | US | others |
| 80# | 68 | 10 | 494 | 70 | 203 | 80# | 434 | 647 | 300 | 297 | 11245 | 3991 |
| 85# | 180 | 27 | 495 | 78 | 166 | 85# | 468 | 713 | 292 | 292 | 10335 | 3821 |
| 90# | 692 | 66 | 828 | 90 | 214 | 90# | 589 | 821 | 315 | 328 | 14588 | 5247 |
| 95# | 1324 | 119 | 934 | 72 | 136 | 95# | 443 | 516 | 223 | 297 | 16295 | 5258 |
| 00# | 2511 | 264 | 1398 | 271 | 437 | 00# | 795 | 1464 | 596 | 1095 | n.a. | n.a. |

Remarks: 1. Each cell is calculated by no assginee cases divided by patent counts of that country.

2. An entry, e.g. **42.0%**, implies the 42% part of patent counts of that country are no assginee.

3. The No Assignee Cases make sense themselves;The number of cases is still steadily increasing worth further field study.

**Figure 1 of Table 2c:Assignee Rates for The Countries Listed**

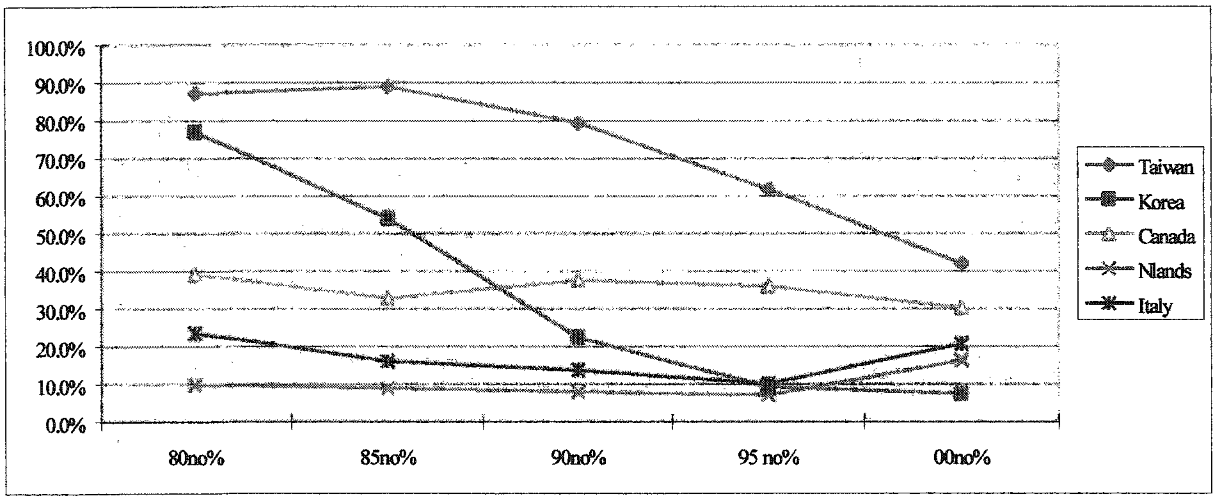



**Figure 2 of Table 2c: Assignee Rates for The Countries Listed and Others**

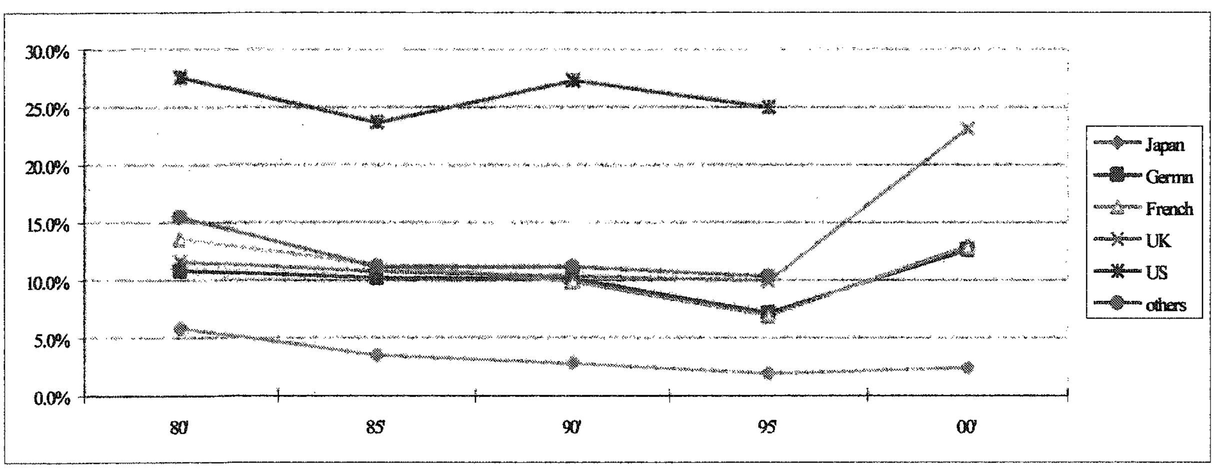


**Table 3: Joint Invnetion and Joint Assignment Between the US and Other Countries**

| year | Taiwan | Korea | Canada | Nland | Italy | year | Germn | France | UK | Japan | sub | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80jt% | 0.000% | 0.000% | 0.159% | 0.000% | 0.000% | 80jt% | 0.067% | 0.045% | 0.078% | 0.040% | 0.057% | 0.054% |
| 85jt% | 0.000% | 0.000% | 0.067% | 0.000% | 0.194% | 85jt% | 0.072% | 0.078% | 0.258% | 0.022% | 0.068% | 0.067% |
| 90jt% | 0.000% | 0.000% | 0.501% | 0.000% | 0.000% | 90jt% | 0.074% | 0.063% | 0.094% | 0.058% | 0.082% | 0.081% |
| 95jt% | 0.047% | 0.000% | 0.425% | 0.201% | 0.150% | 95jt% | 0.139% | 0.156% | 0.235% | 0.229% | 0.203% | 0.207% |
| 00jt% | 0.017% | 0.140% | **0.695%** | 0.241% | 0.142% | 00jt% | 0.267% | 0.390% | 0.948% | 0.233% | 0.301% | n.a |

| year | Taiwan | Korea | Canada | Nland | Italy | year | Germn | France | UK | Japan | sub | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80jt# | 0 | 0 | 2 | 0 | 0 | 80jt# | 4 | 1 | 2 | 3 | 12 | 14 |
| 85jt# | 0 | 0 | 1 | 0 | 2 | 85jt# | 5 | 2 | 7 | 3 | 20 | 23 |
| 90jt# | 0 | 0 | 11 | 0 | 0 | 90jt# | 6 | 2 | 3 | 12 | 34 | 38 |
| 95jt# | 1 | 0 | 11 | 2 | 2 | 95jt# | 10 | 5 | 7 | 53 | 91 | 105 |
| 00jt# | 1 | 5 | 33 | 4 | 3 | 00jt# | 31 | 18 | 45 | 78 | 218 | ***n.a.** |

Remarks: 1. Each cell is calculated by joint-joint cases divided by patent counts of that country.

2. An entry, e.g. **0.70%**, implies the 0.70% part of patent counts of that country are joint-joint.

3. The Joint-Joint Cases make sense themselves;The number of cases is still steadily increasing worth further field study.

4. There should be about **400** joint-joint patent cases issued by USPTO in year 2000, growing at 20% per year.

5.Those cases imply highest probability of technological collaboration and heavy R&D across border.

**Figure 1 of Table 3: Joint-Joint Rates Between US and the Five Countries Listed**

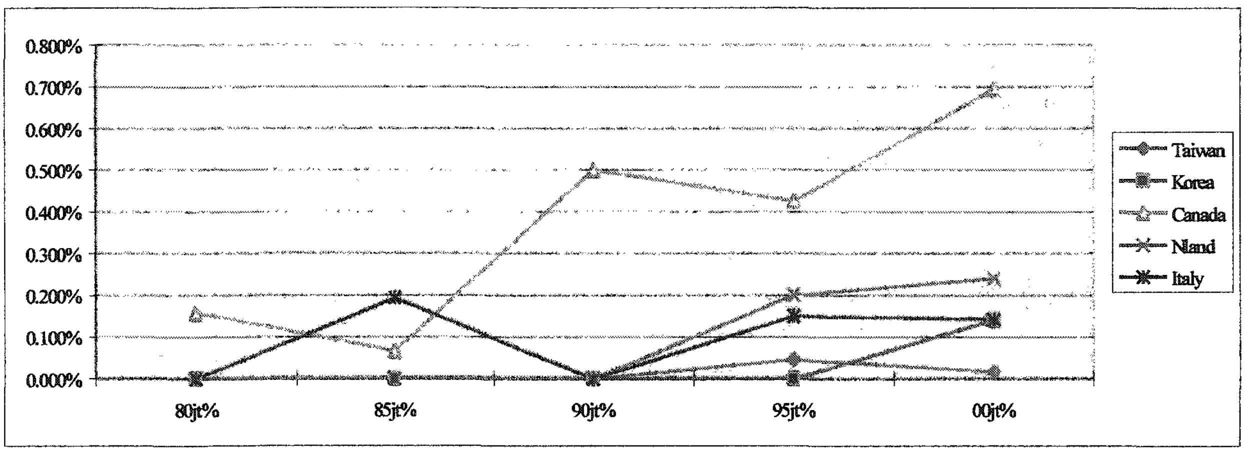



**Figure 2 of Table 3: Joint-Joint Rates Between US and the Five Countries Listed and Others**

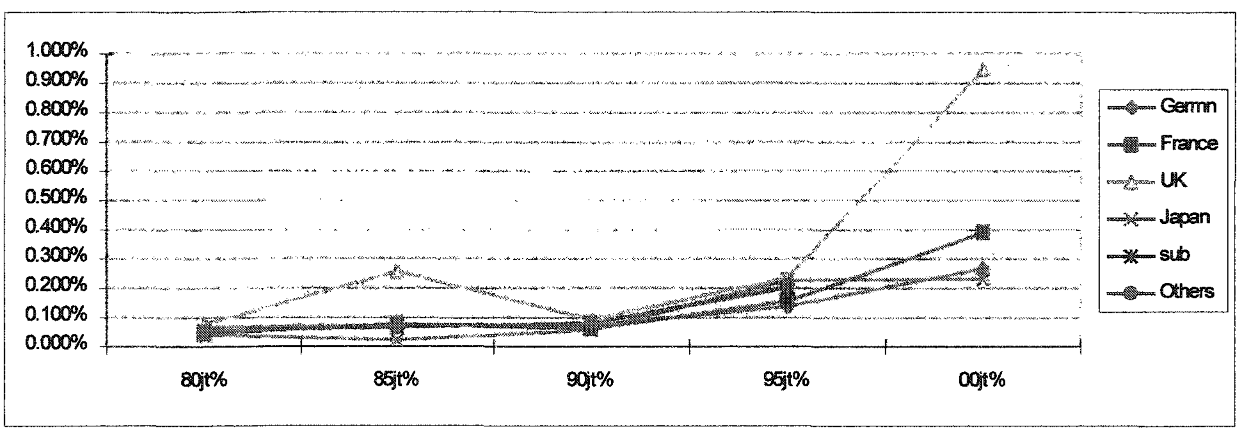


**Table 3: Joint Invnetion and Joint Assignment (Continued)**

| year | Taiwan | Korea | Canada | Nland | Italy | year | Germn | France | UK | Japan | sub | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80jt# | 0 | 0 | 2 | 0 | 0 | 80jt# | 4 | 1 | 2 | 3 | 12 | 14 |
| 85jt# | 0 | 0 | 1 | 0 | 2 | 85jt# | 5 | 2 | 7 | 3 | 20 | 23 |
| 90jt# | 0 | 0 | 11 | 0 | 0 | 90jt# | 6 | 2 | 3 | 12 | 34 | 38 |
| 95jt# | 1 | 0 | 11 | 2 | 2 | 95jt# | 10 | 5 | 7 | 53 | 91 | 105 |
| 00jt# | 1 | 5 | 33 | 4 | 3 | 00jt# | 31 | 18 | 45 | 78 | 218 | *n.a. |

**Figure 3 of Table 3: Numbers of Joint-Joint Cases for Countries Listed**

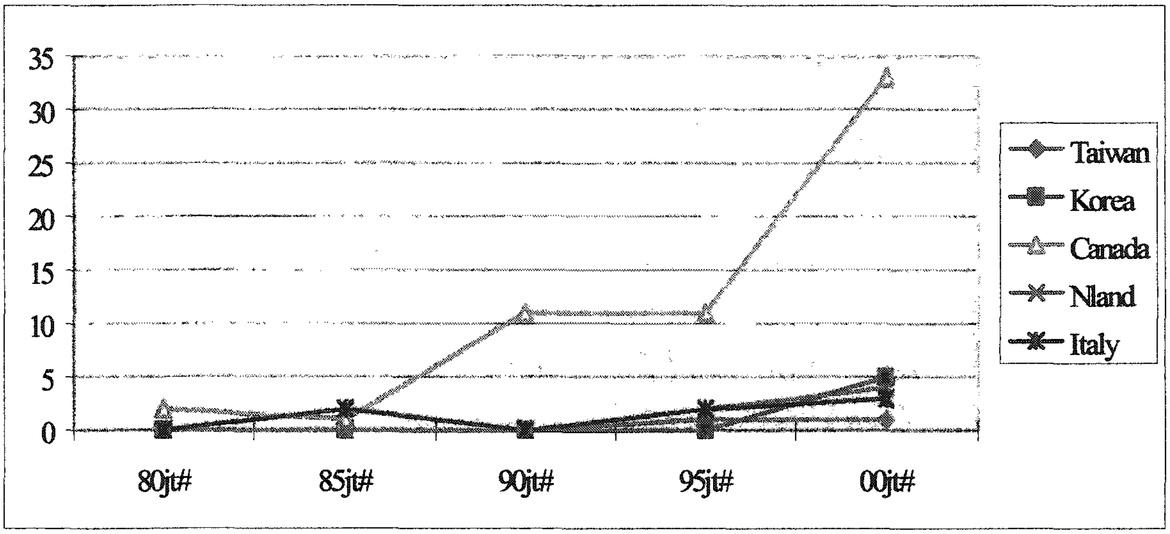



**Figure 4 of Table 3: Numbers of Joint-Joint Cases for Countries Listed and Others**

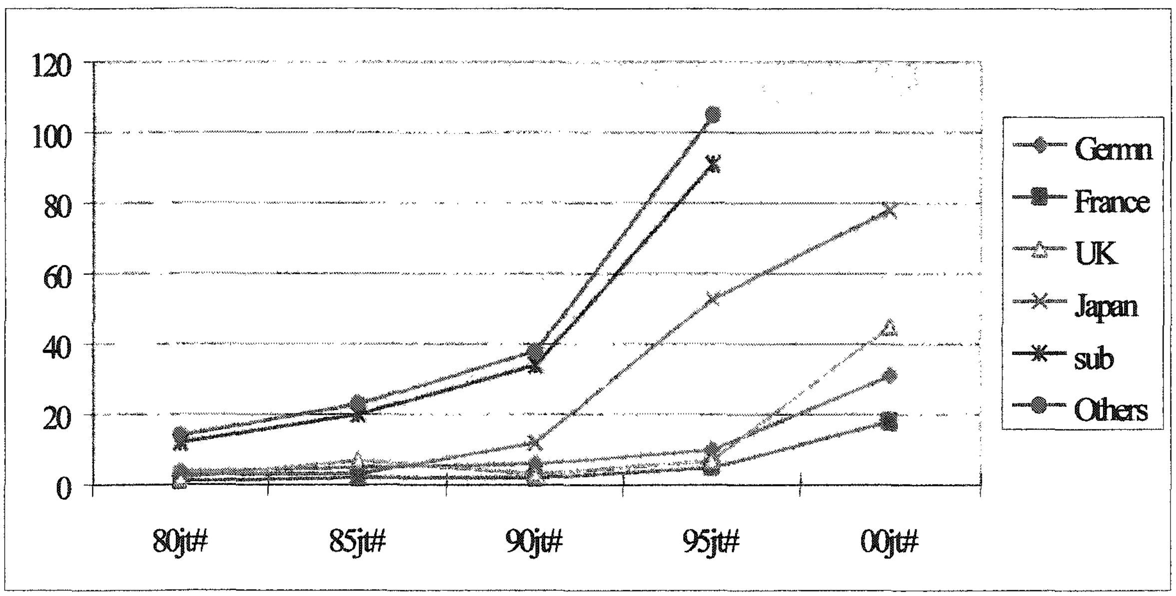


**Table 4: The Distribution of Inventors and Assignees of Sampling Taiwan Cases, 1995-2000**

| **inventor/cas** | **case no.** | **inventor no.** | **Assignee/case** | **case no.** | **Assignee no** | **Remarks** |
|---|---|---|---|---|---|---|
| 1 | 85 | 85 | 0 | 51 | 0 | No assignee |
| 2 | 19 | 38 | 1 | 68 | 68 | |
| 3 | 12 | 36 | 2 | 1 | 2 | *two assignee |
| >3 | 4#(4,4,6,7) | 21 | | | | |
| **2000 sub** | **120 cases*** | 180 | | 120 cases | 70 | Assignee* |
| 1 | 46 | 46 | 0 | 39 | 0 | No assignee |
| 2 | 15 | 30 | 1 | 40 | 40 | |
| 3 | 9 | 27 | | | | |
| 4 | 7 | 28 | | | | |
| 5 | 2 | 10 | | | | |
| **1998 sub** | **79 cases** | 141 | | 79 cases | 12 | Assignee |
| 1 | 35 | 35 | 0 | 31 | 0 | No assignee |
| 2 | 3 | 6 | 1 | 12 | 12 | |
| 3 | 4 | 8 | | | | |
| >3 | 1# (5) | 5 | | | | |
| **1995 sub** | **43 cases** | 54 | | 43 cases | 12 | Assignee |

Data source: Sampling ratio 1: 50 by search USPTO and counting by hand.

Remarks: 1. There are 12, 10 and 7 foreign inventors in 2000, 1998 and 1995 Taiwan sample.

2. There are 3, 6 and 1 foreign assignees in 2000, 1998 and 1995 Taiwan sample.

3. Therefore calculated co-inventor index of Taiwan sample is 1.40, 1.66 and 1.23 but with team size 2.7, 2.14 and 2.38 in 2000, 1998 and 1995.

4. Therefore calculated co-assignee index of Taiwan sample is 70/69=1.0014, 1.000 and 1.000 but with team size 2.000 in 2000 while no case in 1998 and 1995.

# CHAPTER 3: ESSAY NO. 2

## TECHNOLOGICAL CAPABILITIES AND INDUSTRIAL CONCENTRATION


### Abstract

This paper presents a comparative study of the technological development paths and the technological profiles of SMEs in two Asian Newly Industrialized Countries--S. Korea and Taiwan--in comparison with six Advanced Industrialized Countries as well as a list of selected highly populated nations. Using U.S. patent statistics as technology indicators, the quantitative and comparative analysis of this paper shows that S. Korea and Taiwan have achieved a level of technological capabilities that rival those of the advanced countries. They have achieved this through a reliance on generating and accumulating innovative and technological capabilities of their own as opposed to transferring them from other countries. The analysis also shows that the industrial structure has played a major, but different, role in these countries. In South Korea, these capabilities are concentrated in a small number of relatively larger firms (i.e. the Korean Chaebols). In contrast, they are spread across a large number of relatively smaller firms in Taiwan (i.e. Taiwanese innovative SMEs). The relative technological success of Taiwan is therefore attributable to innovative activity of her SMEs (185 *words /keywords: technological capabilities, technology concentration, patent statistics, newly developed countries, Taiwan and S. Korea)*.


## I. INTRODUCTION

### 1.1 Technology Development and Economic growth

Technological development has recently received greater attentions in the ongoing debate on the role of technology in economic growth and development (Dosi and Kogut, 1993;

Dalum, 1992) than in the past. A new spirit of techno-nationalism -- believing that heightened technological capabilities of a nation, or a firm, leads to higher competitiveness -- is emerging. The rapid growth and development in newly industrialized countries (NICs), who have historically lacked rich natural resources, has lent support to the hypothesis that the technological innovation must be at least partly responsible. The strengths and weakness of major advanced industrialized countries' (AICs) technological innovation have also been examined thoroughly since the early 1980s. They are found to underlie their competitive strengths (Cantwell, 1992). Many scholars (e.g., Bartholomew, 1997; Freeman, 1992; Kogut, 1991; and Lundvall, 1992) have devoted their attentions to the description and comparison of the national systems of innovation (NSI) in order to explain competitive performance.

The total factor-productivity growth rates in manufacturing of Asian NICs have reached substantially higher levels than most AIC's in the past two decades. Technological innovations seem to be partly responsible for this increase as these countries have accumulated an impressive record of inventions and innovations (Etemad and Lee, 1999b). However, there has been little debate about the *source and the supporting structure* of increased competitiveness in these newly industrialized countries (NICs). The innovative composition of industrial production at a given location, and a given time, is not an isolated input factor. Rather, it reflects the pattern of technological accumulation over time requiring a longitudinal approach to the problem. The findings of this research suggest that a substantive part of this increased competitiveness is due to the increased technological capabilities over time. This paper aims to shed light on the evolutionary path and the supporting industrial structure of those capabilities in NICs in comparison to comparable AICs.

### 1.2 Development of Technological Capabilities in Asian NICs

The acquisition and transfer of technology have been viewed in most developing countries as a key to raising productivity for sometime. However, technological capability is not an automatic by-products of increased investment and production (Bell and Pavitt, 1995). In contrast to AICs, the pattern of industrialization and competitiveness in dynamic Asian NICs is concentrated in a relatively short time period, is widely-based and show variations across countries. These make them good candidates for studying such time-based phenomena[1] (Dahlman, Hague & Takeuchi, 1995).

These variations are partly because of numerous government interventions, both selective and functional, in the four Asian NICs. For example, under an aggressive and proactive industrial policy, the S. Korea's record of industrial diversification (both widening and deepening), export development and growth became one of the most impressive in the modern economic history. Korea's manufactured export grew at 27.2% per annum during 1965-1980 and 12.9% per annum during 1980-1990 followed by Taiwan's at 18.9% and 10.3%. Similar statistics for Hong Kong are 9.1% and 6.2%; while Singapore's are 4.7% and 8.6% (Dahlman, Hague & Takeuchi, 1995).

Taiwan's developmental strategy, on the other hand, was far less aggressive and elaborate than Korea's. Yet, Taiwan has become as dynamic as S. Korea (Lall, 1995). In contrast to Korean chaebols, however, Taiwan's strength seem to lie in its myriad of SMEs, which have capitalized on its large pool of human capital under protective government policies aimed at promoting small and infant industries. Partly due to their smaller size, Taiwan's manufacturers conducted (and still continue to conduct) far less mass-production, in-house R&D, and international branding than their Korean counterparts (Lall, 1995). These shortcomings have however been offset somewhat by the wide range of technological support services provided by the government (including R&D). A relatively small but growing number of larger firms are appearing. These growing firms continue to invest in their own R&D to develop their own capabilities and support their own brands globally.

Hong Kong and Singapore also offer variations of the same theme. While Hong Kong's policy has been close to lassies-faire capitalism, Singapore's has been interventionist in nature. This suggests that industrial structure has also been an influential factor; and more importantly, raises the question of which is the uniquely Asian model. Due to Hong Kong's reversion back to the People's Republic and Singapore's limited economic influence during the recent Asian economic crisis, it is not clear which one of the remaining two industry-market structures will develop a greater competitive strength in the long term -- Korea with its giant "*chaebols,*" or Taiwan's with smaller but more technologically-oriented enterprises? The massive Asian currency depreciation and economic slowdown in these previously-dynamic south and southeastern Asian countries forces the question of whether the accumulated technological capabilities would *follow* other trends or can they sustain themselves and *lead to* a new wave of renewal. This question merits some consideration as it provides a window onto the relation of techno-industrial structure and technology-led economic growth and development.

This paper follows the following structure: After this introductory section and under the heading of methodological issues, a wide range of related topics, including the purposes and research questions, and the source and characteristics of data are presented in Section II. Section III presents the research findings and discusses them critically. A cautious projection in concluding remarks points to the potential strategic lessons and implications of this study for other aspiring countries.

## II. METHODOLOGICAL ISSUES

**2.1 The Purposes and Research Questions**

Using U.S. patent statistics and complemented by other related secondary data, the major purpose of this paper is to examine the role of inventive SMEs in the relative technological position and its developmental path over time for the Asian NICs. The two mid-sized dynamic Asian NICs,[2] Taiwan and S. Korea, appeared to be good candidates for research. Given the time-dependent nature of the process, a longitudinal comparison of these two NICs with two "comparable" mid-sized advanced industrialized countries (AICs), as a base line, seemed logical. Canada and the Netherlands proved to be the best candidates to provide that base line. The overall comparison should point to degrees of difference and commonality in the path of technological development in all four countries, but especially for Taiwan in contrast to S. Korea.[3] The **research questions** of this study are therefore as follows:

*Have Asian NICs made much progress in the development of technology vis-à-vis AIC countries?*

*What are the technological positions and country capabilities of these mid-sized countries? How do they compare with highly populated countries of Asia?*

*Do technological concentration differs in relation to the industrial concentration and structure of each country[4]?*

*Which country, among the Asian NICs, is more likely than others to provide "the role model" for technology-led development for developing countries?*

*Which longitudinal growth path is more likely to sustain itself?*

**2.2 Basic Comparisons of Four Countries: Are They Comparable?**

*Country Profiles: The Four Asian NICs.* Since there is no a-priori ground for comparing two mid-sized and industrializing NICs (i.e. S. Korea and Taiwan) with larger or advanced countries, such as Germany and France, the targeted countries for comparison purposes had to be chosen carefully. They had to be reasonably comparable. Given that each country has its own socio-political and economical systems, there exists no one country that is completely comparable to another. Given such a potential difficulty, we began with the comparison of somewhat *"similar"* countries in order to understand the basis for their commonality or micro-dissimilarities, before turning to the comparison of the broader national systems of innovation (Lundvall, 1992; Kogut, 1993). The basic argument of national systems of innovation is that all innovations are embedded in a socio-political context within each country (Bartholomew, 1997). Although meaningful comparison requires a comparison of the socio-political and economic context, such a comparison is clearly beyond the scope of this paper. As integral parts of socio-economic structure in each country, industrial concentration and technological specialization may also differ so radically to defy a broad and logical comparison.[5] Due to these concerns, this paper will attempt to highlight differences by performing a more contextually-oriented comparison between the two mid-sized NICs and two mid-sized AICs. Canada and the Netherlands seem to be the best "comparable" countries from AICs. However, a broader base of comparison (both for NICs and AICs) is also carried out to establish the relative position of the base line (whenever necessary).

Compiled from *Asiaweek, Canadian Global Almanac*, and IMD *World Competitiveness*, Table 1 presents the important country profiles of the *four* Asian NICs and *four* somewhat *"similar"* advanced industrialized countries: i.e., Italy, Canada, the Netherlands, and Switzerland. As we can see in Table 1, the four Asian NICs have very different socio-political structure; but appear to possess a higher and positive momentum for economic growth and development. S. Korea has the largest GDP (PPP-based), but the least income per capita, since it has the largest population and landmass amongst the four NICs. In contrast, Singapore possesses the smallest landmass, GDP (PPP-based) and population but the largest income per capita. Overall, S. Korea and Taiwan have created a relatively more similar socio-political and economic structure than those of the two "city-states": i.e., Singapore and Hong Kong, as discussed earlier. Since S. Korea's and Taiwan's GNP have been rated as the 11th and 19th largest economies, they can be logically given the titles of "mid-sized" NICs.

Table 1 also provides the country profiles of the four mid-sized AICs -- Italy, Canada, the Netherlands, and Switzerland. The first two are the 6th and 7th in the G7 countries, while the last two are midsized OECD countries.[6] Statistics in Table 1 suggests that S. Korea's R&D expenditure (US$12383M) are at a comparable level to Canada's (US$12240M); while Taiwan's moderate R&D expenditure (US$5356M) is comparable to that of the Netherlands' (US$6968M). Another important measure to highlight in Table 1 is *The Science and Technology Scale* in the IMD *World Competitiveness Report (1997)*. Taiwan in 1997 was ranked as the 10th, just between Canada (9th) and the Netherlands (12th). We can therefore conclude with some degree of confidence that the comparison of the two mid-sized Asian NICs with the two mid-sized AICs is indeed meritorious.

**Insert Table 1 about here**

*Characteristics of the data set and the population.* We follow the established methodology of most studies in technological concentration and specialization (Archibugi and Pianta,1992 and 1996; Basberg, 1987; Chakrabarti, 1991) by using patent statistics as a technological indicator (Griliches, 1990). In spite of the few drawbacks identified in the literature (Griliches, 1990), patent data offers one the most detailed indicators for studying the patterns of technological specialization at the sectoral level (Narin, Noma and Perry, 1987;Soete and Wyatt, 1983). Several comprehensive surveys of the use of patent are often cited in research related to technology, such as (e.g., Amesse et al, 1991; Archibugi and Michie, 1995; Bell and Pavitt, 1995; Chakrabarti, 1991; Dalum, 1992; Etemad and Seguin-Dulude, 1987; Narin, Albert & Smith, 1992; Smith, 1997). Narin and associates advocate for the use of patent statistics as a powerful indicator for strategic planning of technology as well as technological modifications (Narin, Albert & Smith, 1992). The inappropriate uses of patent statistics are also well known (e.g., see Malerba and Orsenigo, 1996). For example, not all innovations are patented in the same way. Patenting is more prevalent in certain industries than other (e.g., chemical industry). Different technologies are granted patents differently; and different types of firms may have different propensities to obtain patents. It is generally assumed that small and medium-sized enterprises (SMEs) are not as capable as their larger enterprise to cut through the general and legal barriers of the patent systems. Thus, some of SMEs' inventions may remain un-patented leading to potential under-representation. On the other hand, larger enterprises apply and receive patents for tiny improvement; causing possible over-representation. Finally, a patent's impact cannot be fully measured unless specific analyses on patent renewals or patent citations are performed. Overall, patent statistics represent a very homogenous measure of *technological novelty* across countries. They are also available in a long time-series. They provide very detailed data at the firm and the technological-class levels unmatched by other measures, such as R&D expenditures or number of technicians, engineers, and scientists (Griliches, 1990).

*USPTO database*. The data set of this study has been compiled directly from information supplied by the U.S. Patent and Trademark Office (USPTO). As Kogut (1991) has observed, *country capability is a complex phenomenon.* Therefore, we limit the scope of our comparisons of country capabilities to the generation of new technology for which the use of patent statistics is the best technology-indicator. Especially for newly industrialized countries, the question of whether technology generation is a critical component of their national systems of innovation (Bartholomew, 1997) is still in need of a more detailed investigation. While technological capability is only one of many constituent factors impacting international competitiveness, it is an important one. Although patent statistics do not explicitly include the so-called "*organization capability,*" -- another important element in a country's capabilities, accumulation of patent over time must be considered as one of the manifestations of such capabilities. Kogut (1991) has argued that organizational capabilities diffuse more slowly than the technological one. In contrast, diffused technology plays an important role in developing new dynamic capabilities, which in turn facilitates a better strategic management of such capabilities over time. Overall, these arguments point to the higher reliability of longitudinal measures than cross sectional ones. This higher *overtime reliability* makes patent time-series as preferred indicators of technological development than others.[7]

*Assumptions and Potential Biases.* Theoretically, patent statistics are measures of incremental *in-flow* into a country's *revealed technological stock* or capability. Capability is a *stock* measure based on accumulated innovation flows over time for which patent time series are the best proxies. But, patenting abroad, e.g., in the U.S., may hold different significance for different countries, due to their differential *propensities to patent abroad.* Although patenting abroad embodies these propensities in reflecting a country's true innovative activities, patenting in U.S. has the highest priority for firms, who aspire to be competitive globally, since the U.S. is the largest world market for new products and new technologies deserving patent protection and exploitation. Historically, U.S. has had the most efficient patent system in the world (Griliches, 1990). This efficiency makes patenting by SMEs and individuals relatively less burdensome than elsewhere. Therefore, the comparison of the U.S. patent statistics over time does provide a fair portrayal of country capabilities, especially when SMEs are involved. However, this implies a basic assumption that all propensities to patent in the U.S. are the same; and furthermore, patented inventions (in U.S. PTO) hold equal commercial potential and are equally deployed, or commercialized, by all countries at the same rate, which may not hold true in all circumstances. It is important to note that the other prominent measures of innovative activities -- e.g., R&D expenditures -- are indirect and more diffused measures suffer from all the above ills at even a higher intensity. Exhibit 1 provides the context within which these arguments are captured. [8]

**Insert Exhibit 1 about here**

### 2.3 Industry Structure and Concentration

*Patterns of innovative activities: measures, classifications, and sampling.* Malerba and Orsenigo (1996) have developed 6 interrelated measures to analyze technological concentration in 49 technological classes for six AICs. In this study we use two measures. The first and the most important measure of concentration is the *concentration of innovative activities of the top four innovators (C4)* as a ratio of the overall innovative activities in a specific sector or a specific country. The second is the same measure for the top 20 innovators (C20) in a given sector. The use of such measures requires a careful attention to the size; the sampling method and the way samples are formed. We use two different sources to draw samples in order to minimize bias and attain the most representativeness.

*Samples and Hypotheses.* Our *first sample of large firms* in S. Korea and Taiwan are formed from the *Asiaweek 1000*. Asiaweek compiles a list of the "Top 20 Largest Firms" in both S. Korea and in Taiwan, ranked by their annual sales. The total sales of the "Top 20" largest firms of S. Korea are higher by a factor of three than those in Taiwan and account for about half of the whole S. Korean GDP. This indicates that there is a much higher concentration of economic activity in S. Korea than Taiwanese obviating the need for a sample of smaller firms in S. Korea. Given our interest in patenting activities, we hypothesize:

**$H_{1a}$:** That the ranking of patenting activities of the largest S. Korean firms in the U.S. *will be consistent* (or highly correlated) with the ranking of their sales. In contrast however:

**$H_{1b}$:** The ranking of patenting of the largest firms of Taiwan in U.S. is *not* expected *to be consistent* ( or correlated) with the ranking of their sales.

But the question is why should these be the case? The a-priori reasoning is two-fold: i) That innovative activities result in higher returns to innovators in smaller firms than larger ones. In smaller firms, most benefits accrue to the inventor or innovators (e.g., the owners or the technological entrepreneurs), while the larger firms appropriate most, if not all, benefits (Acs et al., 1997). There is a higher incentive to be more inventive (or innovative) in smaller firms. Therefore, one would expect to see higher inventiveness in smaller firms; and ii) That, Taiwan does not have as many large business groups as compared to S. Korea. Similarly, the high technology-intensive industries are not generally populated by large business groups in Taiwan contrary to the case of Korean chaebols (See Industrial Concentration and Inventive Activities for further discussion and results). The above discussion leads naturally to the impact of industrial concentration as formulated in the following hypothesis:

**$H_2$:** Patenting concentration is reflective of industrial concentration in both countries.

In forming *our second sample of firms,* we drew from the list of "Top 100 Largest Firms" from the *Tensha 1000.* Tensha is a prominent Taiwanese business magazine with the earliest ranking of Taiwan's largest firms. As discussed earlier, this is to reduce, and hopefully, eliminate any potential sample bias and to construct the most comprehensive list of the top patent holders in Taiwan. Using this alternative sample of the Top 100 largest firms would allow us to search for and find the largest Taiwanese patent holders in U.S.; and then compare their rankings in sales and patenting for both countries. To form a reliable, yet manageable, longitudinal patent databases, we compiled *patent statistics for five time periods:* 1980-1985, 1986-1990, 1991-1995, 1996-2000[9] as well as the total patenting from 1976 to2000 for all samples (i.e., the top 20 largest firms of Korea and Taiwan in *Asiaweek* and the Top 100 in *TenSha).* An important point to note is that we have also combined patent statistics for all the affiliated companies with their principal business group in both countries. For example, the 418 patent counts in 1976-2000 of Samsung Electronics are included in the Samsung Business Group. As expected, a total of nine companies in the top 20 firms in S. Korea are parts of the top four large business groups of Korea (Chaebols): i.e., Samsung, Hyundai, Daewoo, and Lucky-Goldstar (LG) groups. This heavy concentration further called for a broader measure of concentration (i.e., C20) beyond the measure of concentration for the top four (i.e., C4) companies. As defined earlier, C4 and C20 are the *total patent holdings* of the top *four* and top *twenty* firms as a ratio of the *total patent holdings of all* Taiwanese or S. Korean firms. These two measures will provide us with good tools to examine $H_1$ and $H_2$ and provide for a true perspective on both industrial concentration and technological capabilities in the two countries.

## III. RESEARCH FINDINGS AND DISCUSSIONS

### 3.1 Technological Capabilities Demonstrated

*The two NICs as members of the Top 10 Club.* The Top 10 countries with the highest levels of patenting in U.S. in the last 5 years are shown in Table 2. In this Table two indicators of such activities are provided: a) those who have *"applied for patents"* – i.e., filed a patent application in USPTO; and b) those who have been issued patents. The first signifies the micro dynamics of local inventiveness: i.e., the number of applicants who believe in the novelty of their inventions, have overcome the initial patent application barriers and have "applied for patents." But that belief remains unverified until the patent application is accepted or rejected. The second one actually certifies that the substance of the filed application has been indeed patentable (after examination by USPTO patent examiners for its novelty).

**Insert Table 2 about here**

For the purpose of providing a broader perspective, the patenting of the seven highly populated countries, as shown in Table 2, is still very low. Russia and Brazil have had a rapidly rising starts; China and India have had a moderately rising beginning; while Indonesia, Pakistan, and Bangladesh have had very low starts. Assuming the absence of serious differential propensity to patent in the U.S., these countries appear to have focused their inventive effort on *technology transfer* and on *diffusion of existing technology* from AICs, rather than *generating* new technological capabilities of their own, which would have allowed them to obtain higher patents.[10] Absorption, adoption, adaptation, or imitation of transferred technology may be viewed as novel locally. They will not constitute as innovative efforts internationally and are generally not patentable at USPTO. Furthermore, their large and closed domestic markets may have required even a larger effort than their less-populated and smaller counterparts in order to upgrade their country capability to the international level of innovativeness and competitiveness to merit higher level of patents.

While all G7 countries are in that Top 10 list, Taiwan has gradually exceeded Italy, Switzerland, Sweden, and the Netherlands, and placed just below Canada in 1996; while S. Korea is following very closely. As shown in Table 3 and plotted in Figure 1, the significant *"catching-up"* of Taiwan and S. Korea is obvious. Specially, the "patent filed" cases for Taiwan in 1994 and 1996 are even larger than those of Canada, pointing to potentially higher technological capabilities than Canada's in the near future. Actually after updating data to 2000, we can see that Taiwan with 5976 granted in 2000 became the top 4 patent country in US, just following Japan, Germany and France. Meanwhile, Korea has jumped a position higher than Italy and the Netherlands after 1996.

**Insert Table 3 and Figure 1 about here**

*The Long March.* The information presented in Table 3 suggests that the technology generation capability of the two mid-sized Asian NICs have *exponentially* increased in the recent two decades. As shown in Table 3 and also plotted in Figure 1, the patenting activities of both Korea and Taiwan began to grow quickly and *at an increasing rate* after 1985 and have exceeded those of Italy and the Netherlands after 1995. Following the same growth patterns, both the S. Korea and Taiwan will surpass Canada's inventive activities at the dawn of the new millenium. It is generally accepted that this rapid rise is mainly associated with semi-conductors, consumer electronics, information and computer-related hardware, which have all enjoyed a much higher technological opportunities for patenting than conventional industries. This is leading to deep specialization in these two countries. It is also noted that the patenting activities of Italy and the Netherlands (and even that of Canada) have not kept pace with those of S. Korea and Taiwan (in similar technological classes). These differentials would also be leading to a potentially higher technologically-based capabilities and different technological specialization for each mid-sized countries as time marches on.[11] An unescapable observation in Figure 1 is that both Taiwan and S. Korea are increasing their cumulative patents at a much higher rate (slope) than other countries. Based on their developmental paths shown in

Figure 1, Taiwan's accumulated capabilities are more likely to be higher in the near future (in the sampled classes) than those of S. Korea.

**Insert Table 3 about here**

*Linear Log-Log relationship between patent counts and GDPs*. In justifying the U.S. patenting activities as the system of choice for international comparisons, Smith (1997) point out that about half of all patents in the U.S. are of foreign origin; and, furthermore each country's patents in the U.S. is *proportional to* its gross domestic product (GDP). Our analysis shows, however, that these relationships are *only linear in a log-log space* (i.e., when the log of patent counts and the log of GDP are considered) rather than a direct relationship. This implies an important difference: i.e., *exponential relationship* between patenting and GDP *as opposed to a proportional one* as proposed by Smith (1997). Based on the 1995 data, we re-examined Smith's proposition for all major countries. The result is shown in Table 4 and Figures 2a, 2b, and 2c. With the exception of Turkey, all G7 and OECD countries lie on one regression log line, as proposed by Smith (1997). Although the regression line of the four Asian NICs is consistent with the line of G7/OECD countries in the medium range section, it has a *higher slope*. On the other side, all of the seven highly populated countries are widely dispersed in a cluster *below* the G7/OECD regression line and on a regression line of their own with a *flatter slope*. Figures 2a, 2b, and 2c combined suggest that U.S. patent statistics might be more appropriate indicator of innovative and technological capabilities for the more developed countries, such as Asian NICs, than for the seven highly populated countries. The reason is that patent statistics do not capture other preliminary efforts of these countries at the present time, as reviewed earlier. Initial technological activities, such as those in imitation, adaptation, absorption, and transfer of technology for building future technological capabilities, do not usually generate a large number (if any) of patents. A reexamination of Figure 1 (of Table 3) reconfirms this phenomenon for Taiwan and S. Korea at the earlier stages of their technological development. The slope of their respective patent counts is much flatter in early 1980s than later years.

**Insert Table 4 and its Figures 1, 2, and 3 about here**

### 3.2 Industrial Concentration and Inventive Activities

Given the significant role of individuals and SMEs in inventive activities as reported by Amesse and associates (1991), it is unfortunate that innovations by individuals and SMEs have not attracted much attention (Chakrabarti, 1991). With a few exceptions (e.g., Amesse and associates, 1991), most researchers in the past have not included individual inventors and have focused only on large firms. Examples include, but not limited to, Niosi, 1996; Etemad and Seguin-Dulude, 1987; Patel 1996; Patel and Pavitt 1991. Based on complementary secondary information, it appears that, the density of individuals and SMEs' contribution to inventive activities are larger than generally reported, and especially larger in some countries than others, giving rise to the possibility of under-estimation of SMEs inventive activities and their technological impact in those countries. In our samples, S. Korea and Taiwan are two extreme examples of economies where their industrial structures are dominated respectively by larger and smaller firms. Thus, the examination of technological activities attributable to individuals and SMEs for these two NICs may indeed shed new lights on the reality of inventive activities in relation to industrial concentration.

*The role of individual inventors and SMEs.* In addition to inventions by the large firms, we have also examined patents attributable to the individual inventors or SME entrepreneurs through an experientially-based heuristic. When there is no assignee in a record of the *Patent Gazette*, it is generally assumed that the patent application may have been filed either by an individual inventor not employed by an established large firm or the owner/entrepreneur of a SME. This is mainly because individual inventors at the filing time may neither be prepared to "assign" (e.g., license their potential patent to someone else -- usually the "assignee") nor can they wait until such time that their plans for further exploration of patent (usually by the assignee) are better formulated (Etemad, Lee, 1999a). By examining the "*no assignee*" cases in patent applications at the time of filing, we calculated the "no assignee" rates.[12] That portion of patent applications with "*no assignee*" is used as a proxy to estimate the *share of patented inventions by individual inventors and SMEs* (Etemad and Lee, 1998).[13] This statistic allows us to reexamine the relationship between patenting and the industry structure for smaller firms (i.e., located at the low end of the concentration distribution) in different countries. Although some of these individual inventors may have worked for a firm in the past, they have filed for the invention in a personal capacity. Alternatively, they are mostly the owners/operators of small firms who customarily file their patent(s) under their own names. The exclusion of patents with "no assignees" leads to a systematic *under-estimation* of the innovative activities of individual inventors and smaller companies and naturally their inventive impact in their countries. Consistent with the hypothesis $\mathbf{H_2}$, the share of the patents held by private individual is usually larger in technological classes and countries where individuals and small firms play a greater role.

By calculating the share of inventive activities of individual inventors in the advanced industrialized countries, Malerba and Orsenigo (1996) reported the magnitude of the under-estimation. Their estimated shares (of patents held by individuals) were calculated over the total number of patents held by firms and based on transformed data from the European Patent Office (EPO) database from 1978 to 1991. They fell between one to three percent for

AICs examined: 2.5% for Germany, 2.52% for France, 2.10% for the UK, 2.88% for Italy, 1.09% for the USA and 1.49% for Japan.

*The no assignee cases.* Table 5 shows the long-term trend of "*no assignee" rate* for the 10-targeted countries (of this study) and for others. The no assignee rate calculated for other countries in U.S. patent databases are reported on the top of Table 5 as "Others." This rate has decreased by more than 40% from 15.5% in 1980 to 8.8% at the present[14] (see Etemad and Lee, 1999a and b, for further examination of this issue). It should be noted that about a quarter (24.98% in 1995) of total invention activities of U.S. can be attributed to SMEs or U.S. individual inventors. The fact that the patent records of U.S. residents have consistently had a higher "no assignee rate" than foreign inventors may be partly due to *higher* total patent application and maintenance costs for foreign individual inventors than those in the U.S. forcing them to further finalize their plans before filing. This higher costs may have inhibited them from filing and acted as a barrier to SMEs' eventual patenting in the USPTO. As expected, *S. Korea and Taiwan stand at the two opposite extreme cases* of "no assignee" rate for patents granted in U.S. till recently (7% and 42% in 2000) in our database. This significant difference confirms $\mathbf{H_2}$ at the low end of the concentration distribution (i.e., that the inventive contribution of SMEs' and individuals' in the two countries are very different). S. Korea had a very high no assignee rate in 1980 (77%), but it has steadily declined over time. S. Korea's present rate is comparable to Japan's – similar to the industrial structures of the two countries, which are respectively dominated by Chaebols and Keiretsus -- and also that of France's rates (6% in 1995 and 13% in 2000 in Table 5). The high no assignee rate of Canada (36% for 1995) may also reflect a combination of two factors at work: i) relatively low trans-border costs of patenting in U.S., and also, ii) a high presence of individual and SMEs in Canada as reported by Amesse and associates (1991) and Etemad and Lee (1999b). However, the consistently high "no assignee" rate of Taiwan over a long period time of 20 years (1980-2000) should be attributed only to the large presence of innovatively vigorous SMEs in Taiwan's industrial structure. These figures are further re-examined in the analysis of Industrial Concentrations below.

**Insert Table 5 about here**

*Industrial Concentration of S. Korea vs. Taiwan.* Table 6 and 7 examine industrial concentration for S. Korea and Taiwan. Table 6 shows that S. Korea has had a very heavy concentration of patenting activities by its large conglomerates -- chaebols. This concentration is extremely similar to their sales, as hypothesized by $\mathbf{H_{1a}}$. S. Korean government's intensive supports for large firms has made S. Korea a highly conducive environment for large firms' growth, dominance, and competition domestically and internationally. This suggests the S. Korean view that *"big is good."* As shown at the bottom of Table 6, the patent holding by the Top 4 business groups (C4) have increased dramatically from 8% in 1981-85 to 79% in 1996-2000. Furthermore, concentrated share of Korean patenting activities in U.S. by the four big chaebols -- Samsung, Hyundai, Daewoo, and Lucky-Goldstar (LG) groups -- has been even higher than the concentration of their total sales in the world. This conclusion remains valid even when concentrations of the Top 20 Korea firms (C20), ranked by *Asiaweek* in 1996, are examined. Simply stated, there is only a little Korean patenting activities in U.S. outside of the big four chaebols. These two measures of the inventive concentrations by very large firms (C4 and C20) are almost the same for S. Korea, pointing to a strong positive relationship between inventive activities, size and industrial concentration in S. Korea as hypothesized in $\mathbf{H_{1a}}$.

**Insert Table 6 about here**

Looking at the Taiwan's side of concentration in Tables 7 and 8 (one based on *Asiaweek* and the other based on *Tensha 1000*), it is evident that a totally different structure is at work. The Top 20 Taiwan firms, ranked on sales in 1996 by Asiaweek, have had very low patenting concentration (C20=3% in 1996-2000 and less than 4% over some 20 years -- 1976-2000) in the total patenting activities in U.S. This substantiates that patenting activities of the Top 20 firms are not consistent with their sales as hypothesized in $\mathbf{H_2}$. (in contrast to the S. Korean case). Nor are their concentration figures consistent when the basis of calculation are changed from assignee to inventor (that is to attribute a patent to its inventor as opposed to its assignee). Overall, there is a much higher concentration figure on assignee-basis than inventor-basis.[15] This discrepancy further confirms that these larger firms draw upon other smaller firms' inventive activities (i.e., inventive individuals and SMEs assign patents to larger firms).[16] The major reason is that the most of these big firms in Taiwan are domestically-oriented and without much exporting activities. The sole exception in the Top 4 is the Acer groups. The concentration of the Top 20 patenting (C20) on inventor basis reaches as high as 37% in 1976-2000, 44% in 1996-2000, and 18% in 1991-1995, while the share of their exports remain at about 8% of Taiwan's total exports in the past five years. The consistent pattern of the figures over time *clearly and significantly* confirms hypothesis $\mathbf{H_2}$.

**Insert Table 7 and 8 about here**

A combined and careful re-examination of Tables 5, 6, 7, and 8 yield a consistent picture. A major portion (i.e., about 70%) of S. Korea inventive activities are performed by the top four business groups. In contrast, the top 20 Taiwanese firms, regardless of the basis of sample formation and measurement, *can at most count* for no more than one-third of total inventive activities of Taiwan. Therefore, concentration figures ($C_4$ and $C_{20}$), reported on the bottom of

Tables 6, 7, and 8, confirm both hypothesis $\mathbf{H_1}$ and $\mathbf{H_2}$. Furthermore, the top 20 firms in both countries draw upon the inventive activities of smaller firms: to a *much smaller* extent in S. Korea and *much larger* extent in Taiwan (i.e., no assignee rate at 7% vs. 42%).

*Patenting activities of government R&D institutions*. The major patenting activities of government R&D institutions are shown in Table 9. The patent counts for major government labs in S. Korea have steadily increased from mere 11 patents in 1981-1985, to 26 in 1986-1990, on their way to about one hundred patents annually (e.g., 144 in 1991-1995, and to 372 in 1996-2000). Although their importance, as represented by large share of total patenting activities, was very high in the early stages (i.e., 11/48=23% in 1981-85), it has fallen to a mere 7% at the present time (372/13461=3% in 1996-2000). Obviously the R&D of the private firms has gradually overtaken them due to their explosive technological growth.

**Insert Table 9 about here**

Opposite trends can be seen in Taiwan's case. The share of patenting activities in U.S. were as low as 6/16=38% in 1981-1985. With a steadily increasing trendl a very high share at assignee basis of Taiwan's patenting activities come from the government R&D institutions. The government patenting activities in Taiwan appear under the names of two major institutions: Industrial Technology Research Institute -- ITRI (887 patent counts in 1976-2000) and the National Science Council -- NSC (433 in 1976-2000). It should be noted that the lower participation rate in patenting by large firms in Taiwan is somewhat compensated for by the higher participation rate at assignee basis (G4 at 70% in 1976-2000) of government institutions in Taiwan as most of these patents are eventually assigned to Taiwanese firms for further exploitation and commercialization.

## IV: CONCLUDING REMARKS

Although this paper is intended to be exploratory and analytically descriptive in nature, we have briefly discussed some methodological issues in the use of patenting as an internationally comparable technological indicator. We have analyzed patent statistics to present some *fresh empirical evidence* about the *higher* developmental path of the two Asian NICs' capabilities as compared to a base line of selected target countries including AICs and highly populated countries. A review of country profiles, in terms of related indicators, confirmed that the two selected mid-sized AIC, Canada and the Netherlands, were found to offer a more meaningful basis for comparison with the two mid-sized NICs, Taiwan and S. Korea, than other countries.

Taiwan's and S. Korea's patenting in U.S. point to a noticeable technological presence. They have progressed to the point of generating a significant volume of their own technologies over the past two decades. Their *exponential* progress portrays their technological capabilities, which have well surpassed beyond imitation, absorption and adaptation stages of technology transfer from the AICs. They have indeed entered into the stage of generating *world-class new technologies* of their own. Their annual patenting activities, both in term of "filed applications," and "patents granted," have fast marched into the list of top 10 patenting countries in the world and stand at the *same level of G7* countries in last five years. However, the annual growth of their inventive activities is and is *still increasing at much higher* than most G7 countries. Should this trend continue, they will dominate in certain industries worldwide. Their gains are mostly in specialized new high-technology fields, such as semiconductors and consumer electronics, which offer broad growth potentials. This *specialization* appears to have served them very well.

With regard to the structure of inventive activities, we used two measures: the "no assignee" rate and patenting concentration ratios. The "no assignee" rate is a proxy measures for the extent of individual's and SME's participation in inventive activities. S. Korea and Taiwan stand at the two opposite extremes of the *"no assignee rate"* (7% vs. 42% in 2000). S. Korea's no assignee rate started with a very high rate in 1980 (77%) but it has gradually declined and has recently achieved rates comparable to those of France's (i.e., 13% in 2000) and Japan's as her Chaebols become more mature. In contrast, the high and stable rates in Taiwan and Canada over a relatively long time period are indicative of a large presence of inventively vigorous SMEs in their respective economies and also a low cross-boarder costs of patenting abroad in U.S. for Canadian firms.

Consistent with the above, most of S. Korea's patenting are concentrated in the major four big S. Korean conglomerates. Samsung, Hyundai, Daewoo, and LG Goldstar groups account for 81% of Korean patents in 1996-2000. In contrast, the concentration rate of patenting activities of the top 20 big firms in Taiwan (based on two alternative sources) remained as low as 44% and 22% in 1996-2000. These very low rates of large firms' inventive activities are somewhat compensated for by the higher participation of SME's (as measured by the no assignee rates) and the government R&D laboratories. Unless the reliability and validity of long patent time-series are questioned, this quantitative evaluation of technological capability shows that these two Asian NICs have developed strong firm- and country-specific, cumulative, and differentiated technologies, which will undoubtedly further deepen as time marches on. In contrast to the negligible role of SMEs in S. Korea, Taiwan's SMEs play a more significant role in inventive activities. However, some of these activities are eventually assigned to the larger firm for further commercial exploitation. In other words, Taiwan's inventive environment is much more cooperative than that of S. Korea's (dominated by the Top 4 chaebols).

With respect to the interaction between industrial concentration, firm size and inventive activities, S. Korea and Taiwan seem to stand on the opposite sides of the spectrum: inventive activities are concentrated in the four large chaebols in S. Korea, while there is no evidence of concentration in Taiwan. Yet, they have both achieved levels of technology-generating capabilities comparable to highly industrialized countries. This implies that either there is no uniquely Asian model, or there are subtle relations in these economies that hard statistics, such as patents, are incapable of capturing.

Finally, this research has uncovered consistent evidence, which points toward noteworthy lessons: i) That inventive activities are the precursors of technological capabilities, which in turn support growth and development; ii) That specialization in technological activities holds a higher promise for attaining world-class competitiveness in those areas than otherwise; and iii) That world-class competitiveness is based on, and sustained by, genuinely new innovative activities (and corresponding patents) than other activities related to transfer of old technologies and technological capabilities. The former is the strategy that S. Korea and Taiwan (and the other two Asian NICs, to a lesser extent) have followed; while other developing countries appear to have fallen in the latter pattern in the past two decades or so. All aspiring countries need to re-examine the case of Asian NICs in general and role of their SMEs in particular to devise contextually (i.e., socially, culturally and politically) supportive structures for nurturing their various firms. Taiwan's successful reliance on small and medium-sized firms, as contrasted by large chaebols dominating in S. Korea, is testimonial to the potential viability of both models when they are consistent with their policy environments. However, the recent

Asian financial crisis, where S. Korea did not fair as well as Taiwan, may point to a higher flexibility resiliency of Taiwan's SME-based economy and un-concentrated economic structure. Smaller firm size and lower concentration, similar to that of Taiwan, are also more consistent with a typical developing country structures. For developing and aspiring countries, therefore, Taiwan's "model" appears to hold a higher potential.

## V: FINAL REMARKS

### 5.1 Some Case Studies of Some Specific Patent-Intensive Industries

Asian NICs' successes of building their technological capabilities have been well documented in various studies. There is a story of Korean approach to technological "learning and catching-up[1]" (Lim, 1999), which began from imitation to innovation (Kim, 1997) on the way to Asia's Next Giant (Amsden, 1992). The story of Taiwan is portrayed in series of field studies (Amsden & Chang 1992), which shows the micro-foundation (e.g. business history and personality) of 15 enterprises, in addition to the macro-aspect (e.g. government and culture) of Taiwan's economy. Wade's (1992) book rejected that these successes have resulted from the simple applications of both pure free market and pure government intervention. While they defy quantitative measurement, Lim (1999) show how institutional and organizational skills (organizational capability, Kogut, 1991) help the fast pace of learning and of upgrading technological capability and productivity in Korea.

Industry policies and strategic orientation of two frontier industries (keyboard and personal computer) as well as footwear industry were compared by field interviews (Levy & Kuo, 1991 and Levy, 1988). Furthermore, the successful innovative policies of East Asia are chosen as good lessens for other developing countries such as Argentine (Lall, 1999) to create their own

[1] His book title is *Technology and Productivity: Korea's Way of Learning and Catching Up*.

comparative strategy (Lall, 1995). All of these related literatures clearly point to the increasing openness of their environment for development of technological capabilities of Asia's NICs.

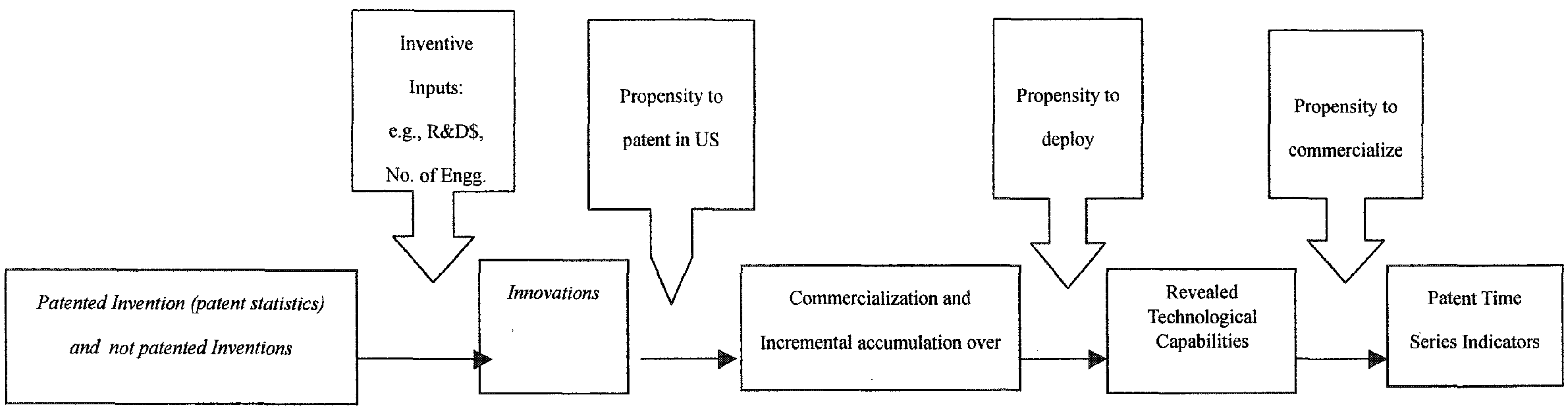
Our quantitative evidence should complement and triangulate their qualitative findings and answer the question of where their technological knowledge of national system of innovation has come from. Admitting that a case study can not meet the objectivity requirements of replicability and mathematical rigor, a MIS methodologist, Allen Lee (1989) maintains that the *detailed case studies* can potentially add great deal to our understaning of important MIS issues. With our quantitative evidence at hand, then, both Eisenhardt's (1989) and Yin's (1989) case study methodology by the deep fieldwork and survey may be even more helpful in building a better-grounded theory. After all, in methodology of non-false science (Popper, 1963) we argue strictly here that only the *systematically* designed *case studies* triangulated with costless quantitative evidence from full sampling of full databases, rather than the detailed MIS case studies (Lee, 1989) from arbitrary sample of one or few cases, could provide better understanding for building testable theories.

**5.2 Patenting Activities of Multinationals and Small Businesses**

High-tech industries (or super-technology) industries are highly dependent on innovation in science and technology (Medcof, 1999). International dispersion of technology units (Medcof, 1997) of multinationals has attracted considerable attention, which could be in large part of the multinationals' response to the globalization phenomenon. Under our newly design family of indicators, we have detected MNCs' and individual inventors' (of Taiwan or South Korea or other G7 countries) contributions to the overall globalization of technology, the full extent of which is needed to be further investigated in order to clarify stock or flow aspects of this trend. While Baldwin, Diverty and Sabourth (1995) Canadian survey shows that technology-oriented large firms have higher productivity, the small producers' performance of invention is still as clear as that of employment (Baldwin, 1996). In order to better understand patenting activity of SMEs and MNCs, we suggest a replication of Etemad's and Amesse's team papers (Etemad & Seguin-Dulude, 1987; Amess et al., 1991;) for Taiwan, South Korea, Canada and Netherlands once more, using new methods of data-mining into knowledge designed and introduced by this research for searching related patent databases on the Web directly, including USPTO, Canadian CIPO, Taiwan, Korea and the Netherlands' respective patent databases. European Patent Office website[2] provides links to 29 patent databases, 39 national patent offices, 31 patent information providers, 9 directories of patent attorneys, etc. European Work Council have also a databases of multinationals in Europe.

[2] Full list of patent-related databases around the world can be found at European Patent Office (2001) www.european-patent-office.org/online/index.htm#database accessed on Aug 10, 2001.

**Exhibit 1: Invention/deployment/commercialization flow**



## ENDNOTES

[1] Most AICs have had a longer tradition of industrial development. In contrast, newly industrializing countries such as Taiwan, Singapore, S. Korea have been agrarian economies prior to WWII. Yet they have achieved similar (or higher) levels of growth and development comparable to some AICs than in the last four decades. This intensified growth rates is making them much better candidates for studying technological capability which is known to cumulative over time.
[2] Although Hong Kong and Singapore are usually included in the set of the four Asian dynamic AICs, popularly referred to as the four Tigers or the four Dragons, the city-state nature of Hong Kong and Singapore made a *systematic* comparison difficult which forced this study to concentrate on S. Korea and Taiwan. Nevertheless, all information for all the four entities were collected, analyzed, but selectively presented.
[3] The longitudinal study of industrial concentration has been analyzed across the technological area, industry, and also at country levels.
[4] Meanwhile, the findings of this research should also facilitate the search for opportunities for cooperation in increasing competitiveness between mid-sized countries with different specialized technological capabilities, such as Taiwan and Canada.
[5] It is difficult to formulate operational definitions or theoretical criteria for comparison consistent with the overall environmental dynamics both the large countries and small countries.
[6] To give a sharper focus to the study, Taiwan and S. Korea (on the NIC side) are mainly compared with Canada and the Netherlands (on the AIC side) henceforth. But relevant information and discussion are selectively presented to preserve the context.
[7] We acknowledge that, it is a far stretch to use patent statistics as a proxy measure for technological capabilities as a whole; and even a farther stretch for country capability. This, therefore, narrows the scope. The limited scope of this paper excludes, for example, organizational as well as managerial capabilities. For this very reason, IMD competitive indicators that incorporate such capabilities were included in the initial comparison in Table 1. From a long-term perspective, however, cumulative patenting activities must reflect the impact of all these capabilities. Patent-time series is therefore the most preferred single statistic over others capturing most, if not all, these effects.
[8] The intermediating impact of conditions and circumstances which lead to, or are determinants of: (i) patenting, ii) deployment of a patented invention, iii) commercialization of the innovations, and iv) accumulation of innovation toward technological capability are ignored by most scholars. Although beyond this study, we explicitly recognize that at least 4 sets of propensities are involved in the theoretical link between accumulation (over time) of technological capabilities and patents as a measure of inventions. These propensities are highlighted in the above model (Exhibit 1). In the absence of any contrary evidence, one must assume that each set has similar values for countries in this preliminary study.
[9] The first period of compliation is done on Oct-Nov 1997, while we updated all possible tables to year 2000 in July 2001.
[10] These are countries with large populations. Except for Bangladesh, they are industrializing at a relatively fast pace. China has captured, and increases to capture, a larger market share in the U.S.; while India is following close behind. Therefore, there is no a-priori reason to assume that different propensity to patent in the U.S. is at work.
[11] This topic is examined in more detail elsewhere (Etemad and Lee, 1998a; and Etemad and Lee, 1998b).
[12] No assignee are the patent that its assignee field is not filled and left blank at the time that patent application was submitted to U.S. Patent and Trademark Office and then published as such in the official Patent Gazette.
[13] The "no assignee" rate is bound to underestimate the true share of individual inventors and SMEs,

because they may have simply assigned their invention to a firm, but it nevertheless provides a first level estimate.

[14] For a detailed discussion and analysis of "no assignee" rate, see Etemad and Lee (1998a and b).

[15] Inventions are usually assigned to the top 20 firms for purposed of deployment and commercialization, by other companies that are not in a position to push forward beyond inventing them (e.g., SMEs and individuals).

[16] For an extensive discussion of the difference in using a patent record on inventor or assignee basis. The former is an explicit measure of revealed inventive activities but does not necessarily point to all the efforts that transform the initial invention to a commercialized/used innovation. However, the latter is a much-closed indication of at least the intention to commercialize which is a better measure of incremental capabilities.

**TABLE 1**
**Background Profiles of Asian NICs and Selected AICs**

| | Italy | Canada | N'lands | Swiss | S.Korea | Taiwan | Hong Kong | Singapore |
|---|---|---|---|---|---|---|---|---|
| population(m) | 57.3 | 29.6 | 15.4 | 7.1 | 45 | 21 | 6.2 | 3.1 |
| GDP(PPP) ($b) | 1045 | 619 | 302 | 171 | 468 | 279 | 137 | 66 |
| per capita ($) | 18070 | 21268 | 17200 | 24483 | 10534 | 13235 | 22527 | 21493 |
| Export ($b) | 190 | 175 | 146 | 84.1 | 130 | 105 | 166 | 102 |
| propensity to export | 18.2% | 28.3% | 48.3% | 49.2% | 27.8% | 37.6% | 121.2% | 154.5% |
| IMD Mgt rank | 27 | 10 | 4 | 9 | 26 | 18 | 2 | 1 |
| IMD Sci &Tech rank | 35 | 9 | 12 | 5 | 22 | 10 | 18 | 8 |
| IMD R&D ($m) | 22378 | 12240 | 6968 | 6860 | 12383 | 5356 | na | 1070 |

*Data Sources: Asiaweek 1996, The Candian Global Almanc 1996, IMD(1997) World Competitiveness Yearbook*

*Remarks: population ratio of Asian NICs about 15:7:2:1; GDP size about 7:4:2:1; income per capita about 3:4:6:6.*

# TABLE 2
## Patenting of Top 10 Patent and Top 10 Population Countries in U.S.

| | *patents issued* | | | | * | | | | | | *patents filed* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1992** | **1993** | **1994** | **1995** | **1996*** | **1997** | **1998** | **1999** | **2000** | **Growth** | **1992** | **1993** | **1994** | **1995** | **1996** | **growth** |
| Total-US | 49968 | 47927 | 49149 | 49679 | 53531 | 55791 | 76012 | 75742 | 78766 | 6.4% | 79875 | 78029 | 96920 | 89940 | 89940 | 3.67% |
| Japan | 23481 | 22942 | 23764 | 22991 | 24355 | 24502 | 32553 | 32948 | 33412 | 5.0% | 38135 | 36148 | 36912 | 42944 | 39810 | 1.49% |
| German | 7960 | 7172 | 7024 | 6946 | 7545 | 7747 | 10206 | 10585 | 11597 | 5.4% | 10851 | 10550 | 11539 | 12421 | 11515 | 1.74% |
| France | 3332 | 3156 | 3051 | 2991 | 3250 | 3467 | 4320 | 4472 | 4621 | 4.5% | 4757 | 4554 | 4790 | 5389 | 4678 | 0.06% |
| UK | 2851 | 2462 | 2424 | 2642 | 2987 | 2829 | 3631 | 4307 | 4748 | 7.3% | 4537 | 4503 | 5104 | 5577 | 4804 | 2.00% |
| Canada | 2311 | 2198 | 2275 | 2535 | 2837 | 3064 | 3832 | 4001 | 4304 | 8.4% | 3975 | 4196 | 4638 | 5420 | 4893 | 5.81% |
| ***Taiwan*** | ***1195*** | ***1453*** | ***1709*** | ***2026*** | ***2477*** | ***2678*** | ***3912*** | ***4664*** | ***5976*** | ***22.7%*** | ***3370*** | ***3847*** | ***4729*** | ***4729*** | ***5108*** | ***11.27%*** |
| ***Korea, S.*** | ***543*** | ***789*** | ***941*** | ***1175*** | ***1603*** | ***2027*** | ***3429*** | ***3740*** | ***3561*** | ***28.2%*** | ***1444*** | ***1512*** | ***2177*** | ***2943*** | ***3932*** | ***29.37%*** |
| Italy | 1455 | 1452 | 1376 | 1273 | 1469 | 1530 | 1950 | 1815 | 2110 | 5.4% | 2345 | 2159 | 2160 | 2512 | 2152 | -1.48% |
| Switzerland | 1369 | 1193 | 1225 | 1236 | 1382 | 1407 | 1638 | 1706 | 1803 | 3.8% | 1839 | 1937 | 1922 | 2075 | 1639 | -2.12% |
| Sweden | 747 | 743 | 754 | 905 | 1043 | 1028 | 1468 | 1664 | 1905 | 13.2% | 1066 | 1162 | 1492 | 1674 | 1439 | 8.89% |
| Netherlands | 1019 | 961 | 944 | 929 | 1006 | 1034 | 1601 | 1631 | 1661 | 7.6% | 1579 | 1549 | 1727 | 1594 | 1727 | 2.56% |
| Autralia | 550 | 433 | 533 | 572 | 611 | 624 | 918 | 929 | 963 | 8.8% | 905 | 853 | 1078 | 1150 | 1090 | 5.52% |
| Belgium | 382 | 351 | 410 | 391 | 643 | 692 | 917 | 900 | 975 | 14.4% | 676 | 666 | 841 | 1080 | 900 | 9.14% |
| Austria | 424 | 320 | 337 | 356 | 418 | 438 | 500 | 596 | 672 | 6.8% | 563 | 507 | 637 | 684 | 532 | 0.21% |
| Denmark | 263 | 288 | 260 | 333 | 374 | 487 | 575 | 669 | 575 | 11.3% | 397 | 496 | 537 | 756 | 567 | 12.25% |
| Norway | 120 | 120 | 128 | 142 | 163 | 175 | 263 | 275 | 306 | 13.2% | 198 | 198 | 196 | 251 | 244 | 6.07% |
| Russia | 0 | 2 | 22 | 90 | 22 | 8 | 8 | 5 | 5 | n.a. | 177 | 185 | 222 | 247 | 246 | 8.84% |
| Brazil | 55 | 58 | 57 | 66 | 88 | 84 | 106 | 133 | 136 | 12.8% | 115 | 106 | 161 | 130 | 136 | 7.36% |
| China | 50 | 58 | 41 | 69 | 78 | 103 | 133 | 172 | 274 | 27.2% | 133 | 124 | 114 | 151 | 256 | 21.79% |
| India | 23 | 21 | 33 | 39 | 62 | 73 | 130 | 156 | 184 | 32.4% | 56 | 54 | 64 | 98 | 105 | 18.80% |
| Indonesia | 6 | 7 | 9 | 8 | 5 | 15 | 17 | 12 | 20 | 30.9% | 15 | 11 | 5 | 7 | 22 | 43.27% |
| Pakistan | 1 | 0 | 1 | 2 | 4 | 1 | 4 | 2 | 6 | n.a. | 5 | 0 | 1 | 3 | 1 | n.a. |

*data dource: 1996 Annual Report of USPTO; after 1996 updated at www.uspto.gov accessed July 21,2001.*

* This column means the search result based on inventor basis. There will a little difference from assgnee basis.

**TABLE 3**

**Long March of Asian NICs: GDP vesus Patent Counts from 1980-2000**

| Country | 1980 | 1985 | 1990 | 1995 | 2000 | 95GDP |
|---|---|---|---|---|---|---|
| Taiwan | 78 | 202 | 872 | 2143 | 5978 | 279 |
| Korea | 13 | 50 | 295 | 1265 | 3561 | 488 |
| Italy | 861 | 1031 | 1555 | 1334 | 2110 | 1049 |
| Canada | 1260 | 1502 | 2195 | 2589 | 4307 | 619 |
| Nlands | 709 | 1336 | 1841 | 996 | 1661 | 302 |

*data source: USPTO and this study* *unit: patent counts*

*remarks: based on resident country or nationality of inventor; GDP(US$b)*

**Figure 1 of Table 3**

**The Long March of Asian NICs: GDP and Number of Patents for 1980 to 2000**

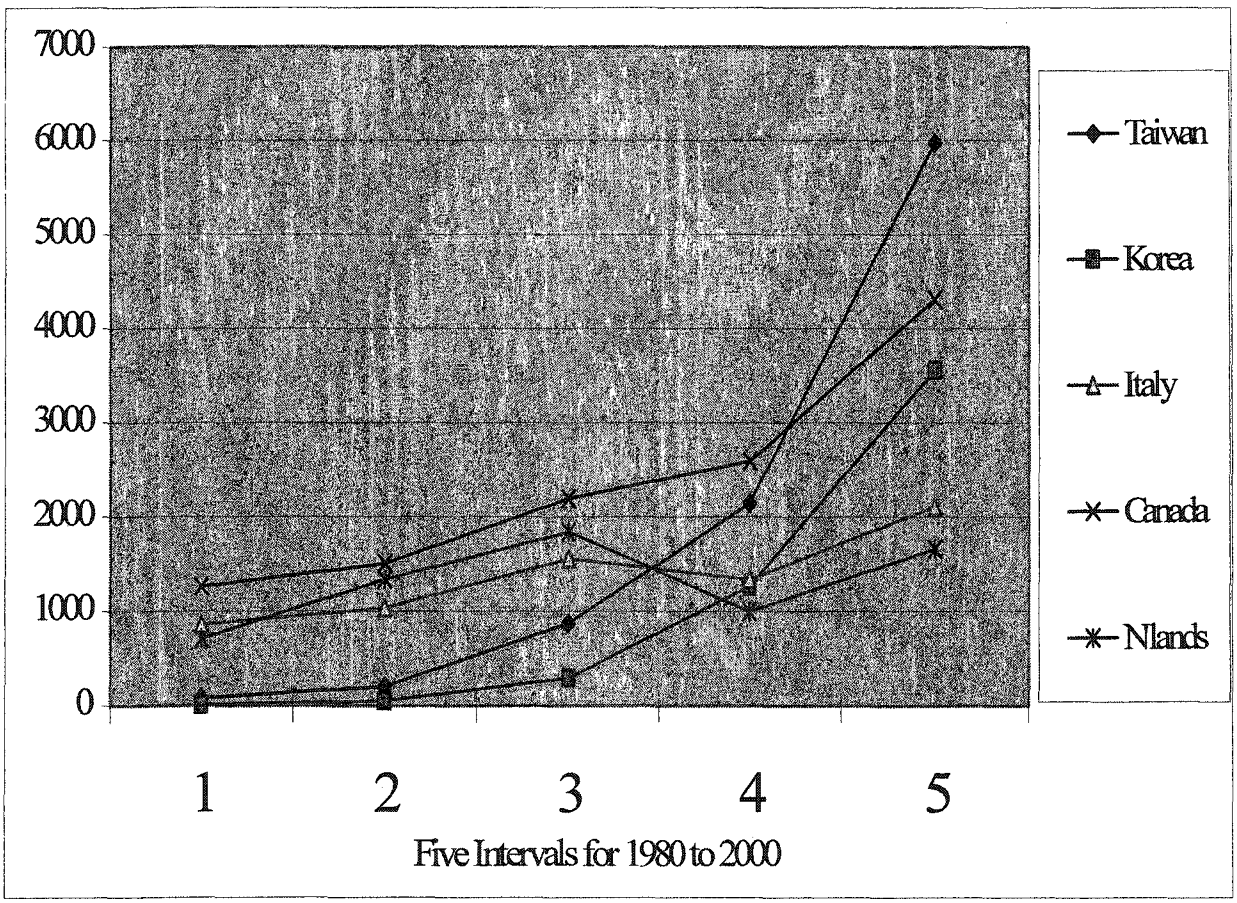


TABLE 4

Log Transfromation of Patent Counts and GDP in 1995

| County | 1995 GDP | 1995 patent# | logGDP | LogPat# | County | 1995 GDP | 1995 patent# | logGDP | logPat# |
|---|---|---|---|---|---|---|---|---|---|
| US | 6738 | 55739 | 6.83 | 4.75 | Russia | 754 | 90 | 5.88 | 1.95 |
| Japan | 2662 | 22991 | 6.43 | 4.36 | Brazil | 921 | 66 | 5.96 | 1.82 |
| Germany | 1643 | 6946 | 6.22 | 3.84 | China | 3172 | 51 | 6.50 | 1.71 |
| France | 1127 | 2991 | 6.05 | 3.48 | India | 1180 | 39 | 6.07 | 1.59 |
| UK | 1054 | 2642 | 6.02 | 3.42 | Indonesia | 651 | 8 | 5.81 | 0.90 |
| Italy | 1045 | 1273 | 6.02 | 3.10 | Pakistan | 281 | 2 | 5.45 | 0.30 |
| Canada | 619 | 2535 | 5.79 | 3.40 | Bangladesh | 151 | 0 | 5.18 | 0.00 |
| N'lands | 302 | 929 | 5.48 | 2.97 | Thailand | 405 | 10 | 5.61 | 1.00 |
| Swi'land | 171 | 1236 | 5.23 | 3.09 | Malaysia | 171 | 11 | 5.23 | 1.04 |
| Sweden | 154 | 905 | 5.19 | 2.96 | Mexico | 650 | 53 | 5.81 | 1.72 |
| Australia | 340 | 572 | 5.53 | 2.76 | Skorea | ***488*** | ***1175*** | ***5.69*** | ***3.07*** |
| Austria | 134 | 336 | 5.13 | 2.53 | Taiwan | ***279*** | ***2026*** | ***5.45*** | ***3.31*** |
| Turkey | 330 | 3 | 5.52 | 0.48 | Hong Kong | ***137*** | ***238*** | ***5.14*** | ***2.38*** |
| *data sources: Asiaweek and this study* | | | | | Singapore | ***66*** | ***53*** | ***4.82*** | ***1.72*** |
| *G7&OECD* | interce | slope | -4.67 | 1.35 | *P10* | interce | slope | -6.04 | 0.45 |
| | | | | | *Asian NICs* | interpc | slope | -6.59 | 1.75 |

**Log Patent Counts and Log GDP for G7 and OECD Countries**

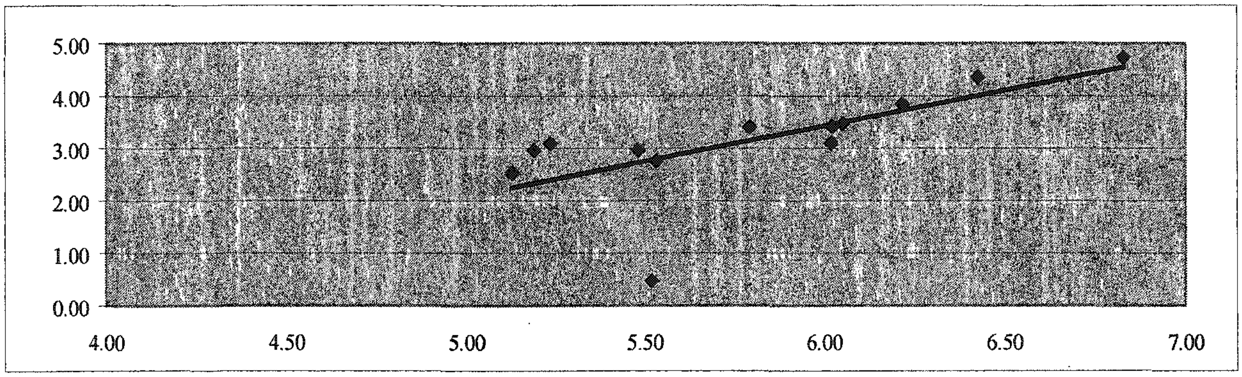



**Figure 2 of Table 4**
**Log Patent Counts and Log GDP for 4 Asian Newly Industrialized Countries**

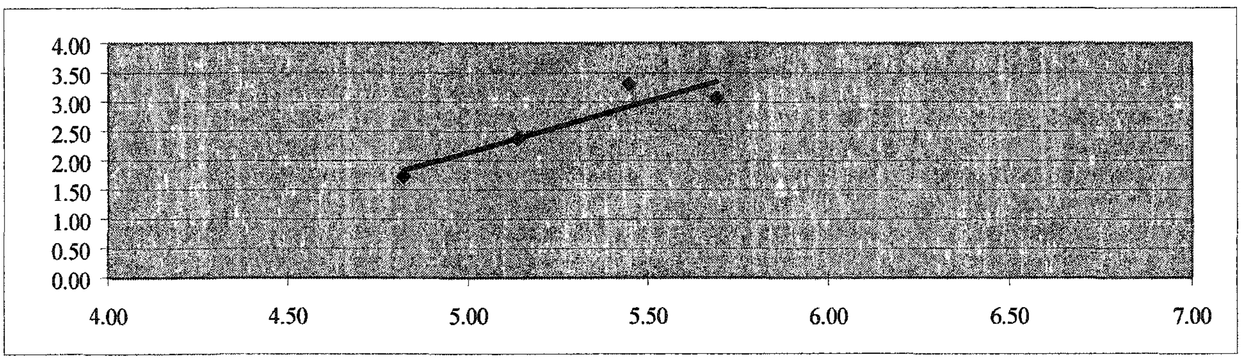



**Figure 3 of Table 4**
**Log Patent Counts and Log GDP for Highly Populated Developing Countries**

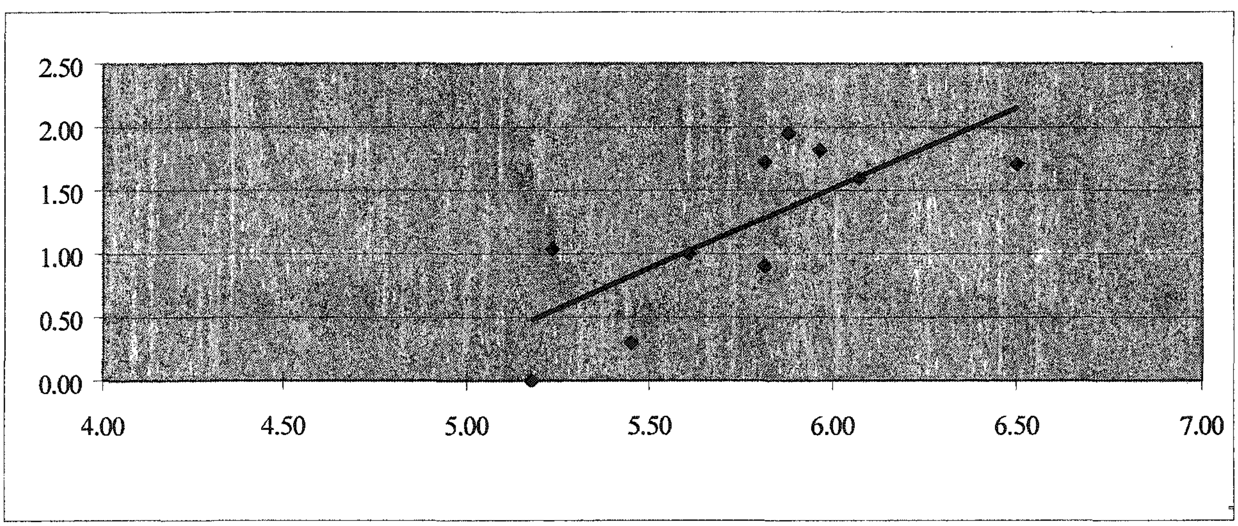


**TABLE 5**
**No Assignee Rates of the Top 10 Patent Countries**

| x* | 2000no% | 967no% | 95 no% | 90no% | 85no% | 80no% |
|---|---|---|---|---|---|---|
| others | n.a | 8.81% | 10.36% | 11.20% | 11.18% | 15.49% |
| US | n.a. | 23.43% | 24.98% | 27.31% | 23.68% | 27.58% |
| Taiwan (tw) | 42.0% | 57.77% | 61.78% | 79.36% | 89.11% | 87.18% |
| S Korea(kr) | 7.4% | 5.76% | 9.41% | 22.37% | 54.00% | 76.92% |
| Canada(ca) | 32.5% | 33.09% | 36.08% | 37.72% | 32.96% | 39.21% |
| Nlands(nl) | 16.3% | 6.95% | 7.23% | 8.01% | 8.96% | 9.87% |
| Japan(jp) | 2.4% | 1.68% | 1.91% | 2.82% | 3.49% | 5.83% |
| Germany(de) | 12.6% | 7.46% | 7.16% | 10.18% | 10.23% | 10.82% |
| French(fr) | 12.9% | 6.08% | 6.97% | 9.87% | 11.35% | 13.58% |
| UK(gb*) | 23.1% | 8.93% | 9.96% | 10.32% | 10.76% | 11.59% |
| Italy(it) | 20.7% | 9.07% | 10.19% | 13.76% | 16.10% | 23.58% |

**No Assignee Patent Cases** unit: patent count

| x* | 2000# | 967# | 95# | 90# | 85# | 80# |
|---|---|---|---|---|---|---|
| others | n.a.* | 8924 | 5258 | 5247 | 3821 | 3991 |
| US | n.a.* | 30662 | 16295 | 14588 | 10335 | 11245 |
| Taiwan (tw) | 2511 | 2704 | 1324 | 692 | 180 | 68 |
| S Korea(kr) | 264 | 190 | 119 | 66 | 27 | 10 |
| Canada(ca) | 1398 | 1808 | 934 | 828 | 495 | 494 |
| Nlands(nl) | 271 | 130 | 72 | 90 | 78 | 70 |
| Japan(jp) | 795 | 758 | 443 | 589 | 468 | 434 |
| Germany(de) | 1464 | 1049 | 516 | 821 | 713 | 647 |
| French(fr) | 596 | 376 | 223 | 315 | 292 | 300 |
| UK(gb*) | 1095 | 534 | 297 | 328 | 292 | 297 |
| Italy(it) | 437 | 259 | 136 | 214 | 166 | 203 |

**Tatal Patent Case of This Country** unit: patent count

| x* | 2000 | 967 | 95 | 90 | 85 | 80 |
|---|---|---|---|---|---|---|
| others | 97584 | 101254 | 50741 | 46869 | 34167 | 25773 |
| US | 78766 | 130858 | 65235 | 53414 | 43647 | 40769 |
| Taiwan (tw) | 5978 | 4681 | 2143 | 872 | 202 | 78 |
| S Korea(kr) | 3561 | 3299 | 1265 | 295 | 50 | 13 |
| Canada(ca) | 4304 | 5464 | 2589 | 2195 | 1502 | 1260 |
| Nlands(nl) | 1661 | 1871 | 996 | 1124 | 871 | 709 |
| Japan(jp) | 33412 | 45118 | 23142 | 20852 | 13399 | 7438 |
| Germany(de) | 11594 | 14057 | 7206 | 8065 | 6971 | 5981 |
| French(fr) | 4621 | 6184 | 3201 | 3190 | 2572 | 2209 |
| UK(gb*) | 4745 | 5982 | 2981 | 3177 | 2713 | 2563 |
| Italy(it) | 2110 | 2855 | 1334 | 1555 | 1031 | 861 |

*data source: USPTO and this study* *no% denotes no assignee rate*

*Remarks:* *1. Patent# and its no assignee rate%*

*2. Year 2000 data cannot be updated due to USPTO close wildcard (*) search engine.*

3. 96-97 data is searched in our data compiing preriod of Oct-Nov 1997.

## TABLE 6
## The Technological Concentration of S. Korea

| | | *S. Korea Top 20* | *US$m* | *patent counts* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rk | Rk2 | Company | 96sales | 76-00 | 96-00 | 91-95 | 86-90 | 81-85 | 76-80 | | Biz type |
| 3 | 37 | SamSung Electronics | 20991 | * | * | * | * | * | * | * | Electronics, appliance |
| 6 | 75 | HyunDai Motor | 13405 | * | * | * | * | * | * | * | Cars |
| 10 | 136 | LG Electronics | 8547 | * | * | * | * | * | * | * | Consumer electronics |
| 13 | 168 | HyunDai Motor | 6873 | * | * | * | * | * | * | * | car dealership |
| 15 | 215 | LG Caltex Oil | 5778 | * | * | * | * | * | * | * | oil refining |
| 17 | 254 | DaeWoo Heavy | 5138 | * | * | * | * | * | * | * | Shipbuilding, machinery |
| 18 | 259 | HyunDai Heavy | 5070 | * | * | * | * | * | * | * | Shipbuilding, machinery |
| 19 | 260 | HyunDai Electronics | 5059 | * | * | * | * | * | * | * | Consumer electronics |
| 20 | 263 | HyunDai Eng& Cons | 4988 | * | * | * | * | * | * | * | Construction |
| 1 | 32 | SamSung Co. | 24964 | 9918 | 6152 | 3533 | 226 | 7 | 0 | * | Trading, invesment |
| 2 | 36 | HyunDai Corp | 21708 | 1871 | 1560 | 301 | 10 | 0 | 0 | * | Trading, invesment |
| 4 | 41 | DaeWoo Corp | 19480 | 2048 | 1954 | 82 | 10 | 2 | 0 | * | Trading, invesment |
| 5 | 74 | LG Intl | 13546 | 1207 | 1202 | 4 | 1 | 0 | 0 | * | trading, invesment |
| 7 | 81 | Korea Electric | 12984 | 25 | 23 | 2 | 0 | 0 | 0 | | power generation |
| 8 | 109 | PoHang Iron | 11206 | 50 | 40 | 10 | 0 | 0 | 0 | | steel |
| 9 | 135 | YuKong Ltd | 8549 | 33 | 27 | 6 | 0 | 0 | 0 | | oil refining, exploration |
| 11 | 140 | Korea Telecom | 8465 | 182 | 182 | 0 | 0 | 0 | 0 | | telecom |
| 12 | 156 | Kia Motors | 7376 | 70 | 62 | 5 | 3 | 0 | 0 | | cars, trucks |
| 14 | 171 | SsangYong Corp | 6800 | 1 | 1 | 1 | 0 | 0 | 0 | | trading |
| 16 | 246 | SunkYong Ltd | 5246 | 20 | 13 | 7 | 0 | 0 | 0 | | trading, oil |
| | | Sub for 4 chaebols | | 12007 | 10584 | 1267 | 152 | 4 | 0 | * | |
| | | Subtoal(net) | 216173 | 12389 | 10932 | 1298 | 155 | 4 | 0 | | |
| | | all Korea assignees | | 17686 | 13461 | 3690 | 485 | 48 | 2 | | |
| | | *C4 (%)* | | *67.9%* | *78.6%* | *34.3%* | *31.3%* | *8.3%* | *0.0%* | | |
| | | *C20(%) or C11(%)* | | *70.0%* | *81.2%* | *35.2%* | *32.0%* | *8.3%* | *0.0%* | | |

*data sources: Asiaweek and this study*

*remarks: Rk denotes ranking in S Korea; Rk2 denotes ranking in Asiaweek's Top 1000 firms;*

** denotes its value is included in its business group due to M&A or other reasons.*

## TABLE 7
## The Technological Concentration of Taiwan Top 20 Based on Asiaweek 1000

***Taiwan 20*** ***US$million patent counts***

| Rk | Rk2 | Company | 96sales | 76-00 | 96-00 | 91-95 | 86-90 | 81-85 | 76-80 | | Buisness type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 87 | Chinese Petro | 12413 | 15 | 8 | 4 | 3 | 0 | 0 | | oil refining, explor |
| 2 | 137 | Taiwan Power | 8542 | 0 | 0 | 0 | 0 | 0 | 0 | | power generation |
| 3 | 207 | ChungHwa Teleco | 5937 | 0 | 0 | na | Na | na | na | | Telecom |
| 4 | 221 | Acer(all) | 5702 | 338 | 271 | 57 | 10 | 0 | na | * | PC &Info |
| 5 | 330 | Nan Ya Plastics | 3992 | 7 | 6 | 1 | 0 | 0 | 0 | | Petrochemicals |
| 6 | 336 | Taiwan Tobacco | 3927 | 0 | 0 | 0 | 0 | 0 | 0 | | tobacco, wine |
| 7 | 387 | China Steel | 3356 | 18 | 2 | 8 | 7 | 1 | 0 | | Steel |
| 8 | 537 | Ho Tai Motor | 2530 | 0 | 0 | 0 | 0 | 0 | 0 | | car dealership |
| 9 | 582 | President Enter | 2338 | 0 | 0 | 0 | 0 | 0 | 0 | | drinks, food |
| 10 | 778 | China Airlines | 1781 | 0 | 0 | 0 | 0 | 0 | 0 | | Airlines |
| 11 | 780 | Ford LioHo Motor | 1777 | 0 | 0 | 0 | 0 | 0 | 0 | | Cars |
| 12 | 830 | Formosa Plastics | 1651 | 0 | 0 | 0 | 0 | 0 | 0 | | Plastics |
| 13 | 891 | TaTung | 1542 | 39 | 7 | 18 | 14 | 0 | 0 | | Consumer electro |
| 14 | 901 | China Motor | 1529 | 1 | 1 | 0 | 0 | 0 | 0 | | Cars |
| 15 | 903 | Formosa Chem F | 1526 | 0 | 0 | 0 | 0 | 0 | 0 | | Textiles |
| 16 | 921 | Chi Mei Industry | 1478 | 8 | 6 | 2 | 0 | 0 | 0 | | Plastics |
| 17 | 959 | SanYang Industry | 1401 | 1 | 1 | 0 | 0 | 0 | 0 | | cars, motorcycles |
| 18 | na | Hualon | 1301 | 9 | 3 | 6 | 0 | 0 | 0 | * | Textiles |
| 19 | na | Far Eastern Textile | 1293 | 3 | 3 | 0 | 0 | 0 | 0 | | textiles |
| 20 | na | Taiwan Sugar | 1201 | 2 | 2 | 0 | 0 | 0 | 0 | | sugar, food |
| | | Total | 65217 | 441 | 310 | 96 | 34 | 1 | 0 | | |
| | | total assignee | | 12504 | 9746 | 2240 | 445 | 53 | 20 | | |
| | | *C20%* | | *3.5%* | *3.2%* | *4.3%* | *7.6%* | *1.9%* | *0.0%* | | |

*data sources: Asiaweek 1000, Tensha 1000, USPTO and this study*

*Remarks: Rk denotes ranking in Taiwan Tensha 1000; Rk2 denotes ranking in Asiaweek's Top 1000 firms;*

** denotes its valuie is included in its business group.*

## TABLE 8
## The Technological Concentration of Taiwan Based on Tensha 1000

***NT$100m patent counts*** ***US$m***

| Rk | Company | 96sales | 76-00 | 96-00 | 91-95 | 86-90 | 81-85 | 76-80 | R | Biz type | 95export |
|---|---|---|---|---|---|---|---|---|---|---|---|
| * | Acer Inc | 575 | * | * | * | * | * | * | * | info and comm | 1775 |
| 1 | United Micro | 225 | 1418 | 1204 | 213 | 1 | na | Na | | electronic | 284 |
| 2 | Taiwan Semicond | 394 | 1150 | 1095 | 54 | 1 | na | Na | | electronic | 570 |
| 3 | Hon Hai Precision | 137 | 787 | 786 | 1 | na | na | Na | | info and comm | 149 |
| 4 | Winbond | 118 | 351 | 328 | 23 | 0 | na | Na | | electronic | 313 |
| 5 | Acer Peripherals | 274 | 338 | 271 | 57 | 10 | 0 | Na | * | info and comm | 287 |
| 6 | Mosel Vitel | 108 | 192 | 187 | 5 | na | na | Na | | electronic | 397 |
| 7 | Compal Electron | 198 | 68 | 61 | 7 | 0 | na | Na | | info and comm | 248 |
| 8 | Delta Electronics | 114 | 51 | 44 | 5 | 2 | na | Na | | electronics | 339 |
| 9 | Inventec | 435 | 39 | 39 | 0 | 0 | 0 | 0 | | info and comm | 380 |
| 10 | China Petrochem | 115 | 38 | 38 | 0 | 0 | 0 | 0 | | chemicals | 0 |
| 11 | Chung Hwa Pict | 250 | 46 | 27 | 19 | 0 | 0 | Na | | electronic | 381 |
| 12 | Quanta Computer | 175 | 16 | 11 | 2 | 3 | na | Na | | info and comm | 299 |
| 13 | Twinhead Intl | 141 | 10 | 10 | 0 | na | na | Na | | info and comm | 311 |
| 14 | Chinese Petroleum | 3249 | 17 | 9 | 4 | 4 | 0 | 0 | | petroleum | 0 |
| 15 | Mitac Intl | 125 | 13 | 9 | 4 | 0 | na | Na | | info and comm | 266 |
| 16 | First Intl | 277 | 9 | 9 | 0 | na | na | Na | | info and comm | 626 |
| 17 | Mag Tech | 160 | 9 | 9 | 0 | 0 | 0 | 0 | | info and comm | 334 |
| 18 | Tatung | 388 | 39 | 7 | 18 | 14 | 0 | 0 | | electronic | 781 |
| 19 | Nan Ya Plastics | 889 | 7 | 6 | 1 | 0 | 0 | 0 | | plastics | 966 |
| 20 | Chi Mei Corp | 344 | 8 | 6 | 2 | 0 | 0 | 0 | | plastics | 1047 |
| | Chuntex Elctronic | 170 | 5 | 5 | 0 | 0 | na | Na | | info and comm | 345 |
| | Kinpo Eletronic | 136 | 4 | 4 | 0 | 0 | | | | electronic | 508 |
| | Hualon | 289 | 9 | 3 | 6 | 0 | 0 | 0 | | textile | 212 |
| | Far Eastern Textil | 290 | 3 | 3 | 0 | 0 | 0 | 0 | | textile | 600 |
| | China Steel | 7856 | 17 | 2 | 8 | 7 | na | Na | | steel | 2 |
| | Taiwan Sugar | 318 | 2 | 2 | 0 | 0 | 0 | 0 | | food | 0 |
| | Formosa Fiber | 417 | 0 | 0 | 0 | 0 | 0 | 0 | | textile | 254 |
| | Pacific Wire | 143 | 0 | 0 | 0 | 0 | 0 | 0 | | electronic | 303 |
| | Tainan Spinning | 119 | 0 | 0 | 0 | 0 | 0 | 0 | | textile | 198 |
| | Formosa Plastics | 363 | 0 | 0 | 0 | 0 | 0 | 0 | | plastics | 182 |
| | ITRI | na | 1353 | 889 | 463 | 1 | 0 | 0 | | govt lab | na |
| | top 4 | 1331 | 3355 | 3413 | 268 | 2 | 0 | 0 | | | 2778 |
| | top 20 | 8347 | 4598 | 4239 | 413 | 35 | 0 | 0 | | | 8706 |
| | total assignee | | 12504 | 9746 | 2240 | 445 | 53 | 20 | | | 105000 |
| | **C4 % on assignee** | | **26.8%** | **35.0%** | **12%** | **0.4%** | **0%** | **0%** | | | **2.6%** |
| | **C20% assignee** | | **36.8%** | **43.5%** | **18%** | **7.9%** | **0%** | **0%** | | | **8.3%** |
| | total inventor | | 31158 | 19709 | 7907 | 2812 | 595 | 135 | | | |
| | **C20% on inventor** | | **14.8%** | **21.5%** | **5.2%** | **1.2%** | **0%** | **0%** | | | |

*data sources: Asiaweek and this study*

*remarks: Rk denotes ranking in Taiwan Patent in US;96 sales and 95 export from Tensha's Top 1000 firms;*

** denotes its value is included in its business group.*

** Acer group including Texas Instrument and Acer Inc (JV) 110.*

**Table 9: The Patenting Activities of Government R&D of S. Korea and Taiwan**

| S. Korea | 76-00 | 96-00 | 91-95 | 86-90 | 81-85 | 76-80 | **G4 full name** |
|---|---|---|---|---|---|---|---|
| KIST | 269 | 179 | 87 | 1 | 2 | 0 | Korea Institute of Science and Technology |
| KAIST | 135 | 90 | 17 | 19 | 9 | 0 | Korea Advanced Institute of Science and Technology |
| ETRI | 3 | 1 | 1 | 1 | 0 | 0 | Electronic and Telecommunication Research Insitute |
| KRICT | 136 | 98 | 34 | 4 | 0 | 0 | Korea Research Institute of Chemical Technology |
| Universities | 10 | 4 | 5 | 1 | 0 | 0 | |
| total Gvert | 553 | 372 | 144 | 26 | 11 | 0 | |
| Sub assignee | 7384 | 13461 | 3690 | 485 | 48 | 2 | |
| ***G%*** | ***7.5%*** | ***2.8%*** | ***3.9%*** | ***5.4%*** | ***23%*** | ***0.0%*** | |
| G4 sub | 543 | 368 | 139 | 25 | 11 | 0 | |
| G4% | 7.4% | 2.7% | 3.8% | 5.2% | 22.9% | 0.0% | |
| **Taiwan** | **76-00** | **96-00** | **91-95** | **86-90** | **81-85** | **76-80** | **G4 full name** |
| ITRI | 1435 | 887 | 463 | 78 | 6 | 1 | Industrial Research Technology Insititute |
| NSC | 433 | 335 | 87 | 11 | 0 | 0 | National Science Council |
| Chung-Shan | 21 | 18 | 1 | 2 | 0 | 0 | Chung-Shan Institute of Sicence and Technology |
| China Textil | 24 | 14 | 10 | 0 | 0 | 0 | China Textitle Insitute (Taiwan) |
| InsOccup | 10 | 10 | 0 | 0 | 0 | 0 | Inst-Occupa-Health |
| Universities | 7 | 3 | 4 | 0 | 0 | 0 | |
| Total Gvert | 1930 | 1267 | 565 | 91 | 6 | 1 | |
| Sub assignee | 2736 | 1841 | 713 | 161 | 16 | 5 | |
| ***G%*** | ***71%*** | ***69%*** | ***79%*** | ***57%*** | ***38%*** | ***20%*** | |
| G4 subl | 1296 | 623 | 575 | 91 | 6 | 1 | |
| G4% | 69.9% | 68.1% | 78.7% | 56.5% | 37.5% | 20.0% | |

*data sources: U.S.PTO data bases and this study.*

*Reamrks: G4 denotes the group of top 4.*

# CHAPTER 4: ESSAY NO.3

## THE INHERENT COMPLEXITIES OF REVEALED TECHNOLOGICAL ADVANTAGE

### ABSTRACT

Using U.S. patent statistics over a period of seven years as technology indicators and the frequently used index of technological specialization, the Revealed Technological Advantage (RTA), this paper first examines the various properties of the RTA. Inherent complexities and inconsistencies, mainly due to different operationalization modes of RTA (e.g., using inventor-based or assignee-based patent information to operationalize RTA) appear to yield inconsistent results. The paper then applies the two operationalization-versions of RTA to three different samples across four fast developing countries in order to both assess RTA behaviour and compare the results. It further examines the technological position and specialization of the two midsized Asian newly industrialized countries (NICs), S. Korea and Taiwan, within the context of similarly oriented industrialized countries, Canada and the Netherlands. The results are in sharp contrast with those reported by the U.S. National Science Foundation Report (1996), and also point strongly to a pattern of large accumulated technological capabilities, as well as specialization, over time for the two Asian NICs. These specialized capabilities appear to be a source of their strong economic and trade performance. *(Keywords: revealed technology (RTA), technological capabilities, technological specialization, patent statistics, Asian Newly Industrialized Countries (NICs), comparative technological positions of Taiwan, and South Korea, comparative technological position of Canada and the Netherlands.).*

# I: INTRODUCTION

The topics of competitiveness in general and technological advantage in particular, as potent means for growth and development, have occupied the centre stage for sometime. Revealed Technological Advantage (RTA) is a much used index to measure cumulative technological achievements as a requisite precondition for attaining innovation- and technology-based world-class competitiveness later (Amendola, Guerrieri, and Padaon, 1992; Amendola, Dosi, and Papagani, 1993). The revealed technological advantage is, however, based on patent statistics. Although one of the most reliable indicators of invention (Griliches, 1990), patent statistics have some shortcomings of their own. Not all inventions, for example, are patentable or patented. Some inventions remain as industrial secrets. Variations in propensities (Scherer, 1983) to patent (e.g., due to size of institutions, different industries and different countries of origins) also impact patent statistics. Against all these shortcomings, patents are the *only tangible* and *comparable* measure of technological advantage (Soete and Wyatte, 1983) and innovative *output*, while other most frequently used measures are measures of various inputs to the technological processes or inventive activities (Basberg, 1982 and 1987; Bell and Pavitt, 1995). In turn, patents -- as inputs -- impact RTA calculations and results.

The above shortcomings not withstanding, the patent records of the U.S. Patent and Trade Mark Office (USPTO) are the most consistent, the most reliable and the most unified measure of inventive output over time (Griliches, 1990; Grupp, 1995). R&D expenditure as well as a number of scientists, engineers and technicians are measures of input and their relationship with output -- i.e., innovative discoveries -- is at best tenuous (Mansfield, 1988). This relationship becomes even less reliable (Chakrabarti, 1991) in a comparative cross-country, cross-industry, and cross-technology studies within the prevailing globalized environment of inventive activities (Archibugi and Michie, 1995).

One of the salient features of a patent application is its blindness to a patent's "citizenship," which at times causes difficulty for researchers and analysts alike. When a patent has to be attributed to a country, two primary addresses can be used to serve the purpose: the address of the "inventor" and the address of the "assignee." Although all patent applications must have an inventor, they may not have an assignee. In some cases the assignee's country of residence is different from that of the inventor. In such cases, the question of *a basis for attribution* of an invention to a country poses some problems.

To illustrate, let us consider a permeable case (Kogut, 1991) in which invention-innovation-commercialization process spans across two countries: A and B. Let us assume that the process assigns a patent to an agent in Country B, called "assignee" here. This assignee (in Country B) pushes successfully the patent (with its foreign "inventor" in Country A) through the innovation, commercialization, and even international trade cycle. For the purposes of attribution, the patent in the above case is the revealed manifestation of the original inventive activities in Country A. It is, however, successfully commercialized in Country B, and becomes a potential source for generating wealth, trade, and relative competitiveness for and from Country B -- mainly due to the efforts of the assignee.

One can easily argue that the above patent should be attributed to its inventor's origin (i.e., Country A) for measuring inventive activities, and for inventive sake; and naturally, if RTA is to measure inventive capacity (or capability), it should be calculated on the information regarding the inventor(s)' country of residence (called the "*inventor-basis*" here). However, if RTA is to measure the existence of preconditions (or accumulation of specialized technological capabilities) for value creation through production and the consequent trade and competitiveness, the information based on the assignee(s)' country of residence (called the *"assignee-basis"* here) should be used to reflect the true reality. Because, in the absence of an enterprising assignee, there is no clear indication whether or not the initial patent would not remain idle. It is only the latter case that is consistent with other established measures of advantage, such as the Revealed Comparative Advantage -- RCA (Balassa, 1965) and the Revealed Production Advantage -- RPA (Cantwell, 1989 and 1992; Soete, 1980 & 1987). Theoretically, both of the above measure should exhibit high correlation with RTA calculated on the assignee-basis. Thus the indiscriminate use of patent-related information, as it may lead to inconsistencies, if not serious distortions unbeknown to users, should be avoided at all costs.

The primary objectives of this paper are therefore two fold: i) to explore RTA's characteristics in general; and ii) examine it for known cases on both the inventor- and the assignee-basis.[1] The secondary objective and a by-product of this paper's analysis is an assessment of several *fast-developing countries'* cumulative technological capabilities and specialization over time.

Specifically, after this introductory note, Section II provides a background literature review of the subject. Research Methodology in Section III discusses RTA in some depth and develops a sampling methodology to test RTA variants (i.e., calculated on "inventor-basis" and "assignee-basis") for known and documented cases. As a part of that sampling methodology, two Newly Industrialized Countries (NICs) with very rapid technological developments, i.e., S. Korea and Taiwan, are selected first. In order to avoid possible distortion, due to the characteristics attributable to NICs' rapid growth or fast technological movement in these two countries, two comparable but highly industrialized mid-sized-economies, Canada and the

Netherlands, are also introduced to serve as comparative baselines (or benchmark). Research Findings and Discussions in Section IV outline the observed RTA complexities; and finally, Concluding Remarks further highlight the relative technological capabilities, specializations, of both S. Korea and Taiwan in certain technological classes.

## II: BACKGROUD

### 2.1 Technological Developments and Economic Growth

Technological development has been recognized as the fundamental factor in economic growth and progress and has recently received a great deal of attentions (e.g., Amendola, Guerrieri and Padaon, 1992; Amendola, Dosi and Papagni, 1993; Dosi and Kogut 1993; Dalum, 1992). A new spirit of techno-nationalism, in contrast to techno-globalism (Archibugi and Michie, 1995: 121), based on the belief that the technological capabilities of a nation, or a firm within it, as the key sources of value and competitiveness (Jaffe, 1986) is gaining rapid currency. Many authors, including Bartholomew (1997), Freeman (1992), Keck (1993), Kogut (1991), Lundvall (1992), Mowery and Rosenberg (1993), and Nelson (1993), to name a few, have devoted their attentions to the description and comparison of the national systems of innovation (NSI) in order to explain differences in economic performance. In the last decade, trends in the competitiveness of the major advanced industrialized countries, related to the underlying strengths and weakness in their performance in research, development and technological innovation, have been examined extensively (Jaffee, 1986; Cantwell, 1992; Narine, Noma and Perry, 1987). Asian NICs, for example, have achieved substantially higher and faster total factor productivity growth rates in manufacturing than those of advanced industrial countries (AICs). Countries such as S. Korea and Taiwan have achieved GDPs rankings of 11 and 19, respectively, in the world in less than a generation. Little attention is, however, paid to the technological capabilities and specialization as potential sources of competitiveness in these major newly industrializing countries (NICs), despite their rapid economic growth and easily observable technological developments.

**2.2 Development of Technological Capabilities in Asia NICs**

The acquisition and development of technology has been long seen in all countries as a key to raising productivity and improving competitiveness (Malerba and Orsenigo, 1996; Scherer, 1983; Schumpeter, 1934). However, technological capabilities are not the automatic by-products of investment and production activities (Bell and Pavitt, 1995). Such capabilities only result from explicit planning for, and investments in, Research and Development (R&D), which are further exploited in various stages of the value chain. Dynamic NICs have experienced wide variations both in achieving industrialization and in the creation of competitive strength (Dahlman, Hague & Takeuchi, 1995). S. Korea's record of export development, growth, and industrial diversification and specialization (Dalum, 1992) is one of the most impressive in modern economic history. S. Korea's manufactured export grew at 27.2% per year during 1965-1980 and 12.9% per year during 1980-1990, as compared with Hong Kong's 9.1% and 6.2%, Singapore's 4.7% and 8.6%, and Taiwan's 18.9% and 10.3% (Lall, 1995). Although Taiwanese government's development strategy has been less selective, less interventionist and far less detailed than S. Korea's, Taiwan has become as dynamic as S. Korea. While South Korea seems to be dominated by large chaebols,[2] Taiwan's strength lies in its myriad of Small- and Medium-Sized Enterprises (SMEs), which have tapped her large base of human capital under the government's protective policy of promoting infant industries (Etemad and Lee, 2001a). Partly due to these polices, Taiwanese firms have remained smaller (than S. Korean's). Taiwan's manufacturers, for example, rely far less on mass production, in-house

R&D, and international branding than their S. Korean counterparts. However, these problems have been offset by easy access to a wide range of technology support services, including R&D. Taiwanese industries have as a result, steadily increased their technological capabilities. A growing number of larger firms have recently emerged (e.g., The Acer Group) and have begun to invest in their own R&D in order to create and support their own production, and distribution, brand and global competitiveness. A couple of questions are therefore open to debate: i) which one of these two countries has accumulated the greater competitive strength over the long haul -- the one with an industrial structure supporting and dominated by the giant "chaebols," or the other more reliant on technologically-capable small and medium enterprises (SMEs); and, ii) which measures reflect the emerging phenomenon more accurately.

## III: RESEARCH METHODOLOGY

### 3.1 The Use of Patent Statistics as Technology Indicators

*Data set and population.* In spite of the few drawbacks identified in the literature (Archibugu and Pianta, 1992; Malerba Orsenigo, 1996; Paci, Sassu, and Usai, 1997), there is a consensus that patent data provides the most detailed indicator for studying the overtime patterns of technological specialization at the sectoral level. Several comprehensive surveys of the use of patent are often cited in research related to technology (e.g., Amesse and Associates, 1991; Archibugi and Michie, 1995; Chakrabarti, 1991; Etemad and Seguin-Dulude, 1987; Griliches, 1990; Smith, 1997; Soete, 1980 and 1987). Narin and associates are amongst scholars that found patent statistics as powerful tools for strategic planning (Narin, Albert and Smith, 1992) especially for developing further technological strength (Narine, Noma and Perry, 1987).

Criticisms of the use of patent data are also well known (e.g., Malerba and Orsenigo, 1996). Their arguments span a wide range. There is no uniform worldwide patenting system. Not all inventions are found equally eligible by the various legal systems to be granted patents. The relevance, quality and impact of patents are *not* captured by simple patent statistics unless complemented by specific analyses of patent renewals and patent citations. At the firm level, different types of firms (e.g., SMEs vs. larger ones) may have *different propensities* to obtain patents (Scherer, 1983). Different technological classes are granted patents differently. However, patent statistics represent the only homogenous measure of technological novelty across industries and countries. Furthermore, they are available in a long time-series. They are also capable of providing very detailed information at the firm, the technological class, and the country levels over time. Additionally, patent databases of the United States Patent and Trademark Office (USPTO) provide the best readily available information of this kind.

The major data set for this study was compiled from information stored at the USPTO. Unlike previous and similar studies, in this research we have collected the information which portray each patent "application form" as published in the official document, the *Patent Gazette*. Therefore our data is as detailed and as reflective as a typical patent application at USPTO.

**3.2 The RTA Index As a Measure of Technology Specialization: Some Inconsistencies**

*The origin of RTA index.* Following others (e.g., Archibugi and Michie, 1995; Archibugi and Pianta, 1992), this study uses the conventional **"Revealed Technological Advantage" (RTA)** as an index of technological advantage and specialization. Basically, the concept of RTA is similar to the Revealed Comparative Advantage (RCA) as captured by the RCA index in the international trade literature (Cantwell, 1989:19). The calculations of RTA index also follow those of RCA's. The RTA index, however, measures comparative advantage in innovative activity rather than comparative advantage in trade. While the RTA index was first used by Soete in the 1980s (as cited by Cantwell 1989:19), the RCA index was first used by Balassa as early as in 1965 (as cited by Cantwell 1989:19).

*The definition and the meaning of RTA when it is greater, smaller or equal to unity.* As an index, RTA is defined as a country's (or region's) share of total patents in a particular technological field (e.g., as issued by USPTO), as a ratio of that country's (or region's) share of total patents in all fields (e.g., as issued by USPTO). Formally RTA is defined as:

$$RTAijt = \left(Pijt \text{ for class } i \text{ in country } j \text{ in time period } t \,/\, \sum_{j} Pijt \text{ in class } i \text{ across all countries in time period } t\right) /$$

$$\left(\sum_{i} Pitj \text{ in country} j \text{ in time period } t \,/\, \sum_{i}\sum_{j} Pijt \text{ in the world in time period } t\right) \qquad [1]$$

*Where Pijt denotes the total patent count of technology class i in country j in time period t*

The RTA index is similar to elasticity in that it is a share of a share. But unlike demand-price elasticity, there is *no direct* relationship between these two shares as is the case for quantity and price in demand-price elasticity. Similar to elasticity, when the country has a *comparative advantage*, its RTA index is expected to be *greater than one* (i.e., a larger share than average) in a given sector (or technology class); and *less than one* when it has a *comparative disadvantage* (Paci, Sassu, and Usai, 1997). As observed by Patel (1996), an RTA of more than one, therefore, is reflective of a country's *relative strength* in a technological field; and less than one indicates a *relative weakness.* However, many other operationalization problems and conceptual questions remain unclear. For example, the RTA for the semiconductor sector in Taiwan in 1995 can be obtained by calculating the associated four elements corresponding to the above formula in two different ways (as shown in case 1 and case 2 below).

*The Country Sample.* Using U.S. patent statistics and other related secondary data, RTA is applied to the case of the two midsized Asian NICs (Taiwan[3] and S. Korea) in comparisons with two midsized Advanced Industrialized Countries (AICs) with relatively "similar" profiles as benchmarks (Canada and Netherlands). We expect to discover both similarities and differences in the paths of technological growth among these four countries. The criteria for selection of these four countries had two major concerns: comparability,[4] and differing levels of developments (see Table 1). Based on these concerns, two *comparable* and relatively fast-developing countries (Taiwan and S. Korea) were selected first. To distinguish the development of technological capabilities from overall development, two comparable advanced industrialized countries with somewhat "similar" characteristics (i.e., Canada and the Netherlands) were then selected to serve as benchmarks.[5] Given the cumulative nature of capabilities and specialization over time, trends have been analyzed longitudinally (from 1980 to 2000) across different technological areas and industries, at the country level for all the four countries concerned. Given the enormity of technological classes (some 600 classes in USPTO), three different combinations of Technological classes were selected to form the bases for this study.

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**Insert Table 1 About Here**

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*The difference in inventor and assignee basis leading to the two qualitatively different RTAs.* The unit of analysis in the database of USPTO is a patent record. This record corresponds with the original application form as initially filed (at USPTO[6]) and then edited and amended by patent examiners. The two most important fields of information in each record are the information concerning the **inventor(s)** and the **assignee(s)**. Each of these fields, when filled out, provides the identity and the stated address(es) of inventor(s) or assignee(s). But, some patent records show a blank assignee field. When there is both an assignee and an inventor, their country of residence *may or may* ***not*** be the same. Although, every patent has at least *one* inventor, there may be *no* assignee at all. Although not important to the inventions itself, the missing assignee information confounds the link between *innovation* and the *patented invention.* The former forms a basis for accumulation of capabilities and competitive advantage when commercialized; while the mere existence of the latter (i.e., a patented invention) may not, as discussed earlier.

Since assignee has traditionally taken patent to the next critical step -- from invention to innovation on the way to increase technological capabilities and commercialization -- missing assignee become the missing link between a novel invention and the corresponding innovation (when commercialized).[7] Furthermore, when there is a difference between the inventor's and the assignee's information field, it *becomes necessary* to approach the above calculation of RTA in two separate parts:

*i) RTA based on inventor's country of residence which we denote by* ***RTAi,*** *and;*

*ii) RTA based on assignee's country of residence as denoted by* ***RTAa****.*

When calculating all the four elements in the RTA formulation, there is a clear need for one to *specify the basis* of the calculations. Alternatively, the assumption and extrapolations on which RTA calculations are based should be clearly specified. In the absence of clear indications, one cannot (and should not) *automatically* assume that the original inventor(s) will have deployed their invention(s) and pushed them forward to become a utilized innovation regardless of the information on the assignee under all circumstances. In the interest of time, space, and further clarification, we introduce facilitating notations here: CCL, IC and AC are to represent respectively, the technological classification, inventor's country of residence, and assignee's country of residence. Two *actual* RTA cases for the same technological class, semiconductors (e.g., CCL = 438) are presented below to highlight the discussion.

### Example Search Logic for Each Part of Calculation RTA

| **Case 1: The inventor basis** | **The associated patent counts for calculating RTAi** |
|---|---|
| IC=Taiwan (tw) and CCL=438 in given time | Pijt (all patented inventions *invented* in class 438 by Taiwanese residents) in given time t |
| (IC=all + IC=U.S.) and CCL=438 | Summation of Pijt for class i=438 for all countries, including the U.S. |
| IC=Taiwan | Summation of Pijt for country j=tw (when Taiwan is the inventing country) |
| IC=all + IC=U.S. and CCL=438 | Double summation of Pijt for the entire world for CCL=438 (The classification number for semiconductor in the USPTO database) |
| **Case 2: The assignee basis** | **The associated patent counts for** |
| AC=Taiwan (tw) and CCL=438 | Pijt (all patented inventions in class i=438 *assigned* to Taiwanese residents) |
| (AC=all + AC=U.S.) and CCL=438 | Summation of Pijt for class i=438, including U.S. |
| AC=Taiwan | Summation of Pijt for country j=tw (when Taiwan is the assigned country) |
| AC=all + AC=U.S. and CCL=438 | Double summation of Pijt for the entire world for CCL=438 |

It should not be difficult to expect different results when assignees' and inventors' information fields are not identical. Indeed, these calculations yield two different results: In Case 1, $RTA_i = 6.13$ and in Case 2, $RTA_a = 10.0$ (for 1996 to 2000). Although both RTAi and RTAa are greater than one, which points to a cumulative technological *advantage* over the time period, RTAa points to Taiwan's greater emphasis on innovative as opposed to inventive aspects.

### 3.3 Technological Class Samples: The Formation of Two Multi-Class Samples

*The sampling of related technological classes.* As stated earlier, there are about 600 classes at the first level (i.e., three-digit codes) in the U.S. patent classification. In this study, we have subjectively selected three partial sub-sets of the available technological classes for detailed examination of RTA behaviour and the technological position of S. Korea and Taiwan as by-products. The criteria for selecting these classes was either relatively high global market shares or high patent counts.

In the *first sample*, we selected 3 diverse technological classes and results are shown in Table 2 and further discussed below (in the next section). In *the second sample* we selected the six semiconductor-related classes with the highest scores on the selection criteria. *In the third sample,* we combined all classes related to computers, mouses, scanners, keyboards, modems, and monitors. Therefore, our third sample contains 18 classes related to the broad area of computers, including the semiconductor.

*Hypothesis.* We hypothesize that: (i) these two NICs would exhibit different technological characteristics, including their evolutionary paths, ($H_{1a}$); and (ii) different specialization and instability, especially in earlier year than in later years ($H_{1b}$). As regards RTA, we hypothesize that: (i) the RTA index to show variations over time for most technology classes before reaching a steady-state in the longer time ($H_{2a}$) and; (ii) not all classes in our two larger samples (i.e., the second and the third samples) for S. Korea and Taiwan to exhibit *consistent* revealed technological advantage (i.e., RTA>1) with both of their associated RTAi and RTAa (i.e. RTA calculated on inventor and assignee basis) ($H_{2b}$). Finally, we hypothesize that RTA calculations based on the two different bases proposed here to yield different results: the rankings of RTAi and RTAa of the two (or the four countries) not to be identical or remain the same over time ($H_{2c}$).

## VI: RESEARCH FINDINGS AND DISCUSSIONS

### 4.1 Examining the Distortion and Sensitivity of RTA for Three Diverse Technological Classes in 1983

A U.S. National Science Foundation report, *Science and Engineering Indicators 1996*, reported that the Taiwan and Korea have "leapfroged" from 1983 to 1993. The Taiwan's and S. Korea's "activity index" in 1993 for 43 and 32 classes, respectively, had exceeded 1.00. In 1983 however, only one class (i.e., class 075: specialized metallurgical process) in Taiwan and only two classes (i.e., class 400: typewriting machines, and class 204: chemistry, electrical and wave energy) had "activity indeces" in S. Korea greater than 1.00 as shown in Table 2 below. Both Taiwan and S. Korea had reached very high values in 1983 (23.9 for Taiwan's class 075; 31.3, and 11.5 for S. Korea's class 400 and 204, respectively). They had reportedly declined dramatically to 3.33 for class 075, 7.03 for class 400, and 0.61 for class 204 in 1993, as shown in Table 2, below.

**Table 2: Comparison of NSF Activity Indices and Calculated RTAs**

| | | NSF Reported RTAs | | 1983 RTAs | |
|---|---|---|---|---|---|
| Class Title | Country | 1983 | 1993 | Inventor Basis | Assignee Basis |
| Class 075: Specialized metallurgical process | Taiwan | 23.9 | 3.33 | 2.35 | 20.43 |
| Class 400: Typewriting machines | S. Korea | 31.3 | 1.10 | 7.03 | 24.22 |
| Class 204: Chemistry: electrical and wave energy | S. Korea | 11.5 | 0.61 | 2.67 | 9.43 |

Source: NSF report 1996 and this research.

"Activity index" in the above report appears to be RTA-based. Regardless of their exact origin, even a cursory examination of the table gives rise to several questions: (i) why these three values in 1983 are so high and much lower in 1993? (ii) what are the bases for calculations of these "country activity indices" -- the RTA value? (iii) if RTAs, what are the implications of these initially high but declining RTA values? (iv) how were the theoretical difficulties (or limitations), discussed above, dissolved or surmounted? (v) how have these difficulties impacted the extremely high or extremely low RTAs reported by the NSF Report?

Like other indicators of technology for a specific technological class and a specific country, RTA index suffers from its own limitations. When the total patent counts of a country is small and/or the total patent counts of a technology class is also small the RTA index is very sensitive to very small increments, such as one or two additional patents. For example, when Taiwan obtained *only one* patent on the inventor basis; and gained *only one* patent on assignee basis in the USPTO class 075 in 1983, its RTAi (inventor basis) and RTAa (assignee basis) reached respectively, as high as 2.35 and 20.43 as shown in Table 2. The same identical increment of one patent (from zero) led to different results: RTAi=2.35 [(1/75) /(351/61993) = 2.35] and RTAa=20.43 [(1/8)/(306/50021)=20.43], which is quite larger than its RTAi counterpart (see Table 3). Similarly, RTAi of S. Korea in 1983 for class 400 and class 204 are respectively 7.03 and 2.67 while RTAa reach as high as 24.22 and 9.43, which illustrate inconsistences outlined earlier.

*Short-Term High RTAs.* Our theoretically refined definitions of RTA (evaluated in terms of *inventor- or assignee basis*) and the associated calculations for RTAi and RTAa prove that in such situations the conventional RTA index is seriously flawed due to its sensitivity to small increments, especially, in shorter time periods. Furthermore our results show different values as compared to those shown in the NSF Report (RTA=23.9 for Taiwan's class 075, 31.3, and 11.5 for S. Korea's class 400 and 204, respectively in 1983). Our calculations clearly point out that *not* all high RTA values should automatically be viewed as stable or sustainable over a long-term, nor as indicator of true comparative technological advantage or specialization even in the short-term. (All the patent statistics and comparative RTA figures for the four countries are shown in Table 3.

**Insert Table 3 about here**

*Long time-series of RTA for the three classes*. Facing the above discrepancies, we should have ideally traced the long time-series of patent counts and calculated their associated RTAs, both on inventor and assignee basis, for the above three classes from 1983 to 1997. However, due to either no additional patents obtained from USPTO or missing data for classes 400and 204, we had to substitute two other alternative -- but related -- technological classes. We selected class 438 (semiconductor manufacturing process), and 327 (miscellaneous electrical nonlinear devices, circuits, and systems).[8] Class 075 (specialized metallurgical process) of Taiwan was kept as a basis of comparison. All the figures leading to these results are shown in Table 4. The three long term-time series show three different patterns representing different characteristics for each technology class. Both classes 438 and 327 show high growth. Their patent counts in the world grew about three times, respectively, from 613 and 735 in 1985, to 1839 and 1232 in 1995, and to 5537 and 1852 in 2000 on inventor basis. The class 075 experienced much lower growth rates as evidenced by patent counts in the world. It grew from 324 in 1985 to 364 in 1995 and 316 in 2000 (almost no growth in 15 years on inventor basis). Both RTAi and RTAa for Class 075 in 1983 were larger than one (2.35 and 20.43, respectively) but *not* close to the NSF's reported figure in 1983. Similarly, our RTA calculation in 1993 (RTAi=0.85 and RTAa=1.26) is much smaller than the NSF figure of 3.33. More importantly, our calculation, as shown in Table 4 for class 075, shows clearly that the path of RTA from 1983 to 1993 has not been a smooth and gradual decline. Rather they have *fluctuated* between 0.00 and a positive numbers over the period. When patent counts for the entire 15 years are considered,[9] RTAi and RTAa of class 075 attain 0.30 and 0.46 for Taiwan, which portrays a totally different picture than those reflected by figures calculated over a shorter term period,[10] (see the last column of Table 4). These results both point to the sensitivity of RTA for smaller increments in the short term and the need for longer-term considerations.

**Insert Table 4 About Here**

### 4.2 The Most Emphasized Technological Classes by S. Korea and Taiwan: A Broader Sample of Six Semiconductor-Related Technological Classes

*The re-examination of the instability of RTA for 6 semiconductor-related classes over five years*. S. Korea and Taiwan are reported as the third and fourth largest producers of semiconductor in the world after U.S. and Japan by several reports (e.g., Institute for Information Industry, Taiwan, 1997). Corresponding to this revealed comparative advantages (RCA), both Taiwan and S. Korea should theoretically show large (e.g., larger than one) RTA.[11] The RTAi and RTAa for major semiconductor-related technology classes (i.e., six classes) for both Taiwan and S. Korea for the last five years (i.e., 1996-2000) are calculated and shown in Table 5. To establish benchmark for comparison, the two mid-sized Advanced Countries -- Canada and the Netherlands -- are also added to Table 5. This table portrays a more comprehensive picture of technological development where both S. Korea and Taiwan show more classes with greater RTAs than Canada and the Netherlands.

**Insert Table 5 about here**

Several interesting findings are noteworthy. First, both the RTAi (on inventor basis) and RTAa (on assignee basis) of almost all classes in S. Korea are larger than their counterparts elsewhere. This confirms the high state of technological development in semiconductor industry in S. Korea as reported elsewhere (e.g., U.S. NSF Report, 1996). Second, while Taiwan has only two classes (class 257 and 438) on mean with consistently greater technological advantage on inventor basis, it has 4 classes (257,438, 327 and 326) on assignee basis (RTAa). This indicates that Taiwan's advantage is based on more of appropriation of Technology (the assignee-basis) than the creation of technology in the sampled classes. The RTAs of class 438 (semi-conductor manufacturing) is consistently greater than one for both countries, indicating that both countries have created and acquired the necessary technology invented elsewhere. Third, only few classes show advantages consistently, either on inventor basis or on assignee basis, which point to the non-steady state of inventive activities over time. Fourth, some RTAi or RTAa are just greater than one for a short period, such as one year, rather than the whole five years, confirming the need to consider RTA over longer, rather than shorter, time periods. These short-lived higher RTAi and RTAa can hardly point to accumulated technological advantages; because all of the absorption, adaptation, imitation, invention, and innovation aspects of technology are cumulative processes.[12] Fifth, all five-year averages (or sum of patent counts over five years and their associated RTAi and RTAa), as reported in Table 6 appear to be much more meaningful for signifying the accumulated technological advantage than one year RTA calculation (See Table 6). S. Korea appears to have accumulated much higher Technological capabilities over time (and specialized) than all countries in the sample on both bases (see last row of Table 6 reporting number of classes with RTAs >1). Finally, our two benchmark mid-sized AIC countries, Canada and the Netherlands, do not show a widely-based and consistent RTA (except for class 330 and 327 for the Netherlands). These RTA figures further confirm the prevailing reality that *Taiwan and S. Korea have accumulated technological* *superiority* and specialized in semiconductor-related classes over time. This accumulation and specialization is differentially much higher than the overall growth phenomenon related to general growth or industrialization.

**Insert Table 6 and 7 about here**

## V: CONCLUDING REMARKS

This paper is exploratory and analytical in nature. We discuss some methodological issues associated with the use of the patent-centred index as an internationally comparable technological indicator. We find that the calculation of the much utilized index, the Revealed Technological Advantage (RTA) should be very specific, because of the considerable difference in results when calculated on inventor basis (RTAi) or assignee basis (RTAa). This difference is not due to errors or inconsistency in the inventor and assignee information in patent records. It is instead due to the assumption behind each basis and how those assumptions correspond with the reality of inventive-innovative activities (as demonstrated in Cases 1 and 2 earlier). Moreover, both the patent classification and the length of the time period of calculation also affect the stability of RTA figure for countries with smaller capability and also for patent classes with smaller base and smaller growth rates. Therefore, the identification of technological capabilities based on the most emphasized or advantageous classes through RTA requires extreme care. RTA should be tracked only over a relatively longer term and complemented with comparative examination of absolute patent counts to avoid misrepresentation. In this study, we re-examined and reported the absolute patent counts for the three samples of technological classes formed for RTA calculations to minimize some of the RTA inconsistencies discussed in the paper.

As regards to technological capabilities and specialization, this paper, present some *fresh empirical evidence* on the capabilities of the two Asian NICs based on Taiwan's and S. Korea's patenting activities in USPTO. Their inventive activities show that they have made large progress in generating new technology. This progress is also reflective of the supportive orientation of their national systems of innovations that has propelled them to surpass beyond the imitation and adaptation stages of technology transfer from the advance countries (which are mostly not patentable). It appears that they have both entered the stage of generating world-class new technologies of their own.

RTA (i.e., RTAi and RTAa) results verified with absolute patent counts lead to the conclusion that Taiwan and Korea have specialized. Our findings show that not all RTAs of all sample classes of the two countries show technological advantage, even for semiconductor and computer related classes for which these two countries have a demonstrated trade of production advantage. Their sectoral patterns of technological specialization are *significantly different* from each other and also from the other two advanced AICs, Canada and the Netherlands. Furthermore, our findings point to the need for a more comprehensive study of similarities and differences of technological capabilities leading to global competition based on specialization in those technological classes concerned with strong policy implications for sectoral development. Since four countries manifest different specializations in the selected technology classes, as stated in the literature, there exists potential opportunities of collaboration for exploiting global opportunities.

## ENDNOTES

[1] A comparison of well-publicized high RTA (calculated on two different basis) and RPA/RCA cases can provide some confirmatory empirical evidence.

[2] Regardless of the effective level of protection offered by the Industrial Policy in S. Korea, the large Korean chaebols have created structural entry barriers for others. This has contributed to the inability of smaller firms to

enter the market in S. Korea. In contrast, small and medium-sized Taiwanese firms can easily enter the market and even receive some protection against foreign competitors.

[3] Relatively high global market shares are defined as a country's export share of a product as the ratio of that country's total exports (e.g., Taiwan's export of US$116B/ total world exports US$3950b=2.68%). In reality, the above export values even for the Top Taiwanese products include both the domestic and some foreign productions. The foreign production share of "information-related products" is as high as 30% in 1996 and 34% in 1997 of Taiwan's export; and this value is expected to rise to about 45% in early 2000. These increasing share of foreign production and the corresponding global market share show that Taiwan has experienced rapid structural change in information industry due to investment in both domestic and foreign production. Their evolutionary patterns seem to be quite different from their conventional RCA counterparts due to differing patterns of foreign investment and technological3 development. Table 1 shows the list of the Top 15 Taiwan products rated as world leaders according to their production value, global market share (gms %) and revealed production advantage (RPA) according to a recent survey in Taiwan (Institute for Information Industry, Taiwan, 1997). The Top 9 of the Taiwan's Top 15 products are related to information and computer industry. The Top 5 products with extremely high gms% and RPA are: (i) mother boards (74% gms, 25 RPA), (ii) mouses (65% gms, 22 RPA), (iii) image scanners (64% gms, 22 RPA), (iv) keyboards (61% gms, 21 RPA), and (v) modems (61% gms, 21 RPA).

[4] Comparability is an obvious concern. A comparison of a small developing country with a large and highly advanced technologically, such as the U.S., Germany, or Japan, defies the purpose. A lengthy discussion is beyond the scope of this paper. Interested readers should see Etemad and Lee, 1998.

[5] These four countries are shown to be "reasonably similar" in socio-economic and political terms, while two being NICs and the other two being AICs (see Etemad and Lee, 1998).

[6] A patent record is the documentation on which a patented invention is based. The focus of documentation is at least an invention, which is common feature of all patents. But this is where commonality stops: a patent may have one or many inventors; non, one or many assignees; inventors' or assignees' countries of residence may or may not be same and hence there lies the inherent difficulties in assigning a patent to a country in order to carry out country level analysis. As Kogut, 1991, terminology country boundaries have become permeable.

[7] Several possibilities arise in this case: i) the inventor proceeds to commercialize the original invention either on his own in his own country of origin, or ii) elsewhere. An assignee may commercialize in the iii) inventor's country, or iv) elsewhere. Alternatively, a fifth possibility is for the inventor to commercialize at all. An incomplete patent application fails to provide even proxy indicators for the above possibilities.

[8] In order to select the alternative classes, we first searched the entire USPTO patent database, over the past 15 years (from 1983 to 1997, where data is readily available for large number of technological classes) for which Korea and Taiwan are known to have developed technological advantages. These turned out to include class 437 (semiconductor manufacturing processes), class 257 (active solid state device), and class 075 (specialized metallurgical processes).

[9] Fifteen years is the duration of time for which patent data for both countries in all classes is available. This duration (or for that matter, the duration of time over which technology is accumulated) can be either studies as ONE time period (although a long one), or be divided into various time increments. From dynamic processes, one would know that smaller time increments, especially in the early formative periods, show different characteristics. The accumulated momentum and inertia of the formation processes, after sufficient accumulation of technology, dampens inherent instability associated with short duration increments.

[10] Even for technological classes with highly intensive patenting activities over the early stages of technology life cycle -- where a rapid succession of many inventions are patented, one would expect the rate of patenting to decay over time and even decline dramatically after most basic inventions are patented. Therefore, both the starting and ending point of RTA calculation and elapsed time on the actual inventive/innovative cycle of which RTA is just an indicator.

[11] A large global market share is a clear manifestation of a nation's comparative advantage. When this advantage is technology-centred, RTA index must achieve higher figures than 1. Similarly when products are locally produced and then exported, then RPA must also achieve figures higher than 1. Thus a large global share in a product line such as computers may lead to RTA $\geq 1$, RPA $\geq 1$ and naturally RCA $\geq 1$ in the longer term.

[12] The ratio of tangible part to intangible part of efforts, especially for developing countries, in their technological development process are in question. This may be higher for developing countries than industrialized countries

**TABLE 1**
**Revealed Production Advantage of Taiwan Top 15 Products**

| 1996 | Production Value | Global | |
|---|---|---|---|
| **Product** | **US$ million** | **Market Share (%)** | **RPA*** |
| Mainboards | 2046 | 74.0% | 25.2 |
| Mouses | 198 | 65.0% | 22.1 |
| Image Scanners | 540 | 64.0% | 21.8 |
| Computer Keyboards | 415 | 61.0% | 20.8 |
| Modems | 870 | 61.0% | 20.8 |
| Power Supplies | 1080 | 55.0% | 18.7 |
| Monitors | 7271 | 53.0% | 18.0 |
| Network Cards | 553 | 39.0% | 13.3 |
| Display Cards | 558 | 38.0% | 12.9 |
| Polyester Fiber | 3655 | 16.6% | 5.7 |
| Electronic Glass Fiber Cloth | 270 | 22.0% | 7.5 |
| ABS Resin | 863 | 21.0% | 7.2 |
| Bolts and Nuts | 1419 | 33.6% | 11.4 |
| Bicycles | 1066 | 9.2% | 3.1 |
| *Sewing Machines | 636 | 26.4% | 9.0 |

*note: * rated by export value* *Remarks: All data are 1996 value.*

**RPA(revealed production advantage)=world share of this product divided by world share of all products*

*data source: Industrial Development Bureau, Institute for Information Industry1997 (Taiwan)*

**TABLE 3**
**Distortions of RTA Due to The Basis of Attribution, Small Patent Class and Small Number of Country Patent Counts**

| *1983* | | *Inventor basis* | | | | *1983* | *Assignee basis* | | | | | No Assignee | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **class#** | **all** | **tw** | **kr** | **ca** | **Nl** | **class#** | **all** | **tw** | **kr** | **ca** | **nl** | **pat#** | **%** |
| All-clas | 61993 | 75 | 28 | 1165 | 699 | all-clas | 50021 | 8 | 7 | 580 | 316 | 11972 | 19.3% |
| #075* | 351 | 1 | 1 | 9 | 1 | #075* | 306 | 1 | 0 | 4 | 1 | 45 | 12.8% |
| #400 | 315 | 0 | 1 | 4 | 0 | #400 | 295 | 0 | 1 | 1 | 0 | 20 | 6.3% |
| #204 | 829 | 0 | 1 | 18 | 8 | #204 | 758 | 0 | 1 | 15 | 2 | 71 | 8.6% |

*data source: Search of this study on the Web*

**RTA Figures for Each Basis of Attribution**

| *RTAijt* | *1983* | *inventor basis* | | | | *RTAijk* | *1983* | *Assignee basis* | | | | *Remarks* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **class#** | **all** | **tw** | **kr** | **ca** | **nl** | **class#** | **all** | **tw** | **kr** | **ca** | **nl** | **class title** |
| #075* | 1.00 | 2.35 | 6.31 | 1.36 | 0.25 | #075* | 1.00 | 20.4 | 0.00 | 1.13 | 0.52 | Specialized metallurgical processes |
| #400 | 1.00 | 0.00 | 7.03 | 0.68 | 0.00 | #400 | 1.00 | 0.00 | 24.2 | 0.29 | 0.00 | Type writing machines |
| #204 | 1.00 | 0.00 | 2.67 | 1.16 | 0.86 | #204 | 1.00 | 0.00 | 9.43 | 1.71 | 0.42 | chemistry: electrical and wave energy |

*Note: Activity Index (RTA) given in NSF(1996) Science and Engineering, three Activity Index (RTAs) are Class 075 (23.9) for Taiwan, class 400 (31.3), and class 204 (11.5) for S. Korea*

## TABLE 4

### Summary RTA Profile of 3 Different Classes in Long Time Series from 1983 to 2000

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| total-I | 61993 | 72625 | 77261 | 77030 | 89594 | 84433 | 102681 | 99245 | 106842 | 107484 | 109902 | 113676 | 113911 | 122953 | 125884 | 166801 | 172265 | 176350 | 2E+06 |
| Taiwan-I | 75 | 123 | 202 | 276 | 419 | 544 | 701 | 872 | 1112 | 1272 | 1533 | 1847 | 2193 | 2477 | 2678 | 3912 | 4664 | 5976 | 30876 |
| total-a | 50021 | 58928 | 63152 | 62326 | 72727 | 68535 | 83049 | 79530 | 85728 | 87444 | 89604 | 92617 | 92512 | 97325 | 100351 | 132508 | 139476 | 146041 | 2E+06 |
| Taiwan-a | 8 | *8* | 16 | 29 | 60 | 71 | 124 | 161 | 212 | 300 | 450 | *548* | *730* | *932* | *1110* | *1771* | *2427* | *3516* | *12473* |
| #438-I | 480 | 656 | 613 | 610 | 677 | 658 | 838 | 783 | 1077 | 1177 | 1492 | 1612 | 1839 | 1823 | 2137 | 2992 | 4263 | 5537 | 29264 |
| #438-A | 460 | 488 | 595 | 599 | 649 | 641 | 822 | 763 | 1053 | 1143 | 1460 | 1580 | 1785 | 1763 | 2076 | 2862 | 4086 | 5300 | 28125 |
| #438-twi | 0 | 1 | 0 | 0 | 1 | 1 | 5 | 4 | 11 | 14 | 22 | 63 | 165 | 222 | 270 | 427 | 655 | 1033 | 2894 |
| #438-twa | 0 | 1 | 0 | 0 | 1 | 1 | 3 | 4 | 11 | 15 | 22 | 63 | 163 | 215 | 273 | 414 | 640 | 1011 | 2837 |
| RTAi | 0.00 | 0.90 | 0.00 | 0.00 | 0.32 | 0.24 | 0.87 | 0.58 | 0.98 | 1.01 | 1.06 | 2.41 | 4.66 | 3.46 | 5.94 | 6.09 | 5.67 | 5.51 | 3.70 |
| RTAa | 0.00 | *15.09* | 0.00 | 0.00 | 1.87 | 1.51 | 2.44 | 2.59 | 4.22 | 3.83 | 3.00 | *6.74* | *11.6* | *12.73* | *11.89* | *10.82* | *9.00* | *7.92* | *10.18* |
| #327-I | 615 | 656 | 735 | 799 | 894 | 744 | 910 | 827 | 942 | 1008 | 824 | 1138 | 1232 | 1315 | 1041 | 1548 | 1706 | 1852 | 18786 |
| #327-A | 590 | 627 | 712 | 780 | 868 | 719 | 873 | 788 | 915 | 968 | 797 | 1102 | 1197 | 1254 | 1020 | 1475 | 1637 | 1750 | 18072 |
| #327-twi | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 5 | 3 | 12 | 11 | 19 | 24 | 13 | 21 | 36 | 43 | 45 | 236 |
| #327-twa | 0 | *0* | 0 | 0 | 0 | 1 | 0 | 4 | 1 | 8 | 7 | *11* | *21* | *13* | *20* | *32* | *40* | *50* | *208* |
| RTAi | 0 | 0 | 0 | 0.35 | 0.24 | 0.21 | 0.16 | 0.69 | 0.31 | 1.01 | 0.96 | 1.03 | 1.01 | 0.71 | 0.95 | 0.99 | 0.93 | 0.72 | 0.75 |
| RTAa | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.34 | 0.00 | 2.51 | 0.44 | 2.41 | 1.75 | *1.69* | *2.22* | *1.47* | *1.77* | *1.62* | *1.40* | *1.19* | *1.65* |
| #075-A | 351 | 330 | 324 | 357 | 347 | 375 | 375 | 388 | 349 | 340 | 339 | 364 | 364 | 256 | 244 | 322 | 373 | 316 | 6114 |
| #075-I | 306 | 294 | 299 | 331 | 314 | 352 | 348 | 364 | 325 | 314 | 317 | 334 | 333 | 227 | 224 | 278 | 347 | 284 | 5591 |
| #075-twi | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 1 | 4 | 2 | 4 | 2 | 2 | 6 | 2 | 0 | 29 |
| #075-twa | 1 | *0* | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 2 | *2* | *3* | *2* | *2* | *2* | *1* | *0* | *20* |
| RTAi | *2.35* | 0 | 0 | 0 | 0 | 0.83 | 0 | 0 | 0.83 | 0.25 | 0.85 | 0.34 | 0.57 | 0.39 | 0.39 | 0.79 | 0.20 | 0.00 | 0.30 |
| RTAa | *20.4* | 0.00 | 0.00 | 0.00 | 0.00 | **5.48** | 0.00 | 0.00 | **3.73** | 0.00 | **1.26** | *1.01* | *1.14* | 0.87 | 0.81 | 0.54 | 0.17 | 0.00 | 046 |

*Data source: USPTO and this study*

*Remarks: In 1997Class 437 semiconductor manufacturing process; in 2001 this class has split into class 438.*

*Class 327 miscellaneous electrical nonlinear devices, circuits, and systems.* *Total-I for 1983-2000 is 1980930*

*Class 075 specialized metallurgical process.* *Total-A for 1983-2000 is 1601874*

**Figure 1 of Table 4: Taiwan Long March of Class 438**

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #438-twi | 0 | 1 | 0 | 0 | 1 | 1 | 5 | 4 | 11 | 14 | 22 | 63 | 165 | 222 | 270 | 427 | 655 | 1033 | 2894 |
| #438-twa | 0 | 1 | 0 | 0 | 1 | 1 | 3 | 4 | 11 | 15 | 22 | 63 | 163 | 215 | 273 | 414 | 640 | 1011 | 2837 |
| | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | total |
| RTAi | 0.00 | 0.90 | 0.00 | 0.00 | 0.32 | 0.24 | 0.87 | 0.58 | 0.98 | 1.01 | 1.06 | 2.41 | 4.66 | 3.46 | 5.94 | 6.09 | 5.67 | 5.51 | 3.70 |
| RTAa | 0.00 | *15.1* | 0.00 | 0.00 | 1.87 | 1.51 | 2.44 | 2.59 | 4.22 | 3.83 | 3.00 | *6.74* | *11.6* | *12.7* | *11.9* | *10.8* | *9.00* | *7.92* | *10.18* |

**Figure 1 of Table 4: Pantent Counts on Inventor and Assignee Bases for Taiwan from 1983 to 2000**

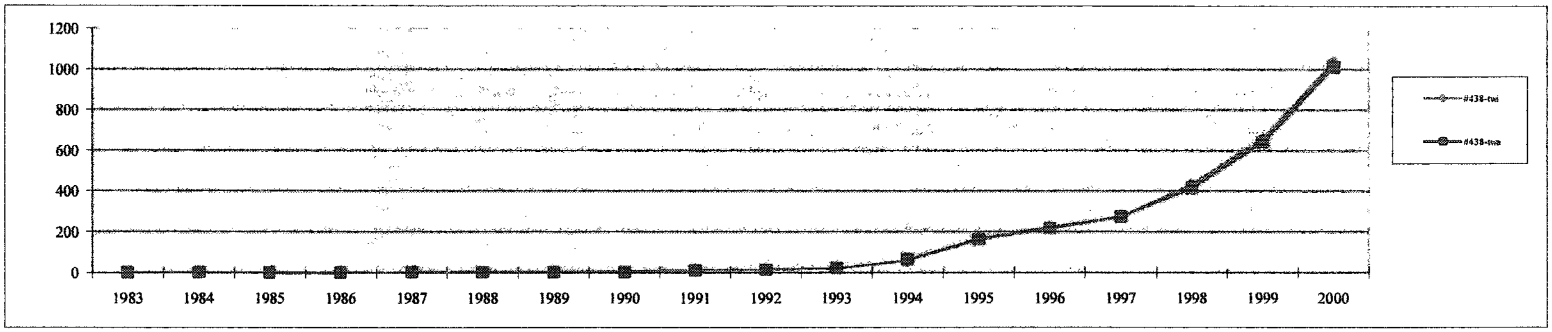
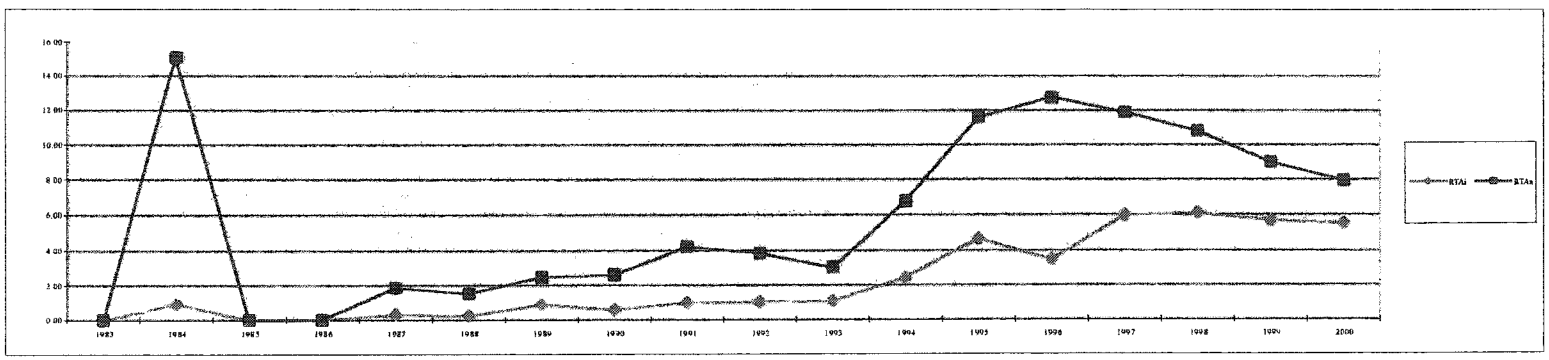



**Figure 2 of Table 4: RTAs on Inventor and Assignee Bases for Taiwan from 1983 to 2000**



**Figures of Table 4: Taiwan's Long March of Class 327**

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #327-twi | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 5 | 3 | 12 | 11 | 19 | 24 | 13 | 21 | 36 | 43 | 45 | 236 |
| #327-twa | 0 | *0* | 0 | 0 | 0 | 1 | 0 | 4 | 1 | 8 | 7 | *11* | *21* | *13* | *20* | *32* | *40* | *50* | *208* |

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | tatal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RTAi | 0 | 0 | 0 | 0.35 | 0.24 | 0.21 | 0.16 | 0.69 | 0.31 | 1.01 | 0.96 | 1.03 | 1.01 | 0.71 | 0.95 | 0.99 | 0.93 | 0.72 | 0.75 |
| RTAa | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.34 | 0.00 | 2.51 | 0.44 | 2.41 | 1.75 | *1.69* | *2.22* | *1.47* | *1.77* | *1.62* | *1.40* | *1.19* | *1.65* |

**Figure 1 of Table 4: Pantent Counts on Inventor and Assignee Bases**

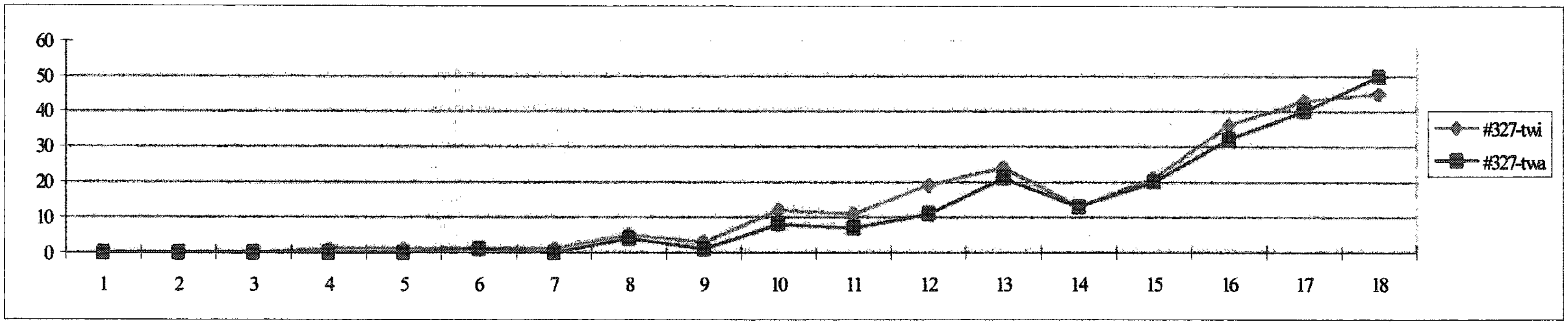
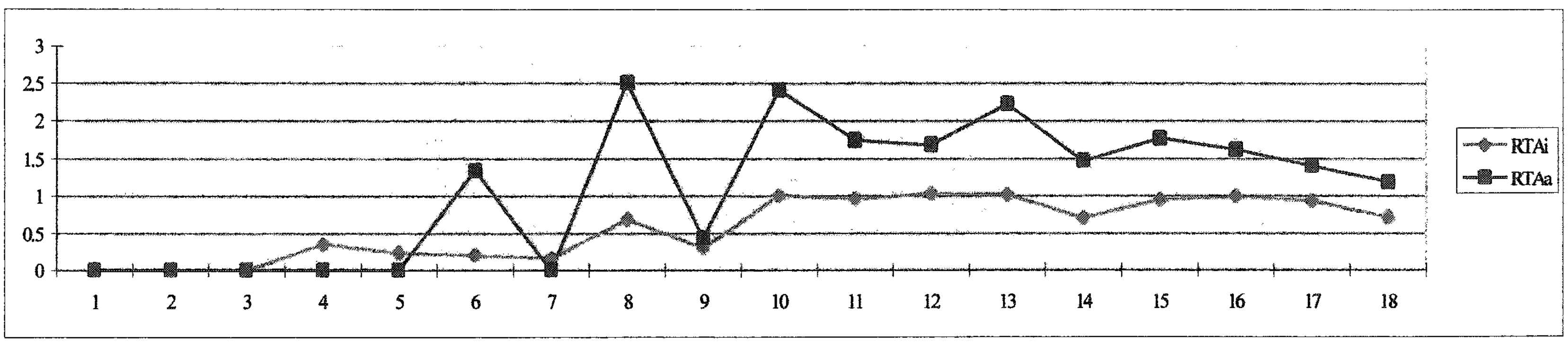



**Figure 2 of Table 4: RTAs on The Bases of Inventor and Assignee Bases**



**Figures of Table 4: Taiwans Long March of Class 75**

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #075-twi | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 1 | 4 | 2 | 4 | 2 | 2 | 6 | 2 | 0 |
| #075-twa | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 0 |
| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| RTAi | 2.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.83 | 0.25 | 0.85 | 0.34 | 0.57 | 0.39 | 0.39 | 0.79 | 0.20 | 0.00 |
| RTAa | 20.4 | ***0.0*** | 0.00 | 0.00 | 0.00 | 5.48 | 0.00 | 0.00 | 3.73 | 0.00 | 1.26 | ***1.01*** | ***1.1*** | ***0.9*** | ***0.8*** | ***0.5*** | ***0.17*** | ***0.00*** |

**Figure 3 of Table 4: Patent Counts on Inventor and Assignee Bases**

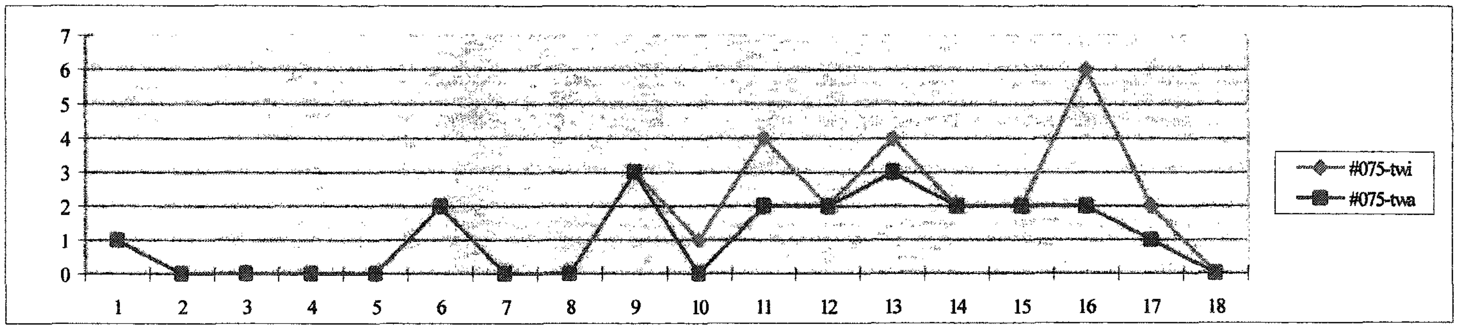



**Figure 4 of Table 4: RTAs on Inventor and Assignee Bases**

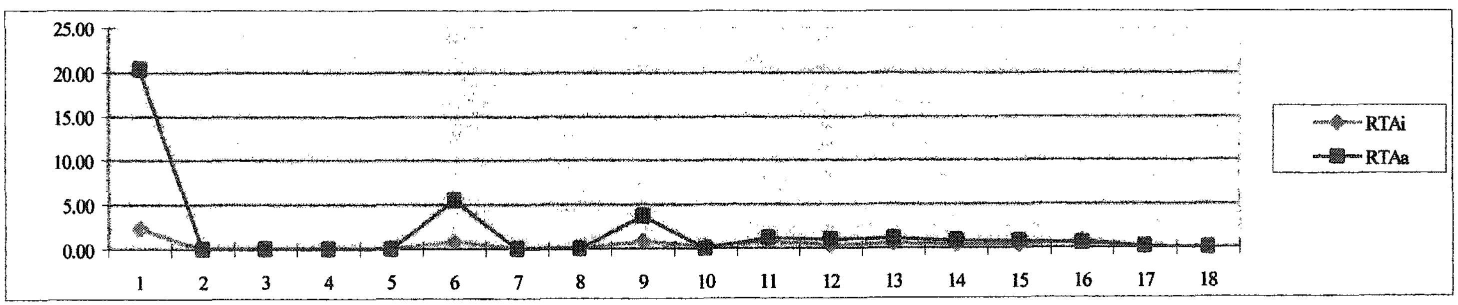


**TABLE 5**

**RTA Summary of 6 Semiconductor Related Classes**

| ***Taiwan*** | | *96i* | *97i* | *98i* | *99i* | *00i* | *RTAi* | | *96a* | *97a* | *98a* | *99a* | *00a* | *RTAa* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Class#** | **score** | **tw** | **tw** | **tw** | **tw** | **tw** | **mean** | | **tw** | **tw** | **tw** | **tw** | **tw** | **mean** |
| #257 | 100 | 1.76 | 1.90 | 2.13 | 2.45 | 2.54 | 2.16 | | 3.31 | 3.31 | 3.37 | 3.53 | 3.52 | 3.41 |
| #330 | 22 | 0.15 | 0.55 | 0.19 | 0.35 | 0.24 | 0.30 | | 0.33 | 1.14 | 0.36 | 0.70 | 0.36 | 0.58 |
| #438 | 22 | **5.7** | **5.99** | **6.16** | **5.87** | **5.6** | 5.87 | | **12.7** | **12.0** | **10.8** | **9.00** | **7.9** | 10.50 |
| #327 | 17 | 0.51 | 0.94 | 1.00 | 0.95 | 0.73 | 0.83 | | 0.11 | 1.79 | 1.62 | 1.40 | 1.19 | 1.22 |
| #326 | 14 | 0.86 | 1.17 | 0.85 | 0.83 | 0.7 | 0.88 | | 1.80 | 2.14 | 1.12 | 1.41 | 1.16 | 1.53 |
| #117 | 11 | 0.23 | 0.44 | 0.15 | 0.47 | 0.37 | 0.33 | | 0.00 | 0.89 | 0.29 | 0.76 | 0.13 | 0.41 |
| x/6 | RTA>1 | 2 | 3 | 2 | 2 | 2 | 2 | | 3 | 5 | 4 | 4 | 3 | 4 |
| ***Korea*** | | *96i* | *97i* | *98i* | *99i* | *00i* | *RTAi* | | *96a* | *97a* | *98a* | *99a* | *00a* | *RTAa* |
| **Class#** | **score** | **kr** | **kr** | **kr** | **kr** | **kr** | **Mean** | | **kr** | **kr** | **kr** | **kr** | **kr** | **mean** |
| #257 | 100 | 2.66 | 2.27 | 2.91 | 3.21 | 2.7 | 2.75 | | 2.13 | 1.99 | 2.46 | 2.77 | 2.46 | 2.36 |
| #330 | 22 | 0.89 | 0.91 | 0.98 | 1.58 | 1.8 | 1.23 | | 0.85 | 0.83 | 0.89 | 0.87 | 1.95 | 1.08 |
| #438 | 22 | 4.94 | **5.84** | 4.54 | 3.69 | 3.63 | 4.53 | | 4.28 | **5.05** | 3.86 | 3.18 | 3.25 | 3.92 |
| #327 | 17 | 2.25 | 3.27 | 2.63 | 2.99 | 3.28 | 2.88 | | 0.19 | 2.80 | 2.35 | 2.61 | 3.02 | 2.19 |
| #326 | 14 | 2.45 | 2.39 | 2.11 | 1.67 | 1.96 | 2.12 | | 2.03 | 2.11 | **15.2** | 1.51 | 1.83 | 4.54 |
| #117 | 11 | 0.69 | 0.59 | 0.70 | 1.17 | 1.38 | 0.91 | | 0.62 | 0.51 | 0.62 | 1.03 | 1.15 | 0.79 |
| *x/6* | *RTA>1* | *4* | *4* | *4* | *6* | *6* | *5* | | *3* | *4* | *4* | *4* | *6* | *5* |
| **Canada** | | 96i | 97i | 98i | 99i | 00i | RTAi | | 96a | 97a | 98a | 99a | 00a | RTAa |
| **Class#** | **score** | **ca** | **ca** | **ca** | **ca** | **ca** | **Mean** | | **ca** | **ca** | **ca** | **ca** | **ca** | **mean** |
| #257 | 100 | 0.43 | 0.22 | 0.21 | 0.18 | 0.18 | 0.25 | | 0.62 | 0.29 | 0.24 | 0.24 | 0.20 | 0.32 |
| #330 | 22 | 0.75 | 0.24 | 0.78 | 0.90 | 1.15 | 0.77 | | 1.25 | 0.40 | 0.61 | 1.06 | 1.88 | 1.04 |
| #438 | 22 | 0.24 | 0.10 | 0.15 | 0.08 | 0.11 | 0.14 | | 0.33 | 0.12 | 0.18 | 0.13 | 0.15 | 0.18 |
| #327 | 17 | 0.40 | 0.39 | 0.57 | 0.59 | 0.57 | 0.50 | | 0.07 | 0.69 | 0.94 | 0.67 | 0.64 | 0.60 |
| #326 | 14 | 0.41 | 0.00 | 0.39 | 0.30 | 0.43 | 0.31 | | 1.63 | 0.00 | 0.35 | 0.41 | 0.45 | 0.57 |
| #117 | 11 | 0.00 | 0.78 | 0.31 | 0.00 | 0.00 | 0.22 | | 0.00 | 0.93 | 0.00 | 0.00 | 0.18 | 0.22 |
| x/6 | RTA>1 | 0 | 0 | 0 | 1 | 1 | 0 | | 2 | 0 | 0 | 1 | 1 | 1 |
| ***Netherlands*** | | *96i* | *97i* | *98i* | *99i* | *00i* | *RTAi* | | *96a* | *97a* | *98a* | *99a* | *00a* | *RTAa* |
| **Class#** | **score** | **nl** | **nl** | **nl** | **nl** | **nl** | **Mean** | | **nl** | **Nl** | **nl** | **nl** | **nl** | **mean** |
| #257 | 100 | 0.89 | 0.65 | 0.73 | 0.61 | 0.5 | 0.68 | | 0.07 | 0.00 | 0.00 | 0.00 | 0.04 | 0.02 |
| #330 | 22 | 3.54 | 1.78 | 2.34 | 1.61 | 1.93 | 2.24 | | 1.00 | 1.47 | 0.71 | 0.00 | 0.27 | 0.69 |
| #438 | 22 | 1.09 | 0.23 | 0.49 | 0.48 | 0.27 | 0.51 | | 0.27 | 0.08 | 0.25 | 0.07 | 0.00 | 0.13 |
| #327 | 17 | 1.98 | 1.05 | 1.09 | 0.75 | 0.7 | 1.11 | | 0.05 | 0.77 | 0.20 | 0.19 | 0.00 | 0.24 |
| #326 | 14 | 0.23 | 0.55 | 0.19 | 0.00 | 0.42 | 0.28 | | 1.20 | 0.37 | 0.00 | 0.00 | 0.00 | 0.31 |
| #117 | 11 | 0.55 | 0.00 | 0.00 | 0.00 | 0 | 0.11 | | 0.73 | 0.00 | 0.56 | 0.00 | 0.00 | 0.26 |
| x/6 | RTA>1 | 3 | 2 | 2 | 1 | 1 | 2 | | 2 | 1 | 0 | 0 | 0 | 0 |

*data source: USPTO and this study*

*remarks: tw denotes Taiwan, kr for S. Korea, ca for Canada; nl for the Netherlands*

*x/6 denotes how many classes of 6 classes have RTA>1*

*score denotes the relatedness score searched in Current US Classfication Description.*

**TABLE 6**

**RTAi and RTAa Results for 6 Semiconductor Related Classes in 1996-2000 (five years)**

| *1996-2000* | | | *Inventor* | | *RTAi* | | | *assignee* | | *RTAa* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **title/patent counts** | **class#** | **Sco** | **all** | **Tw** | **Kr** | **ca** | **nl** | **all** | **tw** | **kr** | **ca** | **Nl** |
| | total | | 764253 | 19627 | 14360 | 18038 | 6933 | 615633 | 9746 | 13461 | 10158 | 39 |
| Active solid state devices | #257 | 100 | 15420 | 920 | 829 | 83 | 91 | 14994 | 845 | 813 | 71 | 2 |
| Amplifiers | #330 | 22 | 2262 | 17 | 58 | 44 | 44 | 2110 | 18 | 54 | 40 | 8 |
| Semiconductor device mftring: process | #438 | 22 | 16502 | 2597 | 1325 | 48 | 67 | 16085 | 2553 | 1302 | 44 | 11 |
| Mis. Active electrical nonlinear devices | #327 | 17 | 7368 | 158 | 405 | 90 | 70 | 18436 | 155 | 403 | 85 | 13 |
| Electrical digital logic circuitry | #326 | 14 | 2865 | 62 | 109 | 22 | 7 | 2801 | 62 | 285 | 26 | 5 |
| single crytal growth processes | #117 | 11 | 1350 | 12 | 25 | 6 | 1 | 1293 | 8 | 24 | 4 | 2 |
| **title/RTAi or RTAa** | **class#** | | **all** | **Tw** | **Kr** | **ca** | **nl** | **all** | **tw** | **kr** | **ca** | **Nl** |
| Active solid state devices | #257 | 100 | 1.00 | 2.32 | 2.86 | 0.23 | 0.65 | 1.00 | 3.6 | 2.5 | 0.29 | 0.02 |
| Amplifiers | #330 | 22 | 1.00 | 0.29 | 1.36 | 0.82 | 2.14 | 1.00 | 0.5 | 1.2 | 1.15 | 0.58 |
| Semiconductor device mftring: process | #438 | 22 | 1.00 | 6.13 | 4.27 | 0.12 | 0.45 | 1.00 | 10.0 | 3.7 | 0.17 | 0.10 |
| Mis. Active electrical nonlinear devices | #327 | 17 | 1.00 | 0.84 | 2.02 | 0.33 | 0.27 | 1.00 | 1.4 | 4.7 | 0.56 | 0.27 |
| Electrical digital logic circuitry | #326 | 14 | 1.00 | 0.84 | 2.02 | 0.33 | 0.27 | 1.00 | 1.4 | 4.7 | 0.56 | 0.27 |
| single crytal growth processes | #117 | 11 | 1.00 | 0.35 | 0.99 | 0.19 | 0.08 | 1.00 | 0.4 | 0.8 | 0.19 | 0.24 |
| class number of its RTA greater than one | | | | 2 | 5 | 0 | 1 | | 4 | 5 | 1 | 0 |

*data source: USPTO and this study* *reamrks: tw denotes Taiwan; kr for S. Korea; ca for Canada; nl for the Netherlands*
*score means its relevant to 'semiconductor'*

**TABLE 7**
**RTAi and RTAa Results for 6 Semiconductor Related Classes in 2000 (one year)**

| ***2000*** | | | *inventor* | *RTAi* | | | | *assignee* | *RTAa* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **title/patent counts** | **class#** | **Scor** | **all** | **tw** | **kr** | **ca** | **nl** | **all** | **tw** | **kr** | **ca** | **Nl** |
| | Total | | 176350 | 5976 | 3561 | 4304 | 1661 | 146032 | 3516 | 3285 | 2592 | 952 |
| Active solid state devices | #257 | 100 | 4057 | 349 | 221 | 18 | 19 | 3971 | 337 | 220 | 14 | 1 |
| Amplifiers | #330 | 22 | 604 | 5 | 22 | 17 | 11 | 570 | 5 | 25 | 19 | 1 |
| Semiconductor device mftring: process | #438 | 22 | 5425 | 1033 | 398 | 15 | 14 | 5300 | 1011 | 387 | 14 | 0 |
| Mis. Active electrical nonlinear devices | #327 | 17 | 1812 | 45 | 120 | 25 | 12 | 1750 | 50 | 119 | 20 | 0 |
| Electrical digital logic circuitry | #326 | 14 | 759 | 18 | 30 | 8 | 3 | 751 | 21 | 31 | 6 | 0 |
| single crytal growth processes | #117 | 11 | 322 | 4 | 9 | 0 | 0 | 308 | 1 | 8 | 1 | 0 |
| **title/RTAi or RTAa** | **class#** | | **all** | **tw** | **kr** | **ca** | **nl** | **all** | **tw** | **kr** | **ca** | **Nl** |
| Active solid state devices | #257 | 100 | 1.00 | 2.54 | 2.70 | 0.18 | 0.50 | 1.00 | 3.52 | 2.46 | 0.20 | 0.04 |
| Amplifiers | #330 | 22 | 1.00 | 0.24 | 1.80 | 1.15 | 1.93 | 1.00 | 0.36 | 1.95 | 1.88 | 0.27 |
| Semiconductor device mftring: process | #438 | 22 | 1.00 | 5.62 | 3.63 | 0.11 | 0.27 | 1.00 | 7.92 | 3.25 | 0.15 | 0.00 |
| Mis. Active electrical nonlinear devices | #327 | 17 | 1.00 | 0.73 | 3.28 | 0.57 | 0.70 | 1.00 | 1.19 | 3.02 | 0.64 | 0.00 |
| Electrical digital logic circuitry | #326 | 14 | 1.00 | 0.70 | 1.96 | 0.43 | 0.42 | 1.00 | 1.16 | 1.83 | 0.45 | 0.00 |
| single crytal growth processes | #117 | 11 | 1.00 | 0.37 | 1.38 | 0.00 | 0.00 | 1.00 | 0.13 | 1.15 | 0.18 | 0.00 |
| class number of its RTA greater than one | | | | 2 | 6 | 1 | 1 | | 4 | 6 | 1 | 0 |

*data source: USPTO and this study*

*reamrks: tw denotes Taiwan; kr for S. Korea; ca for Canada; nl for the Netherlands*
*score means its relevant to 'semiconductor'*

# CHAPTER 5:

## FINAL CONCLUSION AND SUMMARY

### I. FINAL SUMMARY AND OVERALL CONTRIBUTIONS

#### 1.1 Overall Contributions and Research Findings

- Could be or could not be?

As the title of this dissertation implies, our purpose in writing the three essays is to contribute to our better understanding of the aspects, or the processes, of building technological capability through building good measurement indicators of technological capabilities that are used in conjunction with the emerging availability of information on the Internet for knowledge discovery in database (abbreviated as KDD, Norton, 2000). KDD refers to a series of processes involved in scooping out any golden opportunity (Patterson, 2000), from any collection in a mountain of data in any format or media. Among them, data-mining and text-mining are two major tools.

Particularly, there is always a cutting edge *research frontier* (Price, 1963 & 1965b) within the state-of-a-field. All researchers in normal science, need to have several research *paradigms* (Kuhn, 1962) both to provide them with firm research foundations in avoiding infinite twin regress of meaning and truth (Lakatos, 1978) and to explain *constellation* of facts, theories and methods (Kuhn, 1962: 1). The consequence of measurement is a refinement of theory. Before his death, Price (1983) maintained that advances in science and technology are the results of the need to explain new empirical data generated by improvements in new measurement systems.

In Kuhn's (1962) normal science, the three classes of research problems are: i) determining significant facts, ii) matching facts with theories, and then iii) refining and articulating the theory. There have always been well-developed paradigms in related literature with regard to patenting and technology studies. The 'probable true answer' however, belonging to tinkers[1] (Issacson, 1999), is that the measurement systems of patent statistics "could be" used as indirect indicators of technology, if not as measures of technological capabilities, which extend them

[1] In a special *Time Magazine* issue on *The Century's Greatest Minds*, Issacson (1999) maintains in editor's introduction that there is no right answers to debates of tinkers or thinkers have more influential, such as

beyond direct indicators of invention (Seguin-Dulude and Amesse, 1985). In the hierarchy of concepts, for which patent statistics could be used, invention must be considered at the lowest level. Patent cases represent quanta of advances in technological knowledge and a family of related patents should be viewed as the bricklaying of technological capabilities and therefore at a higher level in Kuhn's hierarchy. Following the same logic, one agrees that each single contribution of our manuscripts represents at least a quantum of advances in scientific information in the scholarly bricklaying above the quantum value (Price, 1965b).

Because of the increasing availability of on-line information and Internet technologies, we have had much richer opportunities to develop new measurement systems (Price, 1983) with higher validity and reliability than the conventional patent statistics that we had before. Our three essays are prototypical examples for future potential data-mining tools for on-line or off-line searches, as we have had the opportunity of exploring publicly available patent databases for an *unusually long* period of time in an *extremely detailed* break-down (Pakes, 1985) in the process of theory-refining and empirical studies for practitioners' uses. By bringing the two perspectives of "data-mining into knowledge" and "knowledge work", we have revealed more technological capabilities. Purposefully, these kinds of new measures of technological capability with higher satisfied power of revealing, will help practitioners in technology management (i.e. technology and innovation managers as well as R&D scientists and engineers) to become better equipped with measures and tools as well as concepts for better strategic or tactical planning, organizing and controlling their management practices.

### 1.2 Revealing More of the Moose and the Elephant

Earlier economists, from Schumpeter (1934 & 1939) to Schmookler (1950-1972) and more recently Acs (1989) & Griliches (1989) have long wished for rich theoretical growth with empirical insights for technological progress like "foliage in the Vietnam Jungle (Scherer, 1965)". Although Leonard-Barton (1992b) has recently used another metaphor of seeing "the moose on the kitchen table", it is impossible to see the whole picture in all its dimensions from various perspectives, whether in the thick foliage of a jungle or a moose on a table, in this field. Instead of moose or foliage, we would like to use the proverbial, imaginary "elephant". Our challenge was how to reveal "more" of it by whatever inter-disciplinary method to give a better

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Shakespear or Luther?; Elizabeth or Mogul Akbar? Megallan or Michelangelo?

understanding of the topic of this research—i.e. the technological capability-- in order to contribute to the field (Narin, Albert & Smith, 1992 and Narin, Noma & Perry, 1987) for this age of strategic management of technology (Narin, Albert & Smith, 1992 and Narin, Noma & Perry, 1987).

### 1.3 Overall Contributions of Three Essays

Generally speaking, our contributions in three essays are divided between developing new concepts in patent methodology for practical application and testing of those concepts (and their associated hypotheses), roughly in a one-to-one ratio, as shown in a summary table of contributions below. Based on our new developmental concepts, we have formulated and introduced a series of methodologies in terms of a number of new *indicators and measurements* under the title of *"patent calculation"* in paper No. 1 following the new concept of "data-mining into knowledge" and "knowledge work". These methodologies are designed to detect and reveal the facets of *technological capabilities* and examine the patterns of *global collaboration* underlying patented inventions with a family of related multiple indicators, which were themselves based on the newly-devised concepts and their practical operationalizations. We then proposed a set of hypotheses and tested them as well.

In paper No. 2, we studied the developmental *pattern of technological capabilities* in a selected number of countries, *in relation to their markets and industrial structures*. This paper confirms the strong contribution of small entrepreneurs (in the form of individual inventors, and/or small firms), participating in the patenting process. Even in advanced industrialized countries we found the strong footprints of their contributions. Their presence was detected and measured by the indicator of "no assignee rate" first designed by our research for on-website mining of the *longest and most detailed* (Pakes, 1985) USPTO databases[2].

In paper No. 3, we provide the evidence for selective concentration and specialization in patent-intensive industries in a sample of newly industrializing countries using the index of Revealed Technological Advantage (RTA), which has been used as the conventional indicator of technological advantage in large industries since the 1960s in technology-centered studies. However, our research found that this measure has its own inherent complexities, which are not

[2] These external knowledge bases are characterized as "unusually long and extremely detailed" (Pakes, 1985),

documented in the literature, that impact both the analysis and the results. Thus it must be applied with care and results must be interpreted carefully, especially for comparisons between the different concepts of data mining and conventional statistics.

In summary, the *patent calculation* in paper No. 1 allowed us to identify new relevant concepts with associated measures and indices to provide both a rich context and methodology for exploring a wide spectrum of issues related to inventive activities *embedded in patent data-bases*. They range from *micro-level* (i.e. the role and the extent of contribution of small entrepreneurs to countries' technological capabilities -- in paper No. 2) to *macro-level* (i.e. the role of global collaboration -- in paper No. 1) to *concentration/specialization* as well as *broad participation* in international markets by many firms -- in paper No. 3.

**Table 1: Summary of Specific and Overall Contributions**

| | **Methodological Issues** | **Practical findings / Implications** |
|---|---|---|
| Introductory chapter | Brings two perspectives of data-mining and knowledge work into the understudied topic of technological capability.<br>Proposed a Knowledge Network of Patenting and Technology Studies.<br>Provided an "Overview" of the Literature | The application and value of patent databases as external knowledge base for knowledge workers in knowledge economy are discussed.<br>30 key-nodes charts and overview in the knowledge network. |
| Essay No. 1 | A family of new indicators for an on-line search logic design based on the duality of inventor and assignee in a patent:<br>Co-invention index<br>Co-assignment index<br>Joint Invention<br>Joint Assignment<br>No Assignee Rate<br>Joint Invention and Joint Assignment. | Technological collaboration within same country: the trend is increasing in the long time series in both co-invention or co-assignment,<br>Technological collaboration across country borders: the trend is increasing in the long time series for joint-invention and joint-assignment,<br>The contribution of SMEs from major patenting countries is still significant in US. |
| Essay No.2 | Technological Capabilities and Technological Concentration of patent counts (Patent C4 and C20) versus firm sale size (sales C4 and C20)<br>No Assignee Rate | Evidence of small entrepreneurs contributing to technological capabilities acumulated by two industrial models: larger number of smaller Taiwanese SME versus smaller number of South Korean large Chaebols. |

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which have existed since 1790 and with a breakdown as detail as application forms (full-texts and full images).

| | | |
|---|---|---|
| Essay No.3 | Introduction of two different version of RTAs (RTAi; RTAa) with special care for small technological cases and short term | Inherent Complexity of RTA as an index of technological specialization leading to erroneous conclusions, if undetected. |
| Concluding | Revealing more by continued improvements in concepts, methodology and measurements for strategic technology management. | Unlimited possibility of improvements in the Web age of information through the use of search engine and data-mining tools |

### 1.4 Theoretical and Empirical Contributions

Taken collectively, our three papers on aspects of patents and technology-based capabilities have modestly pushed forward the research frontier from crude database mining into at least a basis for acquisition of knowledge (or meta-knowledge[3]), if not the knowledge itself[4]. We have developed both the necessary theoretical conceptualization and practical measures (absent in the literature) for empiricism to assist us in detecting patterns of concentration, specialization and collaboration in technology-based capabilities (also absent in the literature). We certainly hope that several years after publication, at least one of these three papers would become a high-impact, influential and important paper with a high citation count within the emerging sub-field of patent and technology studies. Generally speaking, all of our findings are consistent with the foundations and theory essentials of "resource or knowledge-based theories" of the firm (and studies) in the related literature.

## II. LIMITATIONS AND AGENDA FOR FUTURE RESEARCH

### 2.1 The Need to Triangulate by Deep Field Study for Complementing Multi-method Approach

All of three essays are explorative and analytical in nature. Our proposed methodology is very quantitative, designed for taking advantage of the new availability of the USPTO website and associated with the emerging data-mining-into-knowledge concepts and tools. From the viewpoint of the *multi- method approach* (Brewer and Hunter, 1989) and the so-called *triangulation* (Eeaterby-Smith, Thorpe and Lowe, 1991) methodology, our research findings,

[3] This kind of meta-knowledge is concise and concrete knowledge about rich technological knowledge. Likewise, as meta-research refers to research on concise and concrete knowledge of scientific research.

[4] In Spender's (1996) Topology of Knowledge, explicit knowledge store in databanks, manuals and so on is referred as objectified knowledge. Tacit knowledge (Polanyi, 1966) refers another tacit dimension that in nature is

particularly for the understanding of an overall picture of technological capabilities, should be taken as preliminary as they do not satisfy the requirements of multi-method triangulation. This can be viewed as a limitation.

Methodological debates in the social sciences are always healthy signs. Skepticism is an essential part of scientific inquiry, and application of different methods may lead to important critical perspectives. In scientific methodology, *triangulation*, a term borrowed from navigation and survey, entails using multiple but independent measures from independent methods. All of our papers advocate and use at least one (though it might be said more) of the four methods for triangulation -- data, theoretical, investigator, and methodological one. In other words, the other three are implicitly missing, and need to be introduced and then triangulated explicitly for confirming our exploratory findings, which is a part of our future research agenda. Eventually, data-triangulation as in our patent-search, will be the most cost-effective method of identifying technological capabilities, while patent statistics may remain as the most important technology indicators.

Furthermore, our interpretations of research findings are preliminary in nature and subject to traditional disadvantages associated with secondary data, as the purposes of patent databases were for examining inventions rather than for economic and managerial decisions. Our proposed interpretations in this dissertation are limited, as is the case for all quantitative research which lack qualitative properties for explicit theory building[5]. After all, interpretation can help theory building. However, theory building must be done within the same paradigm. At least one of Kuhn's three classes of research problems -- determining the significant facts of trends -- was explicitly done in our thesis, while matching and refining the old theories of paradigm were only implicitly elaborated upon. There is a need for more research to triangulate our findings by deep fieldwork, surveys and possible experimentations[6]. Our new empirical data must be taken as the initial stages of data-mining into knowledge and knowledge work to form a

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conscious, automatic, and collective impossible or difficult to articulate explicit.

[5] The normal criticism of quantitative research by qualitative people is always in tones like "good in data, bad in theory", with narrow viewpoint of data-theory cycle have been demonstrated and enlarged by great Kuhn's (1962) paradigm, Lakatos' (1978) firm foundations and practical triangulation, both meta-theoretically and methodologically in philosophy of science.

[6] Non-interactive data, fieldwork, survey and experiment are four chief styles of social research.

fresh quantitative evidence of revealed technological capability rather than imaginary leaps[7] based on few cases resulting in un-testable conjectures (Kuznets, 1972).

As stated earlier, the basic research limitations come from secondary data in general and patent statistics in particular. While secondary data is always non-interactive and non-destructive with higher reliability, it is collected for other legitimate purposes. Such data may suffer from potential validity problems that must be resolved with a lot of costly deep fieldwork and survey studies, which are only possible upon sufficient research funds[8] to help interpretations in addition to refining patent calculations.

In retrospect, traditional patent statistics are well debated in existing literature, as reviewed in the introductory chapter and in the three essays of this thesis, which did not expose us to unforeseen risks. Advice for future research is to combine *quantitative and qualitative* methods (Lee, 1989) following the same paradigms of the inter-disciplinary field of patenting and technology studies (see the total 30 knowledge-intensive key-nodes reviewed in a overview in Appendix IV to chapter 1) whenever possible; and also to move across paradigms (e.g. innovating organization) occasionally, but with care. Therefore, our fundamental suggestion is that our research findings should be complemented and triangulated by questionnaires and interviews in deep fieldwork and survey studies in Taiwan, South Korea and Canada, and then compared to the traditional qualitative research methodology in order to develop a better understanding in the more downwardly-oriented levels of analysis—e.g. from industry to company and to group team level. Basberg (1987) claimed that the study of patent data at the lower level of aggregation (i.e. firm) would be less noisy than higher levels (industry or country).

[7] Quantitative evidence rather than the criticism of imaginary leaps into un-testable conjecture by few cases was described the significant contributions of pioneer Schmookler's ambition by Kuznets (1972). Out of question, we can feel a as similar criticism as Schmookler faced in 1960-1967, leaving unpublished working papers and "data" destined to be collected in his memorial book called—*Patents, Invention and Economic Changes: Data and Selected Essays by Jacob Schmookler* edited by Griliches and Hurwicz (1972). Ironically enough, there are so many patent data and previously unpublished papers in this book after a short academic life in 49 years old (1950-1967). He is definitely a decisive figure in creating a paradigmatic shift towards a structural change of scientific revolution (Kuhn, 1962) in a field of patenting and technology studies.

[8] After all, the basic argument of multi-method approach and triangulation is limited research fund for given researcher at given time period for given fund supplier.

### 2.2 Problem of Aggregation in the Unit of Analysis

Research based on secondary data may suffer problems associated with the unit of analysis. The original purpose of collecting patent documents and their associated statistics were for patent examination and government statistics. When we use them in research, we must be very careful about the interpretation of results due to the difference in the unit of analysis and aggregation. Seguin-Dulude & Amesse's review (1985) examined the various problems of comparison when using aggregated science and technology indicators based on patent statistics. A series of UK based studies at SPRU (Patel, 1996; Patel, 1995 and Patel and Pavitt, 1991) concluded that there is no systematic evidence for *globalization of technology generation* along with the globalization of marketing and production for most multinational corporations (MNCs). The unit of analysis of their studies was about 500 multinationals, over which they aggregated their own databases. They should have recognized that patent statistics can capture technological activities undertaken ouside of MNC's R&D departments, such as design activites in small firms, and production engineering in large firms. In other words, aggregation across all assignees, even in a single multinational may be problematic in a patent database. Their conclusions were based on the assumption of the multinational's domination in technology generation rather than following our full sampling and search of the problem without such assumptions. With the above methodological principles of triangulation and multi-method approach, other detailed refinements might include designing good search engines, whether on or off-line.

### 2.3 Designing Good Search Engines for Future Research

There has been dramatic progress in Internet and database software technology since the grand launch of the Worldwide Web (WWW) in early 1990s[9]. While the data for all of three essays was extracted by the most fundamental of search engines on the Web, called *Advanced Boolean Logic*[10](USPTO, 2001a and 2001b), we have seen an increasing availability of software on the market for data-mining, text-mining or knowledge discovery in a database since

[9] The Worldwide Web (WWW) was developed and founded at CERN (Switzerland) in 1989, while the Mosaic Web browser, the earlier version of currently popular Netscape, was developed later at a US supercomputer center in the beginning of 1990s.
[10] This the term used by USPTO in our data compilation period of Oct-Dec, 1997. Now they change this search into "Manual Search (USPTO, 2001a)."

1997. We are planning to apply for a research grant to the Canadian, Taiwanese and South Korean governments in order to buy, modify and even design brand-new search engines, closely related to data-mining of technology-oriented knowledge, to uncover information and knowledge (meta-knowledge) hidden in the data mountains of patent documents. That sufficiently large research grant will equip us with more research resources to purchase dataset from the USPTO and design our own search custom-tailored engines[11] (Instantis Inc, 2001) to reveal more (or higher) aspects of technological capabilities. In other words, we will be able to increase the power of revealing capabilities in our future research agenda.

### 2.4 Summary

In closing, our contributions in this thesis have laid the brickwork or the foundations upon which researchers, including ourselves, can build strongly. Our new methodology can also constitute a legitimate method in a multi-method approach for building the grand theory of technological capabilities (which is a part of our future research agenda). Although the potential limitations, which we have pointed out in this concluding chapter, are inherent to exploratory research, they should be rectified along the lines suggested here to confirm our findings.

### 2.5 Our Final Thought

After finishing the last section of research travel and effortful writing, it is time for us to make a sweet pause rather at the end, since all researchers have a bitter deadline for preparing their 'ugly' drafts for submission in order to "meet their parent-in-laws on time" (a classic metaphor in Taiwan). As knowledge workers, we should be happy to enjoy our fruitful gains throughout this research at the initial phases of the "data-mining into knowledge" journey. The objective of this thesis was to shed light on the emerging knowledge network of patenting and technology studies so that more researchers can clearly see their way. We hope to have cleared the way for gaining further clarity as well as knowledge of our own in this journey.

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[11] The search engine term refers to various type of search logics (mostly Boolean) on-the web or off-line data-mining (Instantis Inc., 2001). While the term "algorithm" usually refers to mathematical solution logics (flowchart) for programming through computation, in the recent search engine software companies has developed various technologies also called algorithm (Venkat, 2001) for determining the relevance and rankings for a given key word search. Search engine might be installed internally on the given website or externally all available websites around the Worldwide Web. In the present the Web grows by an estimated 6 million documents a day and with search engines indexing less than half of the Web (Instantis Inc, 2001). In effect, as a Webmaster you are creating tempting spider food for various arachnids-(spider-like) search engine to craw the Web.

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## Appendix I: Most Important Documents Of KN Patent Studies (70-100 Documents Of 40-60 Authors).

Remarks: fq column denotes total citations of this document, in which column b refers to book (b) or journal article (j)) cited by a source sample of 1069 journal articles in 1992-1999 SSCI collection. But the 'see' in this column refers to another document by same highly-cited author during our exploration of his or her publications in ABI database or Amazon website.

**Full Tittles of Highly-Cited Documents KN Patent Studies**

| | | | Books | | |
|---|---|---|---|---|---|
| fq | year | b | Authors | Publisher | Title |
| See | 1832 | B | Babbage-C | London: C.Knight | On the Economy of Machinery and Manufactures |
| 15 | 1942 | b | Schumpeter-JA | NYC: Harper&Row | Socialism, Capitalism, and Democracy |
| See | 1958 | B | Cartter-CF&Williams-BR | London: Oxford Univ P | Investment in Innovation |
| See | 1958 | J | Jewkes-J, Sawers-D&Stillerman-R | London: MacMillan | The Sources of Invention. |
| 12 | 1959 | b | Penrose-ET | UK: Oxford Univ Press | The Theory of the Growth of the Firm |
| 32 | 1962 | b | Arrow-KJ chapter | Princeton Univ | Economic Wellfare and the Location of Resources for Invention, in NBER book by Nelson-RR ed. The rate and Direction of Inventive Activity: Economic and Social factors |
| 40 | 1966 | b | Schmookler-J | Harvard Univ | Invention and Economic Growth |
| see | 1972 | b | Griliches-Z &Hurwicz-L eds | Harvard Univ | Patents, Invention and Economic Change: Data and Selected Essays by Schmookler-J |
| 31 | 1969 | b | Nordhaus-WD | MIT Press | Invention, Growth and Welfare: a Theoretical Treatment of Technological Change |
| 16 | 1973 | b | Taylor-CT? | Cambridge Univ | The Economic Impact of the Patent System: a Study of the British Experience |
| 10 | 1976 | b | Rosenberg-N | Cambridge Univ | Perspectives on Technology |
| 15 | 1980 | b | Scherer-FM(1970/1990) | Univ Chicago | Industrial Market Structure and Economic Performance |
| 14 | 1982 | b | Freeman-C(1997) | MIT Press | The Economics of Industrial Innovation |
| 18 | 1982 | b | Kamien-MI&Schwartz-NL | NYC: Cambridge Univ Pre | Market Structure and Innovation |
| 30 | 1982 | b | Nelson-RR&Winter-S | Harvard Univ | An Evolutionary Theory of Economic Change |

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|---|---|---|---|---|---|
| 14 | 1982 | b | Rosenberg-N | NYC: Cambridge Univ | Inside the Black Box: Technology and Economics |
| 11 | 1984 | b | Bound-J, Cummins-C, Griliches-Z, Hall-BH & Jaffe-AB chapter | NBER Univ Chicago Press | Who Does R&D and Who Patents? in NBER by Grilichez-Z ed. R&D, Patents, and Productivity |
| 10 | 1984 | b | Dutton-HI | Manchester Univ | The Patent System and Invention Activity during the Industrial Revolution, 17501852 |
| 15 | 1984 | b | Griliches-Z ed. Change name? | NBER Univ Chicago Press | Innov-Growth-Econ (R&D, Patents and Productivity) |
| 11 | 1984 | b | Scherer-FM | MIT Press | Innovation and Growth: Schumpeterian Perspective |
| see | 1984 | b | Dosi-G | NY: St. Martin's Press | Technical Change and Industrial Transformation |
| 12 | 1988 | b | Dosi-G, Freeman-C, Nelson-RR et al. | London: Pinter Pub | Technical Change and Economic Theory |
| 12 | 1988 | b | Pavitt-K chapter | NYC: North-Holland | Uses and Abuses of Patent Statistics, in Van Raan ed. HDB of Quant Stud S&T |
| 20 | 1988 | b | Tirole-J | MIT Press | The Theory of Industrial Organization |
| 13 | 1990 | b | Dosi-G | NYU Press | The Economics of Technical Change and International Trade |
| 23 | 1990 | b | Porter-ME(1985) | Free Press | Competitive Advantage: Creating and Sustaining Superior Performance |
| 16 | 1990 | b | Scherer-FM& Ross-D (also 1980) | Boston, MA: H. Mifflin | Industrial Market Structure and Economic Performance |
| 33 | 1991 | b | Grossman-GM | MIT Press | Innovation and Growth in the Global Economy |
| 11 | 1991 | b | Krugman-PR | MIT Press | Geography and Trade |
| 10 | 1992 | b | Archibugi-D&Pianta-M | Kluwer Pub | The Technological Specialization of Advanced Countries: a Report EEC on International Scienceand Technological Activity |
| 11 | 1992 | b | Grupp-H ed. | Berlin: Springer | Dynamics of Science Based Innovation |
| 10 | 1993 | b | Neslon-RR | Oxford Univ | National Innovation Systems: a Comparative Analysis |
| see | 1995 | b | Ostry-S&Nelson-RR | DC: Brookings | Techno-Nationalism andTechno-Globalism: Conflict and Cooperation |
| | | | **Journal Articles** | | |
| see | 1926 | j | Kondratieff-ND(1926/1935) | REconStat 17(6): 105-115 | The Long Waves in Economics Life |
| See | 1950 | J | Schmookler-J | JPatOfficeSoc | The Intrepretation of Patent Statistics |
| see | 1957 | j | Schmookler-J (1957) | REconStat 39: 321-333 | Inventors Past and Present |
| see | 1957 | j | Solow-RW(1957) | REconStat 39:312-320 | Technical Change and the Aggregate Production Function |
| See | 1959 | j | Nelson-RR earliest review? | J of Business | The Economics of Invention: a Survey of the Literature |

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| 13 | 1960 | j | Coase-RH | JLawEcon 3: 1-44 | The Problem of Social Cost |
| See | 1963 | J | Griliches-Z&Schmookler-J | AER 53(4): 725-729 | Inventing and Maximizing |
| 14 | 1965 | j | Scherer-FM | AER 55(5): 1097-1123 | Firm Size, Market Structure, Opportunity, and the Output of Patented Invention |
| 10 | 1966 | j | Vernon-R | QJEcon 80: 190-207 | International Investment and International Trade in the Product Cycle |
| 10 | 1972 | j | Nordhaus-WD | AER 62: 428-431 | The Optimum Life of a Parent: Reply |
| 10 | 1972 | j | Scherer-FM | AER 62: 422-427 | Nordhaus' Theory of Optimal Patent Life: a Geometric Reinterpretation |
| see | 1976 | j | Vernon-R | OxBEconStat 41:255-67 | The Product-Cycle Hypothesis in a New International Environment |
| 16 | 1979 | j | Loury-G | QJEcon 93: 395-410 | Market Structure and Innovation |
| 13 | 1980 | j | Lee-T&Wilde-L | QJEcon 94:429-436 | Market Structure and Innovation: a Reformulation |
| 34 | 1981 | j | Mansfield-E,Schwartz-M&Wagner-S | EconJ 91:907-918 | Imitation Costs and Patents: an Empirical Study |
| 18 | 1982 | j | Gilbert-RJ&Newbery-DMG | AER 72(3): 514-526 | Preemptive Patenting and the Persistence of Monopoly |
| 15 | 1983 | j | Scherer-FM | IJIndOrg 1:107-128 | The Propensity to Patent |
| 18 | 1984 | j | Hausman-J, Hall-BH&Griliches-Z | Ecomet 52(4): 909-938 | Econometric Models for Count Data with an Application to the Patent-R&D Relationship |
| 16 | 1984 | j | Pavitt-K | ResPol 13:343-373 | Sectoral Paterns of Technical Change |
| 14 | 1984 | j | Schankerman-M&Pakes-A | EconJ 96:1052-1076 | Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period |
| see | 1985 | j | Harris-C&Vickers-John | JIndEcon 33(4): 461-481 | Patent Races and Persistence of Monopology |
| 12 | 1985 | j | Katz-ML&Shapiro-C | Rand 16(4): 505-520 | On the Licensing of Innovations |
| 10 | 1985 | j | Narin-F&Noma-E | Scimet 7:369-381 | Is Technology Becoming Science? |
| 14 | 1985 | j | Pakes-A | JPolEcon 93:390-409 | On Patents, R&D, and the Stock Market Rate of Return |
| 20 | 1985 | j | Pavitt-K | Scimet 7:77-99 | Patent Statistics as Indicators of Innovator Activities: Possibilities and Problems |
| 11 | 1986 | j | Chisum-DS | UPittsburghLR 47:959-1022 | The Patentability of Algorithms |
| 20 | 1986 | j | Hall-BH, Griliches-Z& Hausman-JA | IEconRev 27(2): 265-283 | Patents and R and D: Is There a Lag |
| 35 | 1986 | j | Jaffe-AB | AER 76(5): 984-1001 | Technological Opportunity and Spillovers of R&D: Evidence form Firm's Patent, Profits, and Market Value |
| 31 | 1986 | j | Mansfield-E | MgtSci 32(2):173-181 | Patent and Innovation: an Empirical Study |
| 14 | 1986 | j | Pakes-A | Econmet 54(4): 755-784 | Patents as Options: Some Estimates of the Value of Holding European Patent Stocks |

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| 15 | 1986 | j | Romer-PM | JPolEcon 94:1002-37 | Increasng Returns and Long-Turn Growth |
| 17 | 1986 | j | Teece-DJ | ResPol 15: 285-305 | Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy |
| 27 | 1987 | j | Basburg-BL | ResPol 16:131-141 | Patents and the Measurement of Technological Change: a Survey of the Literature |
| 57 | 1987 | j | Levin-RC, Klevorick-AK, Nelson-RR&Winter-SG | Brookings 3: 783-820 | Appropriating the Returns from Industrial Research and Development |
| 27 | 1987 | j | Narin-F,Noma-E& Perry-R | ResPol 16:143-155 | Patents as Indicators of Corporate Technological Strength |
| see | 1987 | j | Sirilli-G | ResPol 16: 157-174 | Patents and Inventors: a Empirical Study |
| 11 | 1987 | j | Soete-L | ResPol 16:101-130 | The Impact of technological Innovation on International Trade Patterns: the Evidence Reconsidered |
| 15 | 1988 | j | Acs-ZJ&Audresch-DB | AER 78(4): 678-690 | Innovation in Large and Small Firms: an Empirical Analysis |
| 17 | 1988 | j | Dosi-G | JEconLit 26:1120- | Sources, Procedures, and Microeconomic Effects of Innovation |
| 23 | 1989 | j | Cohen-WM&Levinthal-DA | EconJ 99: 569-596 | Innovation and Learning: the Two Faces of R&D |
| 26 | 1989 | j | Eisenberg-RS | UChicagoLR 56:1017-86 | Patents and the Progress of Science: Exclusive Rights and Experimental Use |
| 12 | 1989 | j | Jaffe-AB | AER 79(5): 957-970 | Real Effects and Academic Research |
| 10 | 1989 | j | Landes-WM&Posner-RA | JLegStu 18:325-363 | An Economic Analysis of Copyright Law |
| 11 | 1990 | j | Cohen-WM&Levinthal-DA | ASQ 35: 128-152 | Absorptive Capability: a New Perspective on Learning and Innovation |
| 30 | 1990 | j | Glibert-R and Shapiro-C | Rand 21(1) 106-112 | Optimal Patent Length and Breadth |
| 84 | 1990 | j | Griliches-Z | JEconLit 28(4): 1661-1707 | Patent Statistics as Economic Indicators: a Survey |
| 36 | 1990 | j | Kelmperer-P | Rand 21(1) 113-130 | How Broad Should the Scope of Patent Protection be? |
| 44 | 1990 | j | Merger-RP&Nelson-RR | ColumLawR 90(4):839-916 | On the Complex Economics of Patent Scope |
| 10 | 1990 | j | Samuelson-P | EmoryLawJ 39:1025-1154 | Benson Revisited: the Case Against Patent Protection for Algorithms and Other Computer-Related Inventions |
| 17 | 1990 | j | Scotchmer-S&Green-J | Rand 21(1) 131-146 | Novelty and Disclosure in Patent Law |
| 10 | 1990 | j | Segerstrom-PS, Anant-TCA&Dinopoulos | AER 80(5): 1075-1091 | A Schumpeterian Model of the Product Life Cycle |
| 16 | 1990 | j | Trajtenberg-M | Rand 21(1): 172-187 | A Penny for Your Quotes: Patent Citations and Value of Innovations |

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|---|---|---|---|---|---|
| 14 | 1990 | j | Waterson-M | AER 80(4): 860-869 | The Economics of Product Patents |
| 21 | 1991 | j | Albert-MB,Avery-D, Narin-F&McAllister-P | ResPol 20:251-259 | Direct Validation of Citation Count as Indicators of Industrial Important Patents |
| 12 | 1991 | j | Ordover-JA | JEconPer 5(1): 43-60 | A Patent System for Both Diffusion and Exclusion |
| 13 | 1991 | j | Patel-P&Pavit-K | JIBS 22(1): 1-21 | large Firms in the Prodcution of the World's Technology: an Important Case of "Non-Globalisation" |
| 28 | 1991 | j | Scotchmer-S | JEconPer 5(1): 29-41 | Standing on the Shoulders of Giants: Cumulative Research and the Patent Law |
| 12 | 1992 | j | Archibugi-D | SciPubPol 19:357-368 | Patenting as Indicator of Technological Innovation: a Review |
| 13 | 1992 | j | Gallini-NT | Rand 23(1): 52-63 | Patent Policy and Costly Imitation |
| 13 | 1992 | j | Grady-MF&Alexander-JL | VirginiaLawR 78:305-350 | Patent Law and Rent Dissipation |
| 10 | 1992 | j | Griliches-Z&Hjorth-Andersen-C | ScanJEcon 94:29-50 | The Search for R&D Spillovers: Comment |
| 10 | 1992 | j | Ko-YS | YaleLawJ 102:777-804 | An Economic Analysis of Biotechnology Patent Protect |
| 14 | 1992 | j | Narin-F&Olivastro-D | ResPol 21:237-249 | Status Report: Linkage Between Technology and Science |
| 20 | 1993 | j | Jaffe-AB,Trajtenberg-M&Henderson-R | QJEcon 108: 577-598 | Geographical Location of Knowledge Spillovers as Evidence by Patent Citations |
| 10 | 1994 | j | Samuelson-P, Davis-R, Kapor-MD&Reichman-JH | ColumLawR 94(8):2308-2431 | A Manifesto Concerning the Legal Protection of Computer Programs |
| see | 1994 | j | Bohn-RE | SloanMJ 36(1):61-73 | Measuring and Managing Technological Knowledge |
| 11 | 1995 | j | Chang-HF | RandJEcon 26(1):34-57 | Patent Scope, Antitrust Policy and Cumulative innovation |
| 15 | 1995 | j | Green-JR&Scotchmer-S | RandJEcon 26(1) :20-33 | On the Division of Profit in Sequential Innovation |
| 10 | 1995 | j | Lerner-J | JLawEcon 38:463-495 | Patenting in the Shadow of Competitors |

# Appendix II: Top 30 KN-PatStud Key-nodes (Scholars)

Remarks: It is with their representative contributed document in chronological order, in alphabetical order (left side) and in frequency order (right side) in de-noised KN-PatStud citation sample searched with related keywords from SSCI 1992-1999.

| *Fq* | *Keynodes* | * | *Representative document in chronological order (year and its frequency)* | | | | * | *fq* | *keynodes* |
|---|---|---|---|---|---|---|---|---|---|
| 32 | Arrow-K* | * | 32 | 1962 | b | Arrow-KJ chapter | * | 65 | Scherer-F* |
| 40 | Schmookler-J* | * | 40 | 1966 | b | Schmookler-J | * | 21 | Albert-M* |
| 41 | Nordhaus-W* | * | 31 | 1969 | b | Nordhaus-WD | * | 32 | Arrow-K* |
| 65 | Mansfield-E* | * | 34 | 1981 | j | Mansfield-E,Schwartz-M&Wagner-S | * | 38 | Scotchmer-S* |
| 18 | Kamien-M* | * | 18 | 1982 | b | Kamien-MI | * | 18 | Kamien-M* |
| 40 | Nelson-R* | * | 30 | 1982 | b | Nelson-RR&Winter-S | * | 33 | Grossman-G* |
| 24 | Rosenberg-N* | * | 14 | 1982 | b | Rosenberg-N | * | 24 | Rosenberg-N* |
| 18 | Hausman-J* | * | 18 | 1984 | j | Hausman-J, Hall-BH&Griliches-Z | * | 18 | Hausman-J* |
| 28 | Pakes-A* | * | 14 | 1985 | j | Pakes-A | * | 28 | Pakes-A* |
| 48 | Pavitt-K* | * | 20 | 1985 | j | Pavitt-K | * | 27 | Basburg-B* |
| 20 | Hall-B* | * | 20 | 1986 | j | Hall-BH, Griliches-Z& Hausman-JA | * | 20 | Hall-B* |
| 67 | Jaffe-A* | * | 35 | 1986 | j | Jaffe-AB | * | 41 | Nordhaus-W* |
| 27 | Basburg-B* | * | 27 | 1987 | j | Basburg-BL | * | 65 | Mansfield-E* |
| 57 | Levin-R* | * | 57 | 1987 | j | Levin-RC, Klevorick-AK, Nelson-RR&Winter-SG | * | 40 | Nelson-R* |
| 51 | Narin-F* | * | 27 | 1987 | j | Narin-F&Noma-E | * | 34 | Cohen-W* |
| 52 | Dosi-G* | * | 17 | 1988 | j | Dosi-G | * | 52 | Dosi-G* |
| 20 | Tirole-J* | * | 20 | 1988 | b | Tirole-J | * | 20 | Samuelson-P* |
| 34 | Cohen-W* | * | 23 | 1989 | j | Cohen-WM&Levinthal-DA | * | 57 | Levin-R* |
| 26 | Eisenberg-R | * | 26 | 1989 | j | Eisenberg-RS | * | 51 | Narin-F* |
| 48 | Gilbert-R* | * | 30 | 1990 | j | Glibert-R and Shapiro-C | * | 48 | Pavitt-K* |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 109 | Griliches-Z* | * | 84 | 1990 | j | Griliches-Z | * | 48 | Gilbert-R* |
| 36 | Kelmperer-P* | * | 36 | 1990 | j | Kelmperer-P | * | 40 | Schmookler-J* |
| 44 | Merger-R* | * | 44 | 1990 | j | Merger-RP&Nelson-RR | * | 36 | Kelmperer-P* |
| 23 | Porter-M* | * | 23 | 1990 | b | Porter-ME(1985) | * | 26 | Eisenberg-R* |
| 65 | Scherer-F* | * | 16 | 1990 | b | Scherer-FM(1980) | * | 22 | Archibugi-D* |
| 21 | Albert-M* | * | 21 | 1991 | j | Albert-MB,Avery-D, Narin-F&McAllister-P | * | 109 | Griliches-Z* |
| 33 | Grossman-G* | * | 33 | 1991 | b | Grossman-GM | * | 44 | Merger-R* |
| 38 | Scotchmer-S* | * | 28 | 1991 | j | Scotchmer-S | * | 20 | Tirole-J* |
| 22 | Archibugi-D* | * | 12 | 1992 | j | Archibugi-D | * | 67 | Jaffe-A* |
| 20 | Samuelson-P* | * | 10 | 1994 | j | Samuelson-P, Davis-R, Kapor-MD&Reichman-JH | * | 23 | Porter-M* |

# Appendix III Raw Cocitation Matrix of 30x30 Keynode Authors 1996-2000 and 1991-1995

### KN-PatStud-30x30 Raw Co-citation Matrix year 1996-2000 fq>=80

| | Alb* | Arch* | Arro* | Bas* | Coh* | Dosi* | Ei* | Gil* | Gri* | Gro* | Jaff* | Klem* | Levin* | Man* | Mer* | Nar* | Nel* | Nord* | Pak* | Pav* | Port* | Ros* | Sa* | Sher* | Schm* | Scot* | Tirol* | Hall* | Kam* | Hausm* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albert-M* | * | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Archibugi-D* | | * | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arrow-K* | | | * | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Basberg-B* | | | | * | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cohen-W* | | | 130 | | * | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dosi-G* | | | 94 | | 102 | * | | | | | | | | | | | | | | | | | | | | | | | | |
| Eisenberg-R* | | | | | | | * | | | | | | | | | | | | | | | | | | | | | | | |
| Gilbert-R* | | | | | | | | * | | | | | | | | | | | | | | | | | | | | | | |
| Griliches-Z* | | | 98 | | 111 | | | | * | | | | | | | | | | | | | | | | | | | | | |
| Grossman-G* | | | 129 | | | | | | 102 | * | | | | | | | | | | | | | | | | | | | | |
| Jaffe-A* | | | | | 83 | | | | 108 | | * | | | | | | | | | | | | | | | | | | | |
| Klemperer-P* | | | | | | | | | | | | * | | | | | | | | | | | | | | | | | | |
| Levin-R* | | | | | 90 | | | | | | | | * | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mansfield-E* | | | 107 | | 123 | | | | 147 | | 81 | | 85 | * | | | | | | | | | | | | | | | | |
| Merges-R* | | | | | | | | | | | | | | | * | | | | | | | | | | | | | | | |
| Narin-F* | | | | | | | | | | | | | | | | * | | | | | | | | | | | | | | |
| Nelson-R* | | | 245 | | 268 | 342 | | | 150 | | 99 | | 84 | 166 | | | * | | | | | | | | | | | | | |
| Nordhaus-W* | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | | |
| Pakes-A* | | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Pavitt-K* | | | | | 92 | 123 | | | | | | | | | | | 180 | | | * | | | | | | | | | | |
| Porter-M* | | | 119 | | 184 | 134 | | | | | 103 | | | 113 | | | 388 | | | 90 | * | | | | | | | | | |
| Rosenberg-N* | | | 109 | | 99 | 134 | | | | | | | | 96 | | | 222 | | | 102 | 95 | * | | | | | | | | |
| Samulson-P* | | | 239 | | | | | | | | | | | | | | | | | | | | * | | | | | | | |
| Sherer-F* | | | 93 | | 130 | | | | 98 | | | | | 131 | | | 155 | | | | 210 | | | * | | | | | | |
| Schmookler-J* | | | | | | | | | | | | | | | | | | | | | | | | | * | | | | | |
| Scotchmer-S* | | | | | | | | | | | | | | | | | | | | | | | | | | * | | | | |
| Tirole-J* | | | | | | | | | | | | | | | | | | | | | | | | 94 | | | * | | | |
| Hall-B* | | | | | | | | | | | | | | | | | | | | | | | | | | | | * | | |
| Kamien-M* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | * | |
| Hausman-J* | | | 90 | | | | | | 85 | | | | | | | | | | | | | | | | | | | | | * |

## KN-PatStud-30x30 Raw Co-citation Matrix year 1991-1995 fq>=80

| | Alb* | Arch* | Arro* | Bas* | Coh* | Dosi* | Ei* | Gil* | Gri* | Gro* | Jaff* | Klem* | Levin* | Man* | Mer* | Nar* | Nel* | Nord* | Pak* | Pav* | Port* | Ros* | Sa* | Sher* | Schm* | Scot* | Tirol* | Hall* | Kam* | Hausm* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albert-M* | * | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Archibugi-D* | | * | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arrow-K* | | | * | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Basberg-B* | | | | * | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cohen-W* | | | | | * | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dosi-G* | | | | | | * | | | | | | | | | | | | | | | | | | | | | | | | |
| Eisenberg-R* | | | | | | | * | | | | | | | | | | | | | | | | | | | | | | | |

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| Gilbert-R* | | | | * | | | | | | | | | | | | | | | | | | | | | | |
| Griliches-Z* | | | | | * | | | | | | | | | | | | | | | | | | | | | |
| Grossman-G* | | | | | | * | | | | | | | | | | | | | | | | | | | | |
| Jaffe-A* | | | | | | | * | | | | | | | | | | | | | | | | | | | |
| Klemperer-P* | | | | | | | | * | | | | | | | | | | | | | | | | | | |
| Levin-R* | | | | | | | | | * | | | | | | | | | | | | | | | | | |
| Mansfield-E* | 87 | | 69 | | 128 | | | | | * | | | | | | | | | | | | | | | | |
| Merges-R* | | | | | | | | | | | * | | | | | | | | | | | | | | | |
| Narin-F* | | | | | | | | | | | | * | | | | | | | | | | | | | | |
| Nelson-R* | 181 | 98 | 211 | | | | | | | 132 | | | * | | | | | | | | | | | | | |
| Nordhaus-W* | | | | | | | | | | | | | | * | | | | | | | | | | | | |
| Pakes-A* | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Pavitt-K* | | | 90 | | | | | | | | | | 116 | | | * | | | | | | | | | | |
| Porter-M* | 110 | | 96 | | | | | | | 103 | | | 231 | | | | * | | | | | | | | | |
| Rosenberg-N* | 97 | | 126 | | | | | | | 95 | | | 175 | | | 85 | | * | | | | | | | | |
| Samulson-P* | 218 | | | | | | | | | | | | | | | | | | * | | | | | | | |
| Sherer-F* | | | | | | | | | | 121 | | | 132 | | | | 184 | | | * | | | | | | |
| Schmookler-J* | | | | | | | | | | | | | | | | | | | | | * | | | | | |
| Scotchmer-S* | | | | | | | | | | | | | | | | | | | | | | * | | | | |
| Tirole-J* | | | | | | | | | | | | | | | | | | | | 80 | | | * | | | |
| Hall-B* | | | | | | | | | | | | | | | | | | | | | | | | * | | |
| Kamien-M* | | | | | | | | | | | | | | | | | | | | 86 | | | | | * | |
| Hausman-J* | | | | | 72 | | | | | | | | | | | | | | | | | | | | | * |

Remarks: All cells are searched directly from SSCI CD-ROM version. The cells with fq<80 are let as blanks for the significant showing the obvious linkages between any pair of 30 key-node scholars. A sign (*) after each author refers all co-citation frequency by all first possible names that cited by all SSCI audiences. See MaCain (1990) for technique overview on author co-citation analysis.

## Appendix IV: Literature Overview of Knowledge Network of Patenting Study: 30 Key-nodes

Remarks:1. Q&As are our comments that we reflect in this new generation of web age; 2. The FQ number of 1st column stands for total citations to this key-node author, including the representative publication in 2nd-5th column.

| FQ | Keynode | Short Overview of Their Representative Publication (most highest cited) with year and book (b) or journal article (j) | | |
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| 21 | Albert-MB,Avery-D, Narin-F& McAllister-P, | 1991 | j | <Patent citations versus peer opinion>> A new and direct validation study is reported that a strong association was found between citation counts for highly cited US patents and knowledge peer opinion as to technological important of the patents. This directly shows that highly cited patents are of greater technical importance than less cited patents, in the opinion of knowledge peer researchers and inventors. Also see Narin-F & Noma-E (1985) |
| 12 | Archibugi-D, SciPubPol 19:357-368 Also see (1996) Patent vs Q-survery, Technov | 1992 | j | Like other indicators, patents as an indicator of invention and innovation have their pitfalls. After reviewing their uses, advantages and disadvantages, this short review (19 pages with 115 references shows the heterogeneous nature of patents, how they can be compared with other indicators, and offers some international comparison. <<Valid or better measures>> Patents are a fascinating indicator because they lead the analyst into the process of invention and innovation in technology and economic changes. They can help to gather information of intangible knowledge phenomenon. While patents are full of traps, some of which can be avoided by careful use. But it is difficult to persuade the platoons of skeptics on their validity. Their bitter criticism has preventing the misuse and testing and improving the quality of data. However, in turn, they are entitled to ask their critics to provide better measures, if they can. In another review (Archibugi-D and Pianta-M, 1996) they review and compare patent statistics (OECD 1994 patent manual) and innovation survey (OECD 1996 innovation manual).<br>Innovation is not a linear process from R&D activities to eventual commercialization of products. On the contrary, its elements interact throughout the various stages to weave a complex web of relationships. |
| 32 | Arrow-KJ in Nelson-RR (1962) NBER book | 1962 | b | Arrow-KJ chapter (1962) in Nelson-RR' NBER book contained a simple economic model that even an idea patent system might well provide an "inadequate" incentive to invent, since inventor return is expected to be incomparable with social return. At one time economists generally agreed on the desirability of strengthening intellectual property rights to promote innovation. Since in most general sense technology is know-how, the invention is interpreted broadly as production of knowledge. Actually, this chapter are most highly cited in Nelson-RR edited NBER book *the Rate and Direction of Inventive Activity: Economic and Social Factors.* |

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| 27 | Basberg-BL, shortest review (10 pages with 95 references) points out <well-known problems and improving validity.> <Set figure of patent, invention and innovation> | 1987 | j | This shortest and to-the-point overview paper, in opposite to Dosi-G's (1988) longer or Griliches (1991) longest review paper, discuss well-known problems and improvements of validity with regard to patent information in measuring technological change. The most available methods of measuring technology change are indirect measures of the process. This review emphasizes the well-known problems and point to overcoming ways. The debate about patent statistics has not advanced since 1950s, 1960s when Schmookler-J published his important works. The same pros and cons are still applied. However, the ways of using and improving the presentation of patent statistics, so as to overcome the problems of validity, there has been some advance. 1) Important patents could be showed by patent life and renewal rate effected annual fee. 2) Foreign patents are expected to be a higher quality than domestic patent on the average. Comparing the patenting activity of several countries in third countries can overcome the legal differences. 3) Each country has the same propensity to patent in the US (Pavit-K, 1980; Soete-L&Wyatt-S, 1983). 4) Patent-to patent citation networks can help in understanding the quality of patents. 5) To study the patent data at the lower possible level of aggregation (firm) will be less noisy that higher level (industry or nation). 6) Data on patent granted do have higher quality than on patent applied because of the screening done by patent examination. 7) The annual change in the number of assignees reflects the interest in the technology, while patent application is only for technological activity. His proposed a vector representing two variables could be assumed to indicate the maturity of the technology. Q&A All of us are believers that desires best measures but keep 2nd best ones and improve them. All problems have being well known and being improved generation by generation. What are our improvement opportunities in this web age? |
| 23 | Cohen-WM& Levinthal-DA, EconJ; Innovation and Learning: Two-faces of R&D, also see Absorptive Capacity (ASQ 35: 128-152) | 1989 | j | <<External knowledge>> Unlike conventional economists, they think R&D is not only generate new information or new knowledge (Schmookler, 1966), but also enhances the firm's ability to assimilates and exploit existing information. Scholars of technological change have observed that firms invest in own R&D to be able utilize external information (e.g. Tilton-JH (1971); (Mowery, 1983)). Tilton states that an R&D effort provided an in-house capability that could facilitate the assimilation of new technology developed elsewhere. Therefore they define a firm's learning or absorptive capacity as its ability to identify, assimilate, and exploit outside knowledge besides own knowledge from the environment, more even to imitate new process or product innovation from the competitor's R&D spill-overs. They regards that the exercise of absorptive capacity differs from learning-by-doing (Spence-AM, 1981; Lieberman-MB, 1984). In sum, absorptive capacity may be created as by-product of a firm's both R&D and manufacturing operation. Q&A: Does the term Capability simply seem equal to a quality definition of ability on broad capacity? |
| 17 | Dosi-G, JEconLit, the longest review (53 pages with 280 references) | 1988 | j | This review by Dosi-G Italian group undertaking at UK SPRU discuss the sources, procedures, and micro-economic effects of innovation, basing on the empirical evidence including the characteristics and effects of micro-electronics-based innovation. His observed that changes in industrial structures and dynamics of industrial performance are the outcomes of (a) innovative learning by single firms; (b) diffusion of innovations and selection among firms. Technological paradigms or trajectories could be defined as technological process along the economical and technological trade-offs. System or organizational learning has a significant amount of organizational indivisibility. Modern factory has also implied "de-skilling" of particular categories of craftsmen. In sum, patenting underestimates the innovation outputs of big firms—which appear to show a lower propensity to patent, while the R&D expenditures are likely to overestimate innovation contributions of small firms. There is Schumpeterian Hypothesis that the concentration and market power affect the propensity to innovate and that bigness is relatively more conductive to innovation. The ease of imitation of a certain innovation and its diffusion may succeed, ceteris paribus, in an inverse relationship with its appropriability. It is hard to doubt that domain of innovation are a major--and still largely unexplored—frontier of economic analysis. |

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| 26 | Eisenberg-RS, JlawEcon | 1989 | j | The patent laws confer exclusive rights in inventions and discovery "To Promote the Progress of Science and useful Arts (US Constitution I(8:8))". Patenting for an exclusive right with full disclosure should also carefully formulate experimental use exemption, since the believing that free access to prior discoveries might be a more effective means of promoting progress. |
| 30 | Gilbert-R and Shapiro-C | 1990 | j | <Infinitely-lived patent breadth for required reward> In providing rewards to innovators, there is a trade-off between patent length and breadth. Gilbert-R and Shapiro-C (1990) provide conditions under which the optimal patent policy involves infinitely lived patents, with patent breadth adjusting to provide the minimum required reward for innovation.<br>The optimal length may be easily infinite under the many circumstances in which the patent policy choice could be viewed as a choice of patent breadth as well as patent length. To given a reward of infinitely lived patents with the minimum market power necessary to attain the required reward level is the socially cost-effective way, in many circumstances. |
| 84 | Griliches-Z, 2nd Longest Review (47 pages with 151 references) in JEonL | 1990 | j | Since almost no good measures at all in the desert of data directly for economic growth, technological change, competitive position of different firms and countries, industrial structure, our arrangements all tend to revolve around notions of differential inventiveness. Patent statistics loom up as a mirage of wonderful plenitude and objectivity. Q&A here. No good or no best? We always need a balanced choice of 'second best" in each generation. Most important is they are available based on –slowly changing standard. No wonder that the idea might be learned and rediscovered generation by generation. Q&A What is our age? after his mention of 'computer age' work of NBER group (Griliches-Z, Hall-, Huasman-, Jaffe-, Pakes-, Schankerman and others). Is it web age? His review is also based on works by NBER, Yale group (Scherer, Nelson, Winter, Levin and others) and the SPRU group (Freeman, Pavitt, Soete and others). Q&A here. What are ISI/CHI group's works (Garfield, Narin and others). His flowchart figure of the knowledge production function (Δk, p.1671) related to six variables: P, R&D$#%, benefits from invention ($Z_1$), others observable ($X_1$) and other unobservable random variables (u,v and$v_1$).Q&A Therefore, did he implied that there are different but improved degrees of observability in different generations? |
| 33 | Grossman-GM & Helpman-E | 1991 | b | <Innovation and Growth in the Global Economy >This MIT Press Readings in Economics is a very useful synthesis of trade and growth theory in a systematic manner with unified notation. It is struck at the end how much the return on traditional differences in factor usage intensities across industries. |
| . 20 | Hall-BH, Griliches-Z& Hausman-JA, IEconRev 27(2): 265-283, no lag evidence but strong relationship and differences across the firms. | 1986 | j | It is a maintained assumption that patents are an indicator of R&D output or success rather than simply the R&D input. However, patent is not the only output of R&D but only a fraction of this output. The fraction may vary considerably industry, firm size, and over time (propensity to patent). Given a large fraction of patents granted are 'worthless' or become worthless in a short period of time, patent can be used as an indicator of this activity in an aggregate even though the information conveyed by an individual patent may be very small. Q&A It is good point of comparison in an aggregate versus individual basis. Even though they have not been able to elucidate the R&D to patent lag structure well, their findings show a persistent significant relationship and widely semi-permanent differences across firms in patenting and R&D policies. Q&A: Not all of patent is equal important? Yes, how about person in same logic questions? Paper? Invention? Innovation? New product or process? Vote? Citation? Only dollar is easily assumed to fixed important, even you can said that utility of each dollar is not same for each person. The answer should come out to distribution not each single case. Some analysts have suggested that international differences in patenting in a given foreign country (particularly US) are a more reliable reflection of international differences in innovative activity than are differences in domestic patenting. |
| 18 | Hausman-J, Hall-BH& Griliches-Z, | 1984 | j | This paper adapts the generalized Poison statistical models in methodology to allow to analyse the relationship between patents and R&D expenditure in panel data of patent counts (nonnegative integers) with both individual affects and over-dispersion, unlike Griliches-Z and Pakes-A (1980) refinements for linear distributed lag models. |

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| 35 | Jaffe-AB R&D Spill-overs Also see his (1989) ResPolicy & (1993) QJEcon | 1986 | j | As newer star of NBER group in computer age, he has won three famous essays 8 years after 1985 Harvard dissertation on R&D knowledge spill-overs and technology opportunity based on primarily computerized patent database (USPTO) along with Harvard Program in Competitive Analysis (PICA) database, FTC line of Federal Trade Commission, and others (e.g. Standard & Poor's Compustat). The 3rd paper makes use of the geographic location of patent citations with that of the cited patents as evidence of the extent to which knowledge spill-overs are geographically localized. They found citations to domestic patents are more patents are more likely to be domestic and more likely to the same state and SMSA as the cited patents. While Marshall-A (1920) identified the reasons of industrial concentration to labor pooling, immediate goods and knowledge spill-overs, Krugman-P (1991) urges to focus on the first two, since knowledge flow, by contrast, are invisible. Like all of bibliometrics believers generation by generation, Jaffe-AB of NBER group in computer age hold that knowledge flows do sometimes leave a paper trail, in form of citation in patents. |
| 18 | Kamien-MI & Schwartz-NL, Market Structure & Innovation | 1982 | b | In this old industrial organization book we can see two related chapter reviews on innovation theories and empirical studies in chapter 2 and chapter 3. The so-called two Schumpeterian Hypotheses, the first means that there is positive relationship between innovation and monopoly power with above normal profits, and the second refers that large firms are more than proportionally more innovative than small firms. Actually Gablraith-J (1952) should receive substantial credits for the second, while Schumpeter for the first. After that, there are technology-push (by scientific knowledge, Nelson, 1959; then Philips, 1966) and demand-pull (by economic opportunities, Schmookler, 1966) hypotheses. The beginning of empirical studies they had reviewed the drawbacks of patent statistics (p.50): (a) mixed major with minor innovation, (b) many patents are never commericalized and (c) many innovations are not patented. |
| 36 | Klemperer-P, | 1990 | j | <How Broad Should the Scope of Patent Protection be?>Whitney-E and his partner did not recover sufficient damage award to compensate for over-generous disclosure details of his cotton gin's patent. Patent scope decisions are more discretion than others. |
| 57 | Levin-RC, Klevorick-AK, Nelson-RR&Winter-SG; | 1987 | j | <Propensity to patent> Patent system does not always play a key role among the various mechanisms to capture innovation return. The patent system functions very differently in different industrial contexts. A flowchart similar with five logic decisions called "Unlike conditions for strong individual patents" is presented in slightly different to Levin-R et al. (1987). These conditions include: 1) knowledge advance is articulable or tacit? 2) observable when in use? 3) of enduring value? 4) independent of other patented inventions? 5) discrete or basic? Also see Winter-SG chapter in a book. Yale group Q-survey. |
| 34 | Mansfield-E,Schwartz-M& Wagner-S, EconJ 91:907-918 | 1981 | j | <Investigation and regression of imitation cost ratio>Unlike the studies of optimum patent life, the patent holder is not always free of imitation for its legal life. There is a considerable need for more studies of the size, determinants, and effects of imitation costs and time. The ratio of imitation cost to innovation of a given new product is hypotheses to be inversely related to the research proportion of innovation cost. Each regression coefficients are statistically significant enough. Their empirical investigation with small sample (48 new products in four industries in US Northeast area) shows that this topic can be carried out in order to understand many aspects of the economics of technological changes. |

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| 44 | Merges-RP& Nelson-RR, ColumLawR 90(4):839-916 <Complex economic effect of patent scope> | 1990 | j | <Enough incentives for subsequent improvements of cumulative technologies> This paper addresses the complex economic effects of a patent depends on its scope. The broader the scope is, the larger the number of competing products and processes that will fringe the patent. Unlike other aspects of the patent system, only a few of patent scope have been focused. Both the Patent Office in examination and then the courts in litigation are constantly making patent scope decisions on more discretionary room constrained by a number of legal principles and the invention itself. Several recent cases have signal the nature and complexity of the questions involved in patent scope decisions, for example, pharmaceuticals and transgenic mouse. <<4 Conlusions>> Multiples and competitive sources of invention in a rivalrous 'race to invent' do tend to rapid technology process than a regime where only one or a few organization control any given technology, particularly cumulative technologies. While in chemical industries invention have some of the features of both discrete and cumulative, the concerns somewhat are mitigated because of the relative rarity of very broad patents and the very well established practice of licensing. The overly broad patent award early in a science-based industry is often dangerous for over-protection to hurt technological progress and to cause later litigation disputes. Patent scope doctrines can be used to approximate the tailoring function proposed by economists who model optimal patent length, with an eye toward incentives for subsequent improvements. |
| 27 | Narin-F, Noma-E &Perry-R <patent citation versus financial performance> | 1987 | j | Patent counts could reveal the size of research inputs, while patent citation counts for the quality or impact of research outputs. Using 17 pharmaceutical companies (hi-R&D industry) as example, this possibility of revealing two different aspects of R&D cycle was indicated by several high correlations (0.8) with expert opinions, budgets and publications, while citations per patent with financial performance. In addition, the concentration of company patents was highly correlated (0.6-0.9) with financial performance. See also Narin-F & Olivastro-D (1992) Status Report: Linkage Between Technology and Science and Narin-F & Noma-E (1985) Is Technology Becoming Science? Cited and citing data from recent biotech patents and bioscience papers show that the bibliometric properties in these two realms are quite similar. Also see CHI associates' publications CHI research.com |
| 30 | Nelson-RR& Winter-S Evolutionary Theory of Economic Capabilities, | 1982 | b | <<Simulation assumptions>> The mathematical structure of simulation model is that of a Markov process in a set of industry states, basing on the three basic assumptions. (1) For most part of firms operate according to decision rules including quite complex reutilized behaviors rather than maximization. (2) The techniques used by a firm may change by the local or incremental search of internal R&D or external imitation. (3) The dynamics of firm search are complemented by the dynamics of market selection. <<Theory is needed to fit>> Theory, to be useful, therefore must organize knowledge and guide research regarding vast inter-industry differences in rates and direction of innovation of innovation, technology progress and productivity growth. Traditional economic research for present understanding this puzzle has been fragmented and much less integrated. They are needed to struggle to 'fit' that market as a selection environment.<br><<Heuristics versus algorithm for optimum>> Under Rosenberg-N (1972) trajectory, an R&D project and its identifying and screening procedure by an R&D organization can be viewed as interacting heuristic search processes. Thus good heuristics with cues, clues and rules of thumb) is the best one for calculating an optimum than an algorithm. Also see (1973) AEA Proceedings 63(2): 446-449 and Research Policy. Q&A Did they define "economic capability"? |
| 31 | Nordhaus-WD also AER 1972 paper on Optinum Patent Life | 1969 | b | This old book, specializing in economic analysis on welfare of invention, growth and patent, first focuses on the nature and production of technological knowledge and 5 styled facts of technological changes (chapter 1). Then both the indivisibilities and externalities have cause imperfections in the inventive market (chapter 5). Then in chapter 5, it discusses research and royalties under a patent system, the optimal life of a patent and welfare implications of a patent system. For optimum patent life, we can also see his highly cited article in 1972 AER 62: 428-431. |

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| 14 | Pakes-A, On Patents, R&D, and the Stock Market Rate of Return | 1985 | j | <Computerized USPTO database>The recent computerization of US Patent Office's database may prove helpful in the context of when and where changes in either inventive inputs or inventive outputs have occurred. However, there is the problem that a priori we do not know the relationship between patent application and economically meaningful measures of these inputs or outputs. <Unusually long and extremely detail> Earlier studies often used successful patent applications as their output measure (Schmookler-J & Brownlee-SH, 1962, Griliches-Z & Schmookler-J, 1963). Patent applications are, at least in principle, available for an unusually long time period in an extremely detailed breakdown. |
| 20 | Pavitt-K, Scimet 7:77-99 also see another review (1988) in VaRaan- AEJ HBD. Q&A Why two articles of different titles with complete same text? | 1985 | j | Q&A: Why he submitted same version to one journal (23 pages with 38 references) and one book (39 pages with 83 references)? Did he obey scholarly ethics? Advances in information technology have increased the actual and 'potential' uses of patent statistics as a proxy measure of inventive and innovative activities. If de Solla Price is right in his interpretation, the scholars of science, technology and society should take recent improvements in quality and availability of patent statistics "rather seriously". De Solla Price (1983) argued that science and technology advances have been made as a result of the need to explain the new empirical data thrown up by improvements in measurement systems. Their richness and detail are likely to have a strong influence in future on the direction, style and results of research on the nature, determinants and impact of invention and innovation. Q&A: Not all of patent is equal important? Yes, how about person in same logic question? Paper? Invention? Innovation? New product or process? Only dollar is easily assumed to fixed important, even you can said that utility of each dollar is not same for each person. The answer should come out to distribution not each single case. Some analysts have suggested that international differences in patenting in a given foreign country (particularly US) are a more reliable reflection of international differences in innovative activity than are differences in domestic patenting. |
| 23 | Porter-ME(1998) | 1990 | b | This book could be called the mother of all business strategy books with over 30 printing in English and translated into 13 languages. Porter's groundbreaking concept disaggregates a company activities and helps to create a "value chain" to figure out how and where an organization to build the blocks of competitive advantage. This book is the essential complement to the path-breaking book (1985) Competitive Strategy: Techniques for Analysing Industries and Competitors. See also the Competitive Strategy of Nations(1990) |
| 14 | Rosenberg-N | 1982 | b | In this book Inside the Black Box: Technology and Economics, Rosenberg revealed that how specific features of individual technologies have shaped a number of variables of great concern to economists. These are the rate of productivity improvement; the nature of the learning process underlying technological change; the speed of technology transfer; and the effectiveness of influential government policies. Meanwhile, Rosenberg's concepts of technology and environmental history have had an acceptance all over the historical and economic research. |
| 10 | Samuelson-P, Davis-R, Kapor-MD&Reichman-JH also see Emory Law J 1990 39: 1025-1154. | 1994 | j | <law, science and technology/legal protection of computer programs?>An analysis and critique of intellectual property protection is instructive for practitioners, scholars, and policy-makers in the area of law, science and technology. This 124 pages manifesto concerning the legal protection of computer programs has been highly cited in this topic, since it analyses on important characteristics of computer program. Use of traditional legal regimes to protect software innovation will lead to cycles of under- and over-protection. Innovation in programs is largely incremental and cumulative compilations of industrial know-how embodied in programs and relied on conceptual metaphors to organize behaviours, in additional to text as construction medium. They propose a sui geniris approach to legal protection of computer programs to remedy market-appropriation of program behaviours by de-compilation through a period of automatic anti-cloning protection for these innovations. Once revealed by de-compilation, the compiled know-how cannot be effectively protected by trade secrecy, copyright, or patent law. The argument in Benson Revisited is that Bensen Court is overruled program-related inventions to be patentable. |

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| 16 | Scherer-FM(1980) Industry Structure and Innovation | 1990 | b | <Compulsory licensing> Scherer-FM's (1990/1980/1970) book has a good review on debates over the merits of compulsory licensing of patent under some circumstances. The compulsory patent licensing confined to cases in which monopoly power has been abused would have little or no adverse impact on technological progress. <Social costs and benefits> Two older of three editions of this old industrial organization book have one special chapter focused on the economics of patent system, while third edition that chapter title changed to market structure, patents and technological change. <Long Bebates> Debates over the patent monopoly have continued ever since the first practice by the Republic of Venice in 1474. Other issues include the costs and benefits and alternative incentives of the patent system. |
| 40 | Schmookler-J, Invention and Economic Growth | 1966 | b | To our knowledge, in the right beginning of patenting and technology study, an significant figure Schmookler-J gave us 13 traceable harvest research publications including 2 books (1966; 1972), 1 U.Pen. dissertation (1951) and 10 articles (1950; 1953; 1954; 1957; 1960; 1962 with Brownlee-SH in AEA; 1963 with Griliches-Z in AER; 1965 chapter, 1975 chapter). Q&A: Is it an old student or short academic life? Why he disappeared in a short time (1950-1975). Is Griliches-Z his mentor or student seeing their co-author AER article? The core area of the field (patenting and technology rather than broader economics of technology (Granstrand-O, 1994)) dealing mainly with relationship between technological changes as measured by patent statistics and economic development has been work done by Schmookler-J (1966) book with a complete bibliography. His research is described as '…so rich and so suggestive…to be the starting point…(Rosenberg-N, 1974: 92)." Schmookler's main conclusion that inventing is determined by economic variables has caused a debate on technology-push or demand-pull. However, Schmookler's works have had a central proposition in the whole methodology debate on patent statistics as a technology indicator. Meanwhile, he seems the first to publish the numbers on aggregate 'total factor productivity (TFP)" (Schmookler-J, 1951 U.Pen dissertation). Unfortunately, there seemed to be little correlation between TFP and patent number Without give up, he redefined patents as an index of inventive "activity", primarily an input rather than output index. Also see Griliches-Z& Hurwicz-L eds. (1972) Patent, Invention and Economic Change: Data and Selected Essays by Jacob Schmookler. |
| 28 | Scotchmer-S (she) also see Scotchmer-S & Green-J (1991) JeconPers 5(1): 29-41 | 1991 | j | Most economic literature on patenting and patent race in technology jungle has lost the focus on the externalities or spill-overs that earlier innovators confer later innovators. Scotchmer-S (1991) paper investigates the use of patent protection and cooperation agreements among earlier innovators' technological foundation and later innovators' improvements to protect incentive cumulative research. The stringency of the novelty requirement in patent law affects the pace of innovation because it affects the disclosure amount of technical information among firms (Scotchmer-S and Green-J (1991)). The social value and its welfare of patent disclosure will differ in first-to-file rule (Japan and everywhere else) with first-to-invent rule (U.S). |
| 20 | Tirole-J textbook see also other good books like Carlton & Perloff (2000) <textbook of industrial organization> | 1988 | b | This book is absolutely classic IO text with an excellent bibliographical guide to treat the new industrial organization (IO) at the advanced- undergraduate and graduate level. In Part I, Tirole develops the modern theory of monopoly with a background discussion of the theory of firm. In Part II, Tirole takes up strategic interaction between firms, starting with a novel treatment of Bertrand-Cournot interdependent pricing problem. He then develops topics having to do with long-term competition, including R&D. He concludes with a "game theory user's manual" and section of review exercises coded to indicate level of difficulty. Q&A here, what is Bertrand-Cournot conjectures (Jaffe-AB, 1986)? Is it interdependent pricing problem? Here we found that answers are in Church-J& Ware-W IO textbook (2000). Cournot-J (1838) game or competition and its Nash equilibrium or solution of classic oligopoly of two spring water firms refers to a state of complete information. Bertrand-J (1883) paradox game or competition refers the state of game where firms compete over pricing under several modern economic conditions (e.g. economic of scale, capacity-constrained). |

**Appendix V: USPTO and Canada IPO Search Pages. (Attach here three web site pages)**